Development of a Manikin Representing a Two-Year-Old Child for Belt-Fit Measurement

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I. INTRODUCTION

Proper belt fit is a pre-requisite for good occupant protection in aviation seats. Protecting the smallest occupants is a particular challenge because the immature pelvis of a child provides a small target for the lap belt. The U.S. Federal Aviation Administration mandates that belts should fit a range of occupants, from large men to children as small as two years of age. A suitable surrogate to evaluate the belt fit for the smallest occupants does not currently exist. To assess belt fitment, seat manufacturers currently place a child of approximately two years of age into the seat. Due to differences in child body dimensions and posture, this procedure lacks objectivity.

A series of previous studies has addressed restraint fit, including belt and harness fit for children [1-4]. These studies have led to the development of standardised procedures for positioning anthropomorphic test devices (ATDs) representing children, and to repeatable and reproducible assessments of belt fit, with and without boosters, that can be linked to belt fit on children [3-4]. However, no currently available ATD is the size of a typical 2yo child, and the available ATDs lack realistic body contours.

Over the past five years, several detailed studies of child body shape have been conducted, measuring hundreds of children aged 1–12 years using laser and optical scanners [5]. Body shape models created from statistical analysis of these data have provided the first detailed information on child body shapes in seated postures [6]. Several of these body shape models are available online at http://humanshape.org/. Recently, the first ATD for which anthropometric specifications were developed using 3D body shape modelling was developed [7].

In the current study, a manikin that represents the body size and shape of a typical U.S. child at 24 months of age was developed. This paper presents an overview of the development methodology and a preliminary assessment of performance in a mock-up of an aviation seat.

II. METHODS

In a recent study, laser scan data from 40 children aged 12–36 months were obtained in a range of postures [8]. Scan data for a seated posture were fitted with a standardised template and a statistical analysis was conducted to predict body size and shape as a function of anthropometric variables. For the current study, the body shape of a seated toddler was parameterised by torso length (crown–rump length) and body weight. Figure 1 shows some example output from the model, using values of 527 mm for crown–rump length and 12.3 kg for body weight [9]. Internal joint centre locations were estimated from the palpated locations of surface body landmarks.

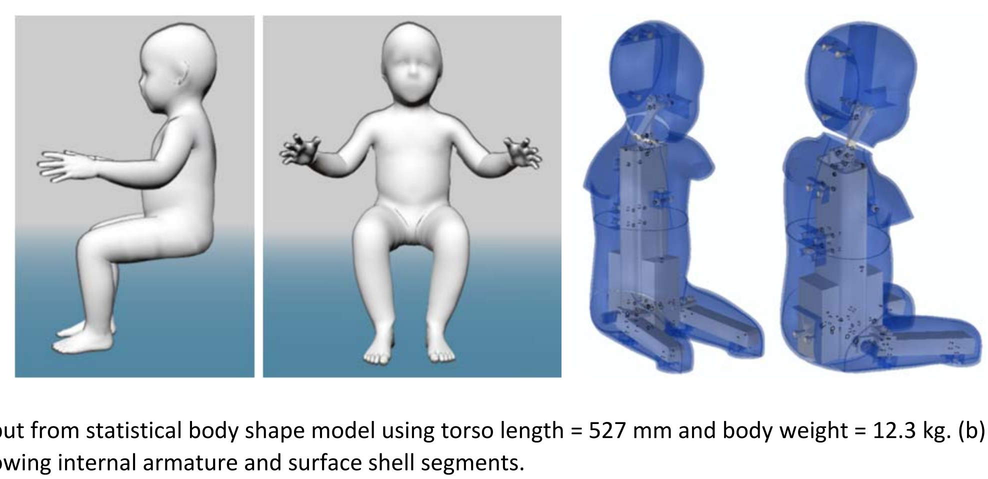

Fig. 1. (a) Output from statistical body shape model using torso length = 527 mm and body weight = 12.3 kg. (b) CAD model of manikin showing internal armature and surface shell segments.

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A manikin design was developed using the external body shape and internal joint linkage. Figure 1 shows two views of the manikin design. A steel armature was created that provides the needed mass and that includes hip joints and two neck joints. The neck joints are connected using a four-bar linkage, which provides a single degree of freedom (DOF) for head motion. Note that the neck motion is intended primarily to allow the back of the head to clear the seat surface across a range of postures.

The manikin surfaces were manufactured using acrylonitrile butadiene styrene (ABS) plastic with a 3D Dimension Elite printer. Following printing, the surfaces were smoothed by exposure to acetone vapour and then painted. The surface components are attached to the armature with conventional fasteners. Figure 2 shows the manikin in an aviation seat.

Fig. 2. Manikin in an aviation seat.

III. INITIAL FINDINGS

Table I shows belt-fit measurements for the two restraint conditions in Fig. 2, at three side-view lap-belt angles. Each condition was measured once by each of three investigators. The upper edge of the lap belt was located relative to a point on the right side of the manikin, at the location of the right anterior-superior iliac spine (ASIS) landmark on the pelvis. Negative values indicate that the belt is forward of or below the landmark. On average, the upper edge of the belt was above the ASIS. Steeper lap-belt angles, achieved by moving the anchorages forward, lowered the belt relative to the pelvis. Adding the harness raised the belt.

TABLE I

MEAN (SD) BELT-FIT MEASUREMENTS – RIGHT SIDE

Belt Angle with Respect to Vertical (deg)	Restraint	Lap Belt Relative to ASIS Surface X (mm)	Lap Belt Relative to ASIS Surface Z (mm)
30	Lap Belt	-11.5 (2.7)	28.6 (1.8)
30	Lap Belt + Harness	-10.6 (1.2)	44.5 (5.2)
54	Lap Belt	-7.8 (0.8)	13.4 (3.9)
54	Lap Belt + Harness	-9.0 (2.7)	30.7 (18.9)
75	Lap Belt	-12.0 (1.3)	1.2 (3.0)
75	Lap Belt + Harness	-12.6 (3.4)	23.9 (2.3)

IV. DISCUSSION

To our knowledge, this is the first child manikin to be created using 3D statistical body shape models and 3D printing. The body shape is visually more realistic than current child ATDs. The relatively low-cost methodology could be used to make other physical manikins with realistic body shapes for applications such as child restraint fit assessment. The manikin demonstrates potential to be used as a tool for assessing belt fit in aviation seating.

V. REFERENCES

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