The Inertial Effects of Booster Seats on Three-Year-Old ATD

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Overview

The Federal Motor Vehicle Safety Standard does not set a maximum weight for booster seats. And child seats, including combination seats, are being constructed with increased robustness, therefore increasing the mass. Booster seats utilize the vehicle seat belt system to restrain the child and the booster seat. Therefore, this study evaluates the potential for increased loading on a child during a frontal impact caused by increased booster seat mass since the booster seat is not attached to the vehicle seat.

Study Objectives

- Better understanding of occupant loading and risk of injury caused by the unrestrained mass of the booster seat
- Determine whether an upper weight limit for the booster seat should be recommended

Methods

Testing was conducted using the deceleration sled at the Kettering University Crash Safety Center and the FMVSS213 fixture crash pulse (Figure 1). Four combinations of booster seat configurations were evaluated. Two combinations provided a baseline of the child loading the belt system utilizing a standard weight booster: the booster was restrained to the vehicle seat with LATCH and tether (Tests 1-3) and a standard configuration booster (not attached to the vehicle) was utilized (Tests 4-6). The other two combinations evaluated the high weight booster seats with (Tests 7-9) and without (Tests 10-12) the use of a tether.

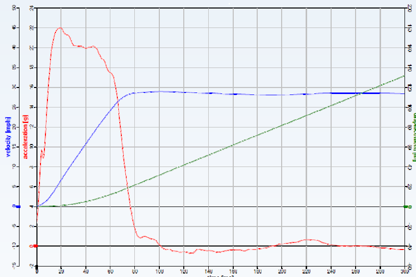

Figure 1: Acceleration, velocity, and displacement of the deceleration sled during impact

An instrumented HIII-3 YO ATD was utilized. The sled, vehicle belts, and tether were also instrumented (Table 1).

Table 1: Test Instrumentation

Location	Type	Axis	Instrument
Head	Acceleration	(X,Y,Z)	Accelerometer
Chest	Acceleration	(X,Y,Z)	Accelerometer
Chest	Displacement	(X)	Potentiometer
Neck	Force	(X,Y,Z)	Load Cell
Neck	Moment	(X,Y,Z)	Load Cell
Pelvis	Acceleration	(X,Y,Z)	Accelerometer
Sled 1	Acceleration	(X,Y,Z)	Accelerometer
Sled 2	Acceleration	(X,Y,Z)	Accelerometer
Lap	Force	On webbing	Load Cell
Shoulder	Force	On webbing	Load Cell

Booster Seat Modifications

The center of mass was initially located for the standard weight booster seat. To increase the mass for the modified seats in Tests 7 through 12, lead weights were added in the locations labeled 1 through 5 in Figure 2. A laser and a vertical mark on the seat were used to maintain the seats weight distribution while adding the mass.

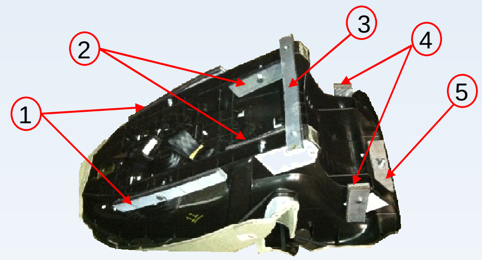

Figure 2: Location of additional booster seat weight

Results and Discussion

Table 2: Seat belt load measurements and effective mass calculations

Sample Group	AVG Lap Load [N]	AVG Lap [g's] @ peak load	AVG Effective Mass [kg]	AVG Shoulder Load [N]	AVG Shoulder [g's] @ peak load	AVG Effective Mass [kg]	AVG Total Effective Mass [kg]
1-3	1778.4	47.7	3.8	3464.6	30.7	11.5	15.3
4-6	1825.8	43.2	4.3	3986.2	40.7	10.0	14.3
7-9	2421.8	50.0	4.9	3641.4	38.0	9.8	14.7
10-12	2392.9	46.2	5.3	4970.0	36.7	13.9	19.2

Effective Mass as shown in Table 2 is the amount of mass applied to the belt system during the peak lap and shoulder loading, based on the system accelerations. Formulas 1 and 2 determine the effective mass of the shoulder and lap portions of the dynamic event. Formula 3 sums the first two effective masses for a total system output. This value was then compared from system to system to determine the difference in effective mass by changing test set up and booster seat weight.

Results - Continued

- Increasing the booster mass increased the lap load by 600N or 33%, in turn could increasing the risk of pelvic and abdominal injury.
- The use of a tether reduced total effective mass for high weight boosters. On average system load decreased by 1300N or 21% by adding the tether.
- The LATCH system, whether used or not, did not have a significant effect on the belt loads.

1.) $m_{Effective Shoulder} = \frac{F_{Peak Shoulder Load}}{a_{At Peak Shoulder Load}}$

2.) $m_{Effective Lap} = \frac{F_{Peak Lap Load}}{a_{At Peak Lap Load}}$

3.) $m_{Effective Total} = m_{Effective Lap} + m_{Effective Shoulder}$

Conclusion

- Booster seats should have an upper weight limit to minimize the effect of inertial loading on children at the lower end of the use weight range.
- Additional research should be conducted to correlate the amount of load applied to the child to the risk of abdominal injury.
- Tether should be recommended for all belt positioning booster seats. Several major seat manufacturers currently recommend the use of a tether.

Acknowledgements

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