Q3S 3 YEAR OLD SIDE IMPACT DUMMY DEVELOPMENT

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ABSTRACT

The Q3s dummy is a three year old child crash dummy optimized for side impact crash testing. The dummy is built on the platform of the standard Q3 dummy that is part of the Q-series of child dummies developed in Europe to replace the P-series. Enhanced lateral biofidelity, durability and additional measurement channels have been designed into the Q3s dummy. The dummy features a new head that eliminates previously reported high frequency noise, an extensible neck that combines improved frontal flexion performance with the lateral and tensile performance of the Q series necks, a highly deformable shoulder with shoulder deflection measurement, a new arm with improved flesh characteristics, a laterally compliant chest and a pelvis with improved upper leg flesh, floating hip cups, and pubic load transducer. Biofidelity performance for the lateral 3 year old ATD is validated against the scaled biofidelity targets published by Irwin et al. (2002) This paper will describe the construction of the dummy and the laboratory biofidelity performance.

INTRODUCTION

According to the National Highway Traffic Safety Administration (NHTSA), about 40 percent of child fatalities to rear-seated children in the age of 0 to 8 years occur in side impact collisions. In the US, side impact crashes kill about 300 young children each year and result in more severe injuries at lower crash severities than frontal collisions.

Although side impact collisions pose a great risk to children in crashes, information about the injury cause and mechanisms is limited. Research has demonstrated the effectiveness of using age- and size- appropriate restraints in preventing injuries in this crash direction. Restraint systems for children need to account for not only the anthropometric differences of children of different ages but also the biomechanical characteristics of the child's body at different ages. In order to effectively assess the safety provided by these restraints systems, child restraints performance testing should take into account these unique characteristics of child occupants.

Except in Australia and New Zealand, there are no legal requirements in effect concerning the crash protection of restrained children in lateral collisions. The majority of test procedures used for consumer information today are based on a preliminary draft test procedure developed under the International Standards Organization (ISO), (Johannsen et al., 2003). The ISO side impact test procedure for child restraint systems is a sled based procedure that includes specifications for an intruding door member. This procedure offers the possibility to simulate the main mechanisms of lateral collisions, such as acceleration of the struck car and intrusion of the struck side structure. No appropriate side impact child test dummies and associated injury criteria, however, have been available at the present time to assess the merits of this test procedure or the potential countermeasures for side impact intrusion that such procedure would promote.

The purpose of this paper is to present the design and current biofidelity performance of the Q3s, a 3-year old dummy developed specifically for side impact testing. The Q3s dummy (Figure 1) is a modified version of the Q3 omni-directional child crash dummy that was developed and evaluated in Europe under the EC funded CREST (1997 - 2001) and CHILD (2002 - 2006) programs. The Q3s features enhanced lateral biofidelity corridors based on scaling factors applied to ISO TR9790 biofidelity corridors (Irwin et al., 2002). It also includes improved kinematics, overall test performance, durability and additional measurement channels. The paper will review the dummy's basic features, gives background to the design updates and present the test results obtained so far.

DESIGN & METHODS

The Q-series to date exists of a Q0 (infant), Q1, Q1.5, Q3 and Q6 dummies. Key design features are the anatomical representation of body regions, the relatively simple and modular design, the use of dummy-interchangeable instrumentation and easy handling properties (limited components, easy assembly and disassembly, simple calibration). As the standard Q-dummies already include some multi-directional characteristics and their design more easy to modify than traditional dummies, the Q-series was selected as a starting point for the development of a series of biofidelic side impact child dummies. The first dummy in this series, referred to as Q3s, is based on the Q3 dummy platform. The updates required for the Q3s are summarized below.

