FIRST GENERATION OBESE ATD (FGOA)

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ABSTRACT

This paper sets forth the need for an Obese ATD. The goal of this study was to build a prototype that accurately represents an obese subject with a BMI of 35 kg/m^2, and also to explore new ATD flesh material options.

The prototype ATD was designed using a THOR-M platform and a 35 kg/m^2 BMI target. The finished prototype was then tested on a rear seat buck at 29 km/h and 48 km/h. The kinematic data from these tests was compared to the kinematic data from previous tests ran at the University of Virginia using a 35 kg/m^2 BMI PMHS. This comparison was used to evaluate the existing prototype and reform the next iteration of the ATD.

INTRODUCTION

The obesity rate has increased dramatically in the U.S. and many places in the world in recent years. From 1980 to 2000, the prevalence of obesity in Americans increased from 14.4% to 30.5% [1]. In 2009-2010, approximately 78 million adult Americans – over 35% of the adult U.S. population - were obese (defined as a Body Mass Index, BMI, greater than or equal to 30 kg/m2) [2].

Obese occupants pose unique challenges for restraint systems. In addition to the increased mass of the occupant, the increased amount of centrally-located subcutaneous tissue associated with obesity limits the ability of the lap belt to properly engage the pelvis. Depending on the anthropometry of the occupant, the increased depth of the subcutaneous tissue can result in the lap belt being located more anterior and more superior relative to the pelvis than would be observed in a non-obese occupant [3]. In many cases, the depth of tissue around the waist, thighs, buttocks, and abdomen may result in the lap belt being placed above the level of the anterior superior iliac spines. This sub-optimal belt position may result in limited-to-no engagement of the pelvis in frontal impacts, resulting in excessive forward motion of the occupants and direct loading of the lap belt into the abdomen [4][5]. In addition to the effect on abdominal injury risk, this may lead to increased injury risk to the lower extremities through striking the knee bolster [6][7], and increased risk of injury to the chest due to a greater portion of the restraining load being applied to the torso [8][9].

Current anthropomorphic test devices lack the ability to assess restraint interactions with obese occupants. The Hybrid III 95% male dummy – the only current ATD representation of a "large male" – has a height of 188 cm and a weight of 101 kg. This corresponds to a BMI of 28.6 kg/m^2. This is less than the 65th percentile BMI in U.S. adults (ages 20+) [2]. In addition, the Hybrid III 95th does not take into account changes in body mass distribution or increases in superficial soft tissue depth associated with obesity.

METHODOLOGY

ATD Development

The First Generation Obese ATD (FGOA) is built on an existing platform of the THOR 50th percentile male ATD. The conversion to an obese ATD is accomplished through a flesh jacket representing the superficial tissue of an obese male. The FGOA flesh jacket consists of chest, pelvis, and upper thigh fleshes. The flesh jacket is constructed from different molded materials that allow the flesh to be pliable enough so that the dummy buttock and thighs would fit and conform into a seat. The legs and arms were ballasted to meet their target weights (Table 1).

The external geometry of the current prototype of the FGOA jacket is based on the anthropometry of a selected obese male post mortem human surrogate (PMHS) previously reported in a series of frontal impact restraint sled tests [4][5]. That subject had a height of 189 cm, mass of 124 kg, and BMI of 35 kg/m^2. The internal skeletal dimensions of that subject (e.g., the internal diameter of the ribcage) were similar to those of a 50th percentile male PMHS [4]. Thus, the majority of the difference in the mass and exterior dimensions between this particular obese subject and a 50th percentile male occurred as a result of increased superficial tissue and abdominal fat. The finished ATD can be shown in Figure 1.

Figure1. Completed Obese ATD prototype

Once the Obese ATD prototype was complete, the external dimensions were measured and compared to the external dimensions of the PMHS (See Table 1). Furthermore an overlay picture of the 35BMI PMHS and Obese ATD is shown in Figure 1. Minor dimensional differences were noticed between the flesh jacket and PMHS, and will be corrected in the next version of the ATD. Also, differences in the seated height can be improved by using a slightly stiffer pelvic flesh material. Table 2 below indicates the target mass distribution weights; these distributions were based on a the THOR-M ATD.

