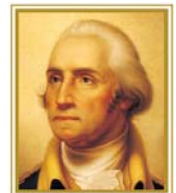


Using Consumer Information Testing to Improve Rear Seat Occupant Protection

Seong-Woo Hong, Chung-Kyu Park,
Richard M. Morgan, and Cing-Dao Kan
George Washington University

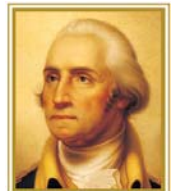
Shinhee Park and Hanil Bae
Hyundai-Kia Motors



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Past Studies of Rear Seat Safety

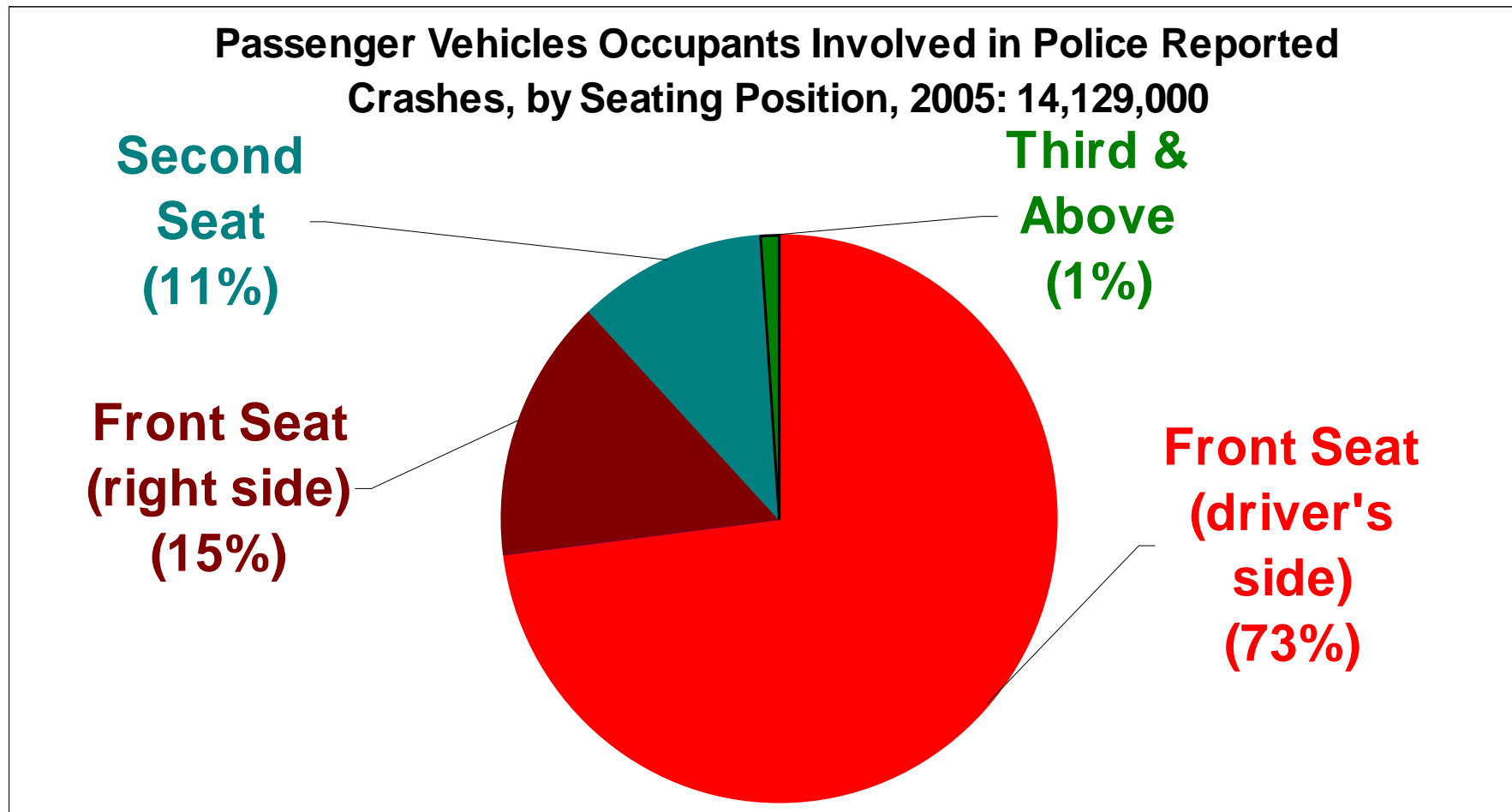
- **Zellmer et al. of Autoliv (1998)** in real-world crashes in mid 1990s, injury severity in rear seat less than in the front seat.
- Zellmer did rear-seat sled tests with a 50th male dummy.
- The pretensioned belt and the force-limited belt lowered the head and neck loading, and generally reduced the chest injury values.