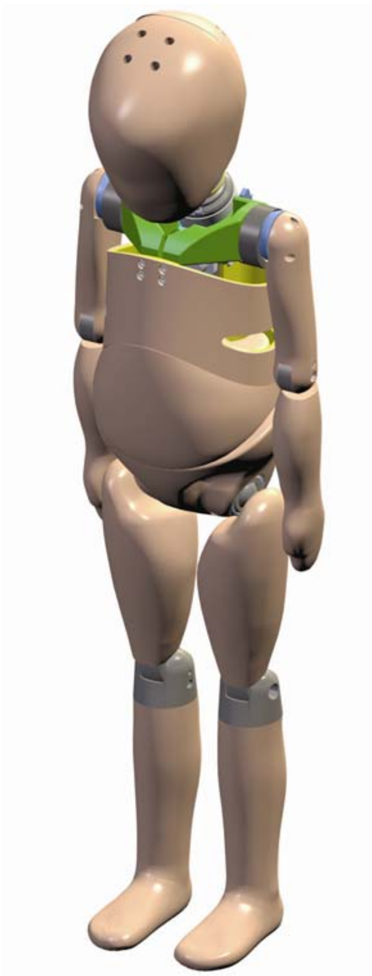

Figure 1 Q3s Dummy

The Q3s Head

Head Construction The Q3s skull material has been changed from the original design. The reason for this change is that the original Q3 urethane material exhibited a relatively low natural resonant frequency. This ringing was evident on head acceleration data especially during OOP airbag testing as noted by Berliner et al (2000). Changing the material to a higher modulus fiberglass increased the natural frequency enough for the CFC 1000 filter to attenuate the noise. The head assembly still has the flesh molded directly to the skull which insures a proper fit. The head shape and mass properties have not changed. As in the original design, an L-shaped steel bracket molded into the skull provides the mounting surfaces for the head instrumentation (linear and rotational accelerometers) and the upper neck six axis load cell.

Frequency Response To verify the Q3s head, the frequency response of the head assembly was measured. The head assembly, removed from the dummy, was suspended by strings and the skull was impacted using an Endevco model 2126 modal hammer. The impact surface was the skull material located behind the chin. The resultant vibrations were measured with 3 uniaxial accelerometers mounted on the standard Q3 head instrumentation mount at a sample rate of 25khz. Usually 1 axis of the 3 would provide a clear indication of the natural resonance frequency of the head. The frequency calculation was accomplished by timing the peak to peak period of the unfiltered data from the head accelerometers. The data were also filtered with the CFC1000 filter to show that the noise was successfully attenuated. These tests were confirmed using a complete dummy seated in front of a passenger airbag. The airbag was centered in front of the head 10" away. The airbag was fired and the head accelerations were recorded.

Head Impact Biofidelity Lateral head biofidelity is described in by Irwin et al. (2002) as a head drop on a 50mm thick steel plate from a height of 200mm. Van Ratingen et al. (1997) described a drop from 130mm for both frontal and lateral directions and FMVSS Part 572 Subpart P describes a drop from 376mm in the frontal direction. The head was suspended on cables such that during the lateral tests the impact point on the head was angled up 35 degrees from the lateral plane during the left and right side tests. In the frontal tests, the head is suspended so the impact point is 28 degrees above the frontal plane. Three (3) uniaxial accelerometers were mounted at the head center of gravity. The data were collected at 10 kHz and a CFC1000 filter was employed.

The Q3s Neck

The Q3s neck (Figure 2) is a new component and consists of 3 natural rubber segments bonded to aluminum plates with an internal cable assembly. The objective was to develop a neck that meets both frontal and side impact requirements combined with realistic elongation properties. The effective axial spring rate (130N/mm average over 11mm) of the Q series neck is controlled initially by the properties and cross-section of the neck rubber segments but then climbs rapidly once the neck cable becomes taut. This allows the neck to stretch under tensile loads but also limit the maximum elongation to protect the integrity of the neck. The segmented design distributes the bending moments over the entire length of the neck reducing the tendency to buckle at the neck midpoint. The outer shape of the neck is round and mostly symmetrical with each rubber segment having a circumferential V-groove. The head - cervical spine - thoracic spine interfaces are solid connections through 6 axis load cells on each end of the neck. .

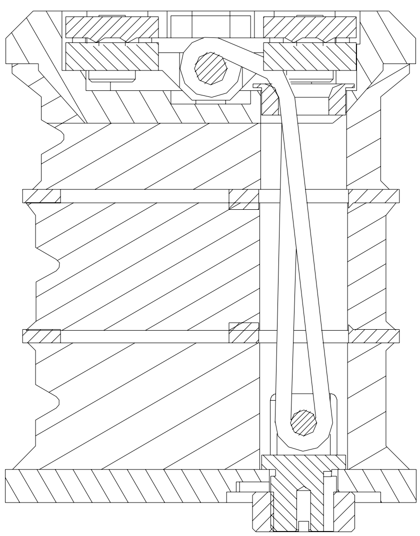

Figure 2 Q3s Neck Assembly (midsagittal cross section)

Frontal Flexion The Q3s neck is designed to meet the frontal flexion characteristics specified in the 49CFR Part 572 subpart P and the lateral flexion properties specified in the Irwin et al (2002) corridors. This was accomplished by locating the neck cable towards the back of the neck. The neck cable becomes taut during frontal flexion pulses and limits the amount of rotation of the neck while the upper neck load cell measures an associated increase in moment. The Q3s frontal flexion data was measured using a Q3s head on a standard part 572 neck pendulum at 5.5 m/s using a deceleration pulse similar to the HIII 3yo standard certification test. Head rotation was measured using rotary pots attached to the head and the pendulum filtered at CFC 180 and the moment was measured using an IF-217 6 axis load cell mounted at the upper neck location filtered at CFC 600.