Table1.
ATD VS. PMHS External Measurements

Location	ATD measurements (cm)	PMHS measurements (cm)
Chest Breadth - 4th Rib	42	40
Chest Breadth - 8th Rib	41	36
Chest Depth - 4th Rib	29	23.5
Chest Depth - 8th Rib	30	25.5
Hip Breadth	44.5	39.1
Chest Circumference - 4th Rib	130	110.7
Chest Circumference - 8th Rib	119	114.3
Waist Circumference - At Umbilicus	123.5	120
Waist Circumference - 8cm above Umbilicus	120	119.7
Waist Circumference - 8cm below Umbilicus	126	116.9
Thigh Circumference	65	68.6
Shoulder Breadth (Biacromial)	49	43
Seated Height	93.5	98

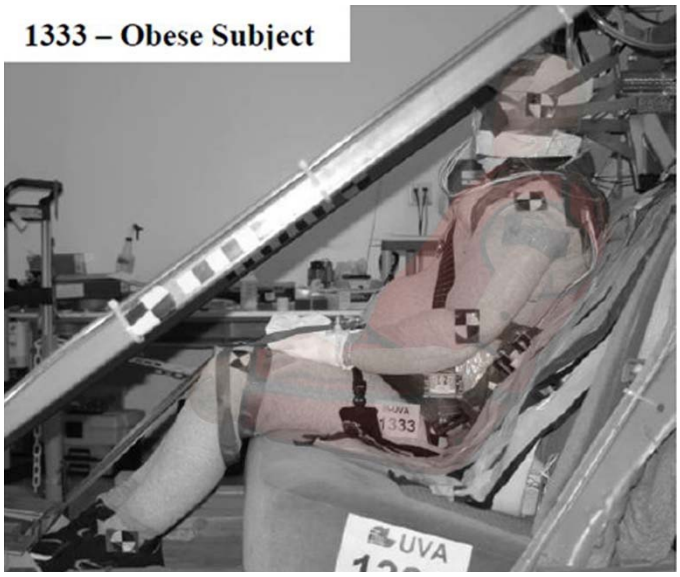

Figure2. Overlay of Obese ATD with 35BMI PMHS.

Table2.
Body Mass Distribution Targets

Segment	Hybrid III (lbs)	THOR (lbs)	Obese Design Targets (lbs)
Head	10 (5.8%)	10.2 (6.1%)	10.2
Neck	3.4 (1.9%)	3.64 (2.2%)	3.64
Upper Torso	37.9 (22.1%)	29.59 (17.9%)	49
Lower Torso	50.8 (29.7%)	62.3 (37.7%)	112
Upper Arm (each)	4.4 (5.1%)	4.4 (5.3%)	7.25
Lower Arm + Hand (each)	5 (5.8%)	5 (6.05%)	8.25
Upper leg (each)	13.2 (15.4%)	9.81 (11.9%)	16.2
Lower leg + feet (each)	12 (14%)	10.47 (12.7%)	17.4
Total Weight	171.3	165.15	273

Testing

Four tests, including two 48 km/h and two 29 km/h were performed with a sled buck representing the rear seat occupant component of a 2004 mid-sized sedan (See Figure 2.) Data was collected from accelerometers located in the head, neck and pelvis as well as angular rate sensors located in the head and T1 position. The tests were performed based on the test conditions of the obese PMHS test completed at the University of Virginia.

Figure3. Dummy sled test set-up, right side view.

RESULTS AND DATA

The trajectories shown below illustrate the trajectories from the 48km/h testing completed on a 23 kg/m^2 BMI PMHS (Figure 3), a 35 kg/m^2 BMI PMHS (Figure 4), and the obese ATD (Figure 5). As you can see from these comparisons, the ATD mimicked the substantially greater forward pelvis and knee motion caused by increased mass of the lower body and limited-to-no interaction between the pelvis (bone) and the lap belt that was seen in the 35 kg/m^2 PMHS.