Lateral Flexion Performance The Q3s neck is tested for lateral performance using a modified Q3 head on the standard Part 572 neck pendulum. The modification of the head entails a small metal rod that is threaded into the rear of the skull cap. This allows the attachment of the rotary pots for measurement of head rotation. A 6-axis load cell measures the moment about the X-axis. The data are collected at 10kHz. The rotary pot data and the moment data are plotted against corridors defined in Irwin et al. (2002)

The Q3s Shoulder

The shoulder is usually the first part of the dummy to be struck in a lateral test, therefore human-like shoulder stiffness is very important. The shoulder must be durable enough for severe impacts and also handle the forces caused by the flailing arm on the non-struck side of the dummy. The design intent was to improve the compliance and durability of the Q3s shoulder while maintaining proper anthropometry and mass distribution. A flexible rubber shoulder was developed to achieve this design goal (Figure 3). The Q3s rubber shoulder component consists of high strength aluminum parts that attach at the sternum, shoulder joint, and spine of the dummy. These parts are joined by a steel cable and the entire assembly is encased in natural rubber that forms the shape of the shoulder. The steel cable flexes with the soft rubber but limits the amount of tension that can be applied to the rubber which helps to protect it from overloading. The shape of the rubber forms the external features of the scapula and clavicle and provides a surface for the seat belt routing. Biofidelity corridors for shoulder deflection and impact response are described Irwin et al. (2002) A string pot attached to the spine is used to measure lateral shoulder deflection. The shoulder joint itself consists of a ball and socket in order to simulate the humerus scapula joint, the ball on the shoulder and the socket integral to the upper arm bone. The upper arm has urethane flesh covering the entire outer surface of the arm which helps reduce the inertial peak from a pendulum impact.

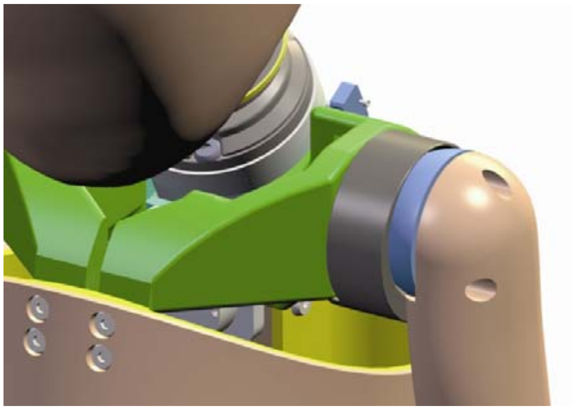

Figure 3 Shoulder Joint

Shoulder Biofidelity The shoulder was evaluated using ISO 9790 shoulder test 1, scaled as suggested by Irwin et al. (2002) The pendulum used for this test is 1.7kg. The impact angle was 90 degrees from the frontal plane at 4.5m/s centered on the shoulder joint. The dummy was seated upright with the upper arm positioned vertically down. The force data was collected using a probe mounted uniaxial accelerometer, the deflection data was collected using a string pot mounted on the front surface of the thoracic spine and connected to the bottom of the shoulder joint. The data are filtered using the CFC 180 filter.

The Q3s Thorax

Like the standard Q3, the Q3s ribcage consists of a 1 piece urethane ribcage with a bonded PVC outer skin layer. The shape, contour and thickness of the ribcage have been changed to provide improved lateral compliance. The ribcage is attached to an aluminum thoracic spine that connects the rubber lumbar spine and the shoulder-neck complex. An IRTRACC displacement sensor measures lateral displacement between the side of the ribcage and the thoracic spine.

Thorax Biofidelity To assess the biomechanical performance of the thorax, the ribcage was impacted using the 1.7kg pendulum. The impact angle was 90 degrees from the frontal plane at 4.3m/s centered on the IRTRACC rib mounting screws. The dummy was seated upright with the arm positioned vertically up. Force data was collected from a probe mounted uniaxial accelerometer, rib deflection data was collected from an IRTRACC mounted between the thoracic spine and the ribs, centered vertically on the dummy ribcage, and T1 acceleration was measured at the top of the thoracic spine. The dummy was positioned in the sitting position on 2 sheets of 2mm thick mechanical grade Teflon. The pendulum force and T1 acceleration data were filtered with the FIR 100 filter. The IRTRACC rib deflection data were filtered with the CFC180 filter. Biofidelity response is described in Irwin et al. (2002)

The Q3s Abdomen

The Q3s abdomen is the same component used on the Q3 dummy. It consists of a PVC skin filled with urethane foam. The abdomen fits neatly into a cavity formed by the ribcage on top and the pelvis assembly on the bottom.

Abdomen Biofidelity Corresponding to ISO TR9790, abdomen biofidelity is assessed using drop tests and sled tests in Irwin et al. (2002) instead of pendulum tests. These tests have not yet been conducted so far due to their complex nature. Van Ratingen et al. (1997) suggested tests using the 3.8kg probe at 4.8m/s and 6.8m/s. The impact was aimed at a spot 30 degrees forward of the lateral plane of the dummy at a point centered between the bottom of the ribcage and the top of the pelvis flesh without striking either. The dummy was positioned in the sitting position on 2 sheets of 2mm thick mechanical grade Teflon. The response data were collected from a probe mounted accelerometer at 10 kHz sample rate and filtered using the FIR 100 filter.

The Q3s Pelvis

In a lateral impact the dummy shoulder and pelvis are the first to contact the side of the child restraint; thus the kinematics of these regions of the dummy are very important. The pendulum impact response corridor described in Irwin et al. (2002) dictates that the flesh be compliant. The construction of the dummy is such that the H-point of the dummy is covered by the flesh of the upper leg. So improving the lateral impact response of the pelvis meant changing the characteristics of the upper leg. The upper leg consists of a steel reinforced urethane femur with a hollow PVC flesh shape that is filled with soft silicone rubber. The hip joint socket in the pelvis assembly is allowed to deflect inwards a maximum of 6mm. A cylindrical rubber buffer provides the spring force and preload for the hip socket. After 6mm of hip socket deflection a plastic hard stop limits further inward movement of the hip. A single channel force transducer measures force at the rubber buffer. The travel stops at both ends of the hip socket travel are plastic to prevent high frequency noise being introduced into the dummies sensor data. Biofidelity corridors for lateral pelvic pendulum impact are described in Irwin et al. (2002) The pendulum dimensions are derived from the adult 17.3kg probe described in ISO9790 yielding a diameter of 70mm, a 100mm radius on the face of the impacting surface and a mass of 2.27kg. Impact point of the pendulum is at the greater trochanter at 90 degrees from the frontal plane of the dummy. The dummy was positioned in the upright sitting position on 2 sheets of 2mm thick mechanical grade Teflon. The test is conducted at 4.5m/s as specified in Irwin et al. (2002) and at 5.2m/s as specified in van Ratingen et al. (1997). The data are filtered using the CFC 180 filter.

RESULTS

A series of tests as outlined in the previous section was performed at the FTSS Certification Lab on the Q3s prototype. Where relevant comparison data are available, this paper will report, besides the Q3s results, the results of identical tests on a standard Q3 dummy and HIII 3 year old dummy.

Head Resonance

The new fiberglass material has doubled the resonant frequency of the Q3s head assembly. At approximately 1.5 kHz, the Q3 urethane head material exhibited a frequency response that was too low to be filtered effectively by the CFC 1000 filter. The filtered data in the airbag test for that material showed a -30 to +60G trough to peak swing in the head acceleration thus complicating HIC calculation. The new fiberglass material for the skull also resonates but at frequencies at or above 3.0 kHz, high enough to be significantly suppressed by the filter.

In the airbag tests the resultant resonant frequencies were 1.5 kHz for the urethane head and 3.0 kHz for the fiberglass head. The acceleration plots filtered using the CFC 1000 filter showed pronounced high frequency noise for the Q3 head (Figure 4) and significantly suppressed noise for the new Q3s fiberglass head (Figure 5).