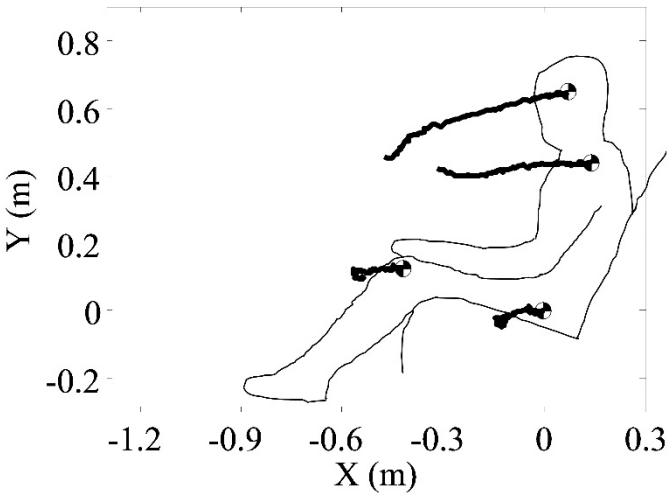

Figure4. Trajectory of the 23BMI PMHS [4].

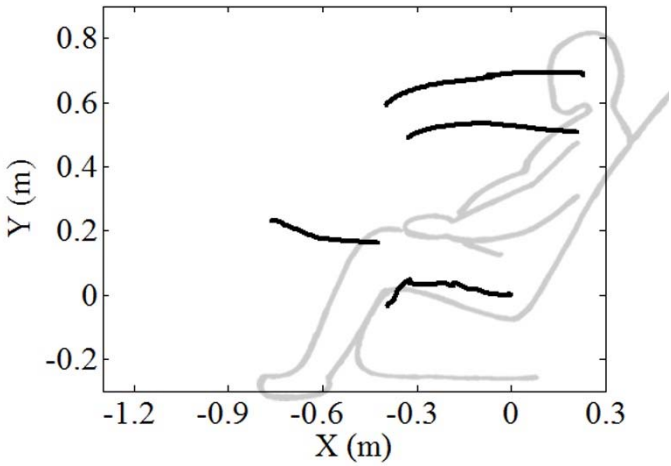

Figure5. Trajectory of the 35BMI PMHS [4].

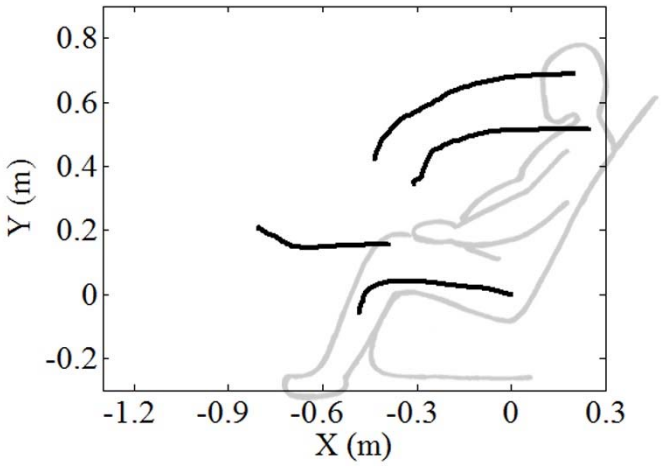

Figure6. Trajectory of the 35BMI Obese ATD.

Forward motion of head and knee of the dummy were 14 cm and 4 cm less than those of PMHS, and forward motion of pelvis of the dummy was 7 cm greater than PMHS. The mean peak of upper shoulder belt, lower shoulder belt, and lap belt tension in dummy tests were 6.5 kN, 6.7 kN, and 8.8 kN, and in PMHS tests, they were 6.4kN, 6.3 kN, and 8.3kN. Peak head, chest, and pelvis accelerations also tended to be greater with the dummy than with the PMHS.

CONCLUSIONS

The results suggest some differences in the kinematics and dynamics of the dummy compared to the PMHS that may be indicative of differences in the interaction of the posterior pelvis flesh and the seat, and a difference in mass distribution affecting relative loads on the various portions of the seatbelt. The differences in the head trajectories most likely stem from differences that already existed between the THOR ATD and the PMHS.

To correct the differences, next steps will be to create new flesh components for the arms and lower legs rather than ballasting the bones. More evaluation will be conducted on the stiffness of the material used for the flesh components as well.

Despite these differences, the obese dummy still exhibited the same kinematic characteristics that were highlighted as potentially challenging for restraint systems by the PMHS tests – most notably, both exhibited substantial forward motion of lower body and subsequent backwards rotation of the torso affected by limited engagement of the lap belt with the pelvis. This suggests that although further refinement may be warranted, this dummy may prove useful as a research tool to begin investigating the challenges of, and potential strategies for, the safe restraint of obese occupants.

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