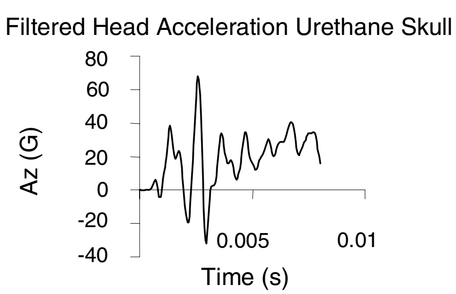

Figure 4 Head Az for the Urethane Skull

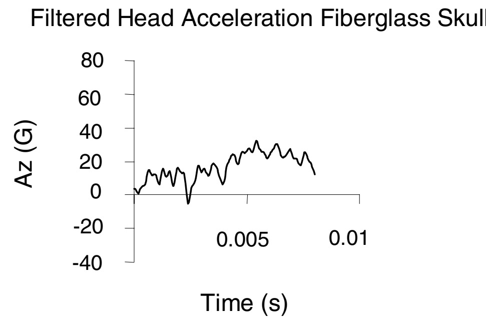

Figure 5 Head Az for the Fiberglass Skull

<u>Head Drop Response</u> Table 1 shows the head impact response of the Q3s. While the head impact response meets all the relevant specifications for the Q3, Q3s and Hybrid III 3 year old ATDs, the current performance is at the high end of the Irwin et al (2002) corridor and at the low end of the Part 572 subpart P corridor. The data presented here was measured at the CG of the head assembly while the PMHS data collected by Hodgson and Thomas (1975) and others, that formed some of the basis for the scaled child corridors, necessarily measured accelerations on the outside of the skull where the sensors could be rigidly mounted. When the dummy head is measured in this fashion by adding angular rate sensing to the instrumentation package, the head acceleration results are about 15 - 20% higher. This is because the chosen impact point on the head does not produce a resultant force directly through the center of gravity of the head. The head both bounces and rotates after impact. In the Hodgson study, intact cadavers and decapitated heads were dropped onto a rigid plate with a 15% associated increase in measured head acceleration resulting at least partly from the fact that the neck was not restraining the rotation of the head. Since the dummy head is always intended to be used attached to the rest of the ATD the effect of the after impact rotation is ignored and the resultant acceleration at the CG is used in this paper.

Table 1 Head Impact Response

Drop Height	Q3s Resultant (G)	Reference	Specification (G)
200mm Lateral	165	Irwin et al	121-171
130mm Lateral	123	van Ratingen	93-159
130mm Frontal	123	van Ratingen	89-153
376mm Frontal	258	49CFR Part 572 Subpart P	250-280

Neck Biofidelity The Q3s neck appears to have achieved its goal of meeting both the lateral moment verses angle flexion corridors described in Irwin et al (2002) and the frontal moment verses angle flexion corridors described in FMVSS 572 Subpart P. The neck was tested at 5.5 ± 0.1 m/s using the pulse defined in the Code of Federal Regulations (CFR), 49, Part 572, Subpart P for the HIII 3YO. The results (Figure 6) show that the Q3s neck generally matches the frontal flexion corridors for the HIII 3YO neck.

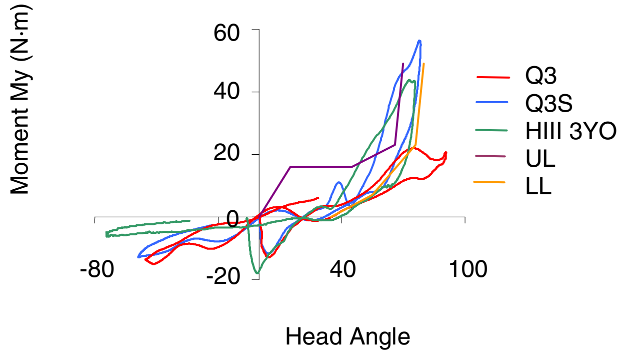

Figure 6 Neck Frontal Flexion

The lateral neck pendulum tests shown in Figure 7 resulted in a peak lateral moment Mx of 25 Nm with a peak rotation of the head of 80 degrees. The HIII 3YO neck results are not shown in the graph but due to its frontal flexion oriented design it would rotate less than 40 degrees in this lateral test.

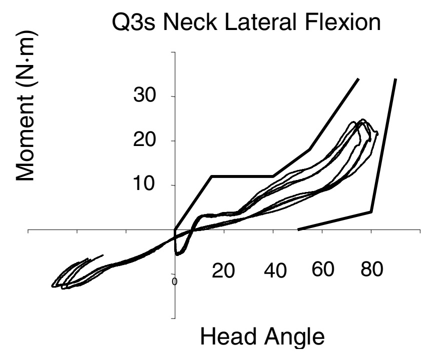

Figure 7 Q3s Neck Lateral Flexion

Tensile Stiffness

The Q3s neck, like the Q3 neck, is extensible whereas the HIII 3YO neck is not. The axial spring rate of the neck in tension has 2 modes, low rate for distractions less than 11mm and high rate above 11mm. In addition to providing overload protection to the neck, this property has the benefit of providing a distinguishable change in the Fz test data once the neck distraction has exceeded 11mm. In the quasi-static tensile test the axial spring rate of the Q3s neck began at 180N/mm decreasing to 60N/mm and averaging 130 N/mm for distractions less than 11mm. Above 11mm distraction, the axial spring rate increased gradually over the next 4mm to an approximate value of 1000N/mm. Figure 8 plots the Neck tensile load against elongation for the Q3s along with the FMVSS Part 571.208 axial tension limit for the three year old ATD.

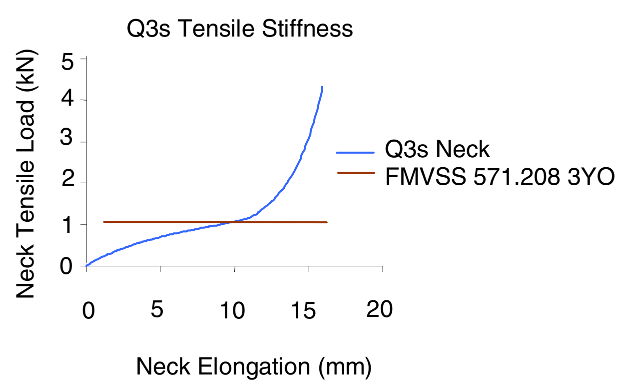

Figure 8 Q3s Tensile Stiffness

Shoulder Impact Tests

The new shoulder assembly in the Q3s shows a marked reduction in impact force over the standard

Q3 design and over the HIII 3YO. The improvement can be attributed to 2 design elements. The first is the lateral compliance of the shoulder joint and the second is the compliance of the upper arm flesh. Since the standard Q3 has a hard urethane surface at the probe impact point, it suffers from an inertial peak at impact and while the shoulder is laterally compliant its deflection is less than that of the Q3s shoulder. The HIII 3YO has a soft vinyl flesh covering the upper arm at the impact point but it has little lateral compliance in the shoulder joint.

Bolte et al. (2000) concluded that acromial – sternum deflection could be used as an injury criteria. The string pot is attached anterior, inferior and inboard of the actual shoulder joint and measures the lateral deflection of the shoulder joint but not the flesh compression of the upper arm. Shoulder rotation due to oblique impacts or swinging arm motion will have an effect on the shoulder deflection measurements either increasing or decreasing the measured deflection. The effect varies with the direction of movement of the shoulder and arm. When handling the Q3s ATD it is apparent that the shoulder allows a wide range of motion to the arm and also deflects under oblique loads. Future testing will provide data from the complete series of biofidelity tests and also should allow the characterization of the oblique impact response.

The shoulder assembly was evaluated using the ISO 9790 test as scaled in Irwin et al. (2002) Figure 9 shows the lateral impact force at the shoulder. The peak value for the new Q3s shoulder is 1.15kN, the original Q3s shoulder is 2.1kN, and for the HIII 3YO is 2.2kN. The Irwin et al (2002) corridor peak is .5kN.

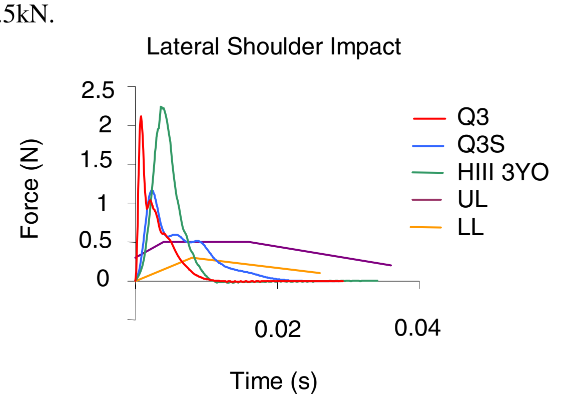

Figure 9 Lateral Shoulder Impact

Figure 10 shows the deflection measured by the string potentiometer mounted between the thoracic spine and the shoulder. Peak deflection in the Q3s was 17mm which is 4mm lower than the lower deflection limit of 21mm specified in Irwin et al. (2002) The Q3 dummy shoulder deflected 11 mm as measured by an IRTRACC that had been attached between a specially modified shoulder joint and the thoracic spine of the dummy. This measurement is not possible in the HIII 3YO.

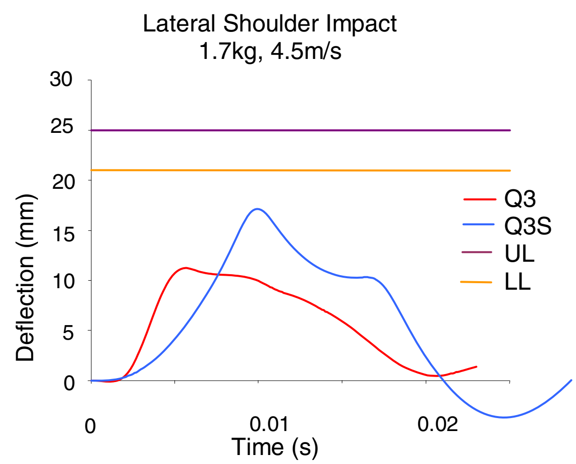

Figure 10 Lateral Shoulder Deflection for the Q3 and Q3s

Thorax Impact Response

The Q3s ribcage has good lateral compliance as evident by the pendulum force and the IRTRACC rib deflection measurements. The Q3 ribcage had been optimized for frontal impact and performed less well against the Irwin et al (2002) force corridor. The HIII 3YO ribcage does not have provision for lateral rib deflection measurements. In addition, the frontal orientation of the HIII 3YO ribcage suggests the conclusion that it is not a suitable design for lateral loading. Figure 11 shows the force time curve for the lateral thorax impact using the 1.7kg impactor. The peak force of the Q3s was .67kN and the peak deflection was 24mm. The peak force for the HIII 3YO was 1.6kN. The Irwin et al (2002) corridor peak is .66kN.

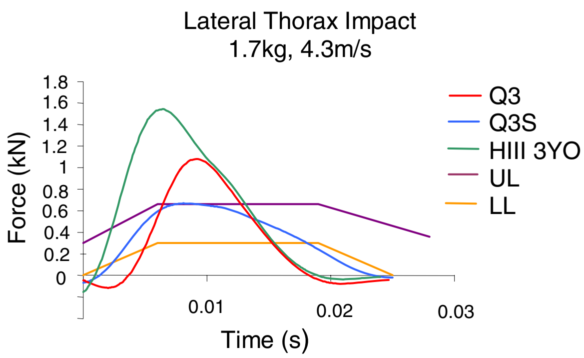

Figure 11 Lateral Thorax Impact Force for the Q3, Q3s, HIII 3YO

The HIII 3YO performed the closest to the Irwin et al (2002) corridor for T1 acceleration at 15G max with the Q3s following at 17.5G and the Q3 at 33G. The differences between the Q3s and Q3 can be explained by the greater compliance of the Q3s ribcage since the mass distribution of the 2 ATDs is similar. The better performance of the HIII 3YO cannot be explained by the differences in thorax compliance but likely due to the mass distribution in the upper thorax. Figure 12 shows the T1 acceleration results for the Q3s, Q3 and HIII 3YO. The corridor suggested by Irwin et al (2002) has peak acceleration of 15G.

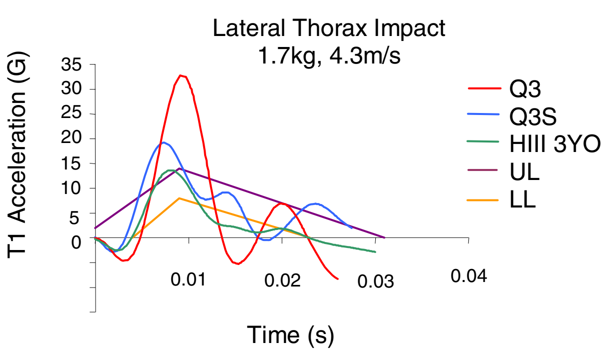

Figure 12 T1 Acceleration for the Q3, Q3s, HIII 3YO

Table 2 shows the lateral rib deflection for the Q3 and Q3s dummies. The Q3s ribcage is more cylindrically shaped than the Q3 version, while not as anthropometrically accurate to a 3 year old child, it provides more lateral compliance. The HIII 3YO is not shown because it does not have lateral rib deflection measurement capability.

Table 2 Lateral Chest Deflection for the Q3, Q3s

Dummy Type	Chest Deflection (mm)
Q3s	24.0
Q3	12.9
HIII 3YO	n/a

Abdomen Response

The Q3s abdomen performed well against the scaled corridors suggested by van Ratingen et al (1997) recommended scaled corridors for the 3 year old ATD abdomen of 1.05kN and 1.575kN maximum for impacts at 4.8m/s and 6.8m/s respectively. Future sled and drop tests must confirm the biofidelity performance of this body region. Figures 13 and 14 show the abdominal impact response of the Q3s at 4.8 and 6.8m/s using the 3.8kg impactor plotted against biofidelity curves suggested in van Ratingen et al.

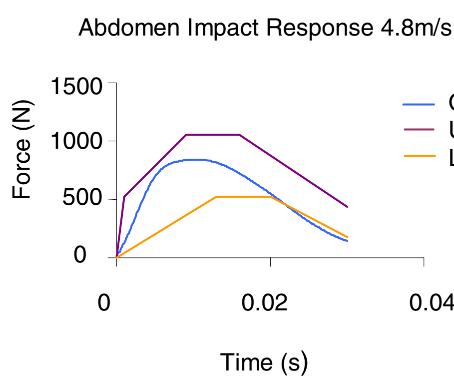

Figure 13 Q3s Lateral Abdominal Impact Response at 4.8m/s

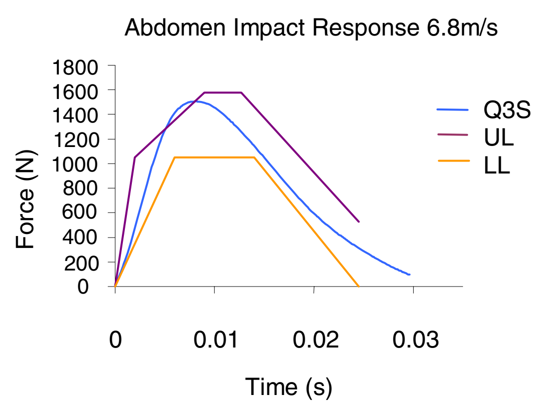

Figure 14 Q3s Lateral Abdominal Impact at 6.8m/s

Pelvis Impact Tests

The pendulum impact results are presented at two velocities, 5.2m/s and 4.5m/s. Irwin et al. (2002) suggested a velocity of 4.5m/s and provided scaled corridors for that velocity. The 5.2m/s data was included because that was the Q3 test configuration in van Ratingen et al. The existence of that data made a convenient means to provide a side by side comparison. The combination of softer upper leg flesh, floating hip cups, and the rubber buffer help the Q3s perform closer to the Irwin et al corridors in the pendulum tests. Figure 15 shows the force time curves for lateral pelvic impacts at 5.2m/s for the HIII 3YO, the standard Q3 and the Q3s dummies. The force time curve for the Q3s is also plotted against the Irwin et al (2002) corridors at 4.5m/s in Figure 16.

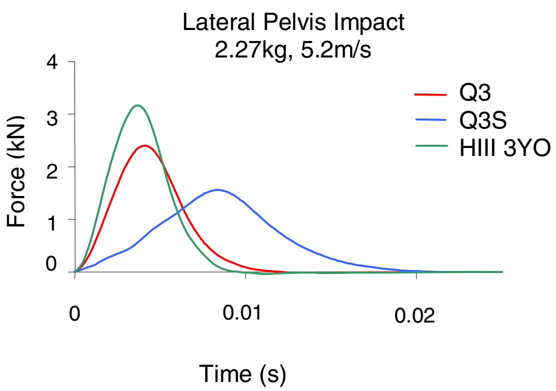

Figure 15 Lateral Pelvis Impact Force at 5.2m/s for the Q3, Q3s, HIII 3YO

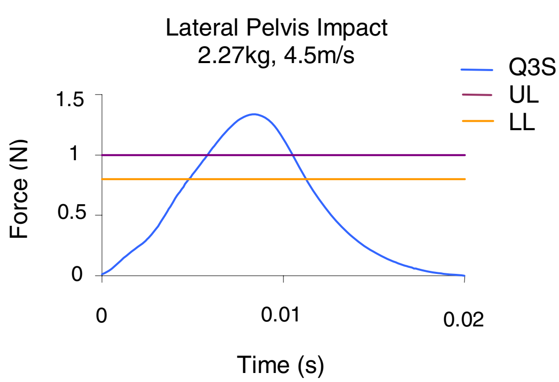

Figure 16 Q3s Lateral Pelvis Impact Force at 4.5m/s

DISCUSSION AND CONCLUSIONS

The new Q3s dummy incorporates improved lateral impact performance and enhanced instrumentation for side impact testing. Several of the original Q3 components were replaced by more compliant yet durable components. The shoulder design is a good example of this. The urethane clavicle of the Q3 was replaced with a molded rubber version. This means the shoulder joint is suspended between the thoracic spine and the sternum on a D-shaped rubber component. Lateral impacts to the shoulder cause it to collapse inward thus improving both impact response and shoulder deflection. The molded-in steel cable flexes with the shoulder joint laterally but provides protection against extreme tensile loads. In the case of the pelvis, the hip joints were allowed to compress inward. This increased the overall compliance of the pelvis assembly in the lateral direction and permitted the implementation of a pubic load cell. The dummy now has lateral force or displacement sensors at the shoulder, ribcage and pelvis which are also the primary lateral impact locations. Further study of the usefulness of these sensors and the development of injury criteria are needed. Also investigation of the oblique response characteristics of this dummy is required since many side impact events, in particular when the dummy is seated in the rear, involve an oblique component. An initial assessment against published biomechanical targets by Irwin et al. (2002) indicates that the Q3s provides an important improvement in terms of biofidelity compared to the original Q3 and the H-III 3YO dummies. Moreover, the design updates to the head and neck have been effective in addressing known head resonance issues and providing omni-directional neck biofidelity respectively.

The biofidelity assessment presented in this paper is not complete as it does not include all recommended test conditions given by Irwin et al. (2002). Specifically the Heidelberg and WSU type sled tests are an important means to assess the full-body dummy response and interaction between shoulder, thorax and pelvis regions. Furthermore, the dummy has not yet been exposed to the test conditions in which it is likely to be used in the future, i.e. lateral hinge-door sled tests following the ISO protocol and in-vehicle tests. More testing of the Q3s therefore is imperative and ongoing as part of the OSRP Q3s Task Group activities.

Finally, the design principles applied to the Q3s are currently used on the other sizes of Q-dummies, such as the Q6, in order to extend the series of side impact child dummies.

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