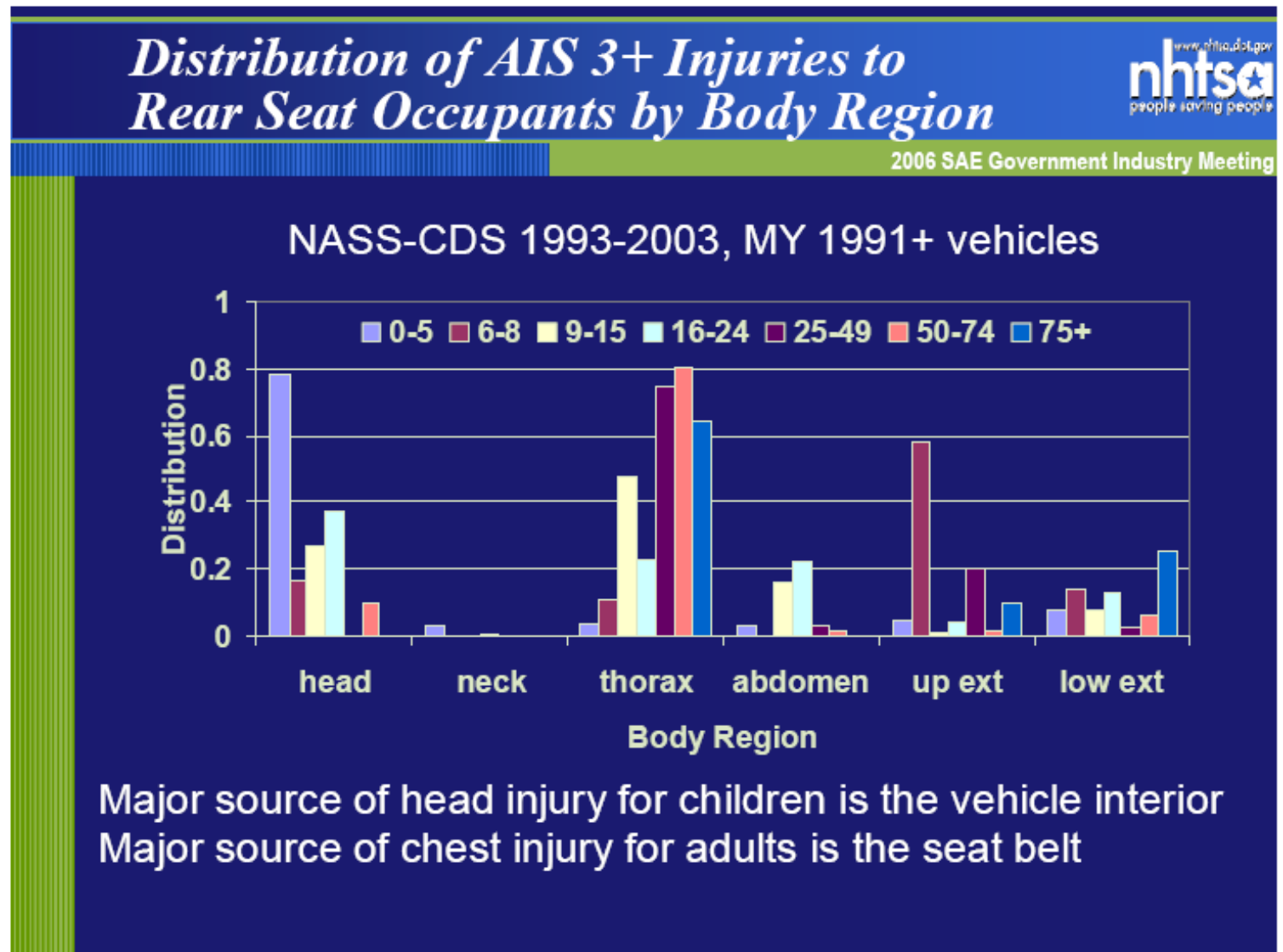
Recent Studies of Rear Seat Safety

- **Tylko of Transport Canada (2005)** reported on 3 full-scale crashes.
- **Saunders of NHTSA (2006)** reported on 7 NCAP frontal crash tests.
- **Mizuno and JNCAP NHTSA (2007)** reported on a frontal crash test.
- In all 3 studies, 5th female dummy in the rear seat had much higher head and neck injury values than the dummy in the front seat. Generally, the rear seat dummy had higher injury values for the chest.

Utter of NHTSA(2007) Rear Seats have 12% Crash-Involved Occupants



Kuppa of NHTSA (2006) Type of Injury



Recent Studies - Rear Seat No Longer Always Safer

- **Smith and Cummings (2006)** studied 56 thousand passengers in FARS. For belt restrained occupants in air bag vehicles, older occupants (30 – 59 years and ≥ 60 years) in the rear seat had a higher risk of death.
- **Kent, Kuppa, et al. (2007)** real-world crash data suggests that the fatality and serious injury risk in frontal crashes is higher for older occupants in rear seats than for those in front seats.

Recent Studies of Rear Seat Safety – Kent and Kuppa (2007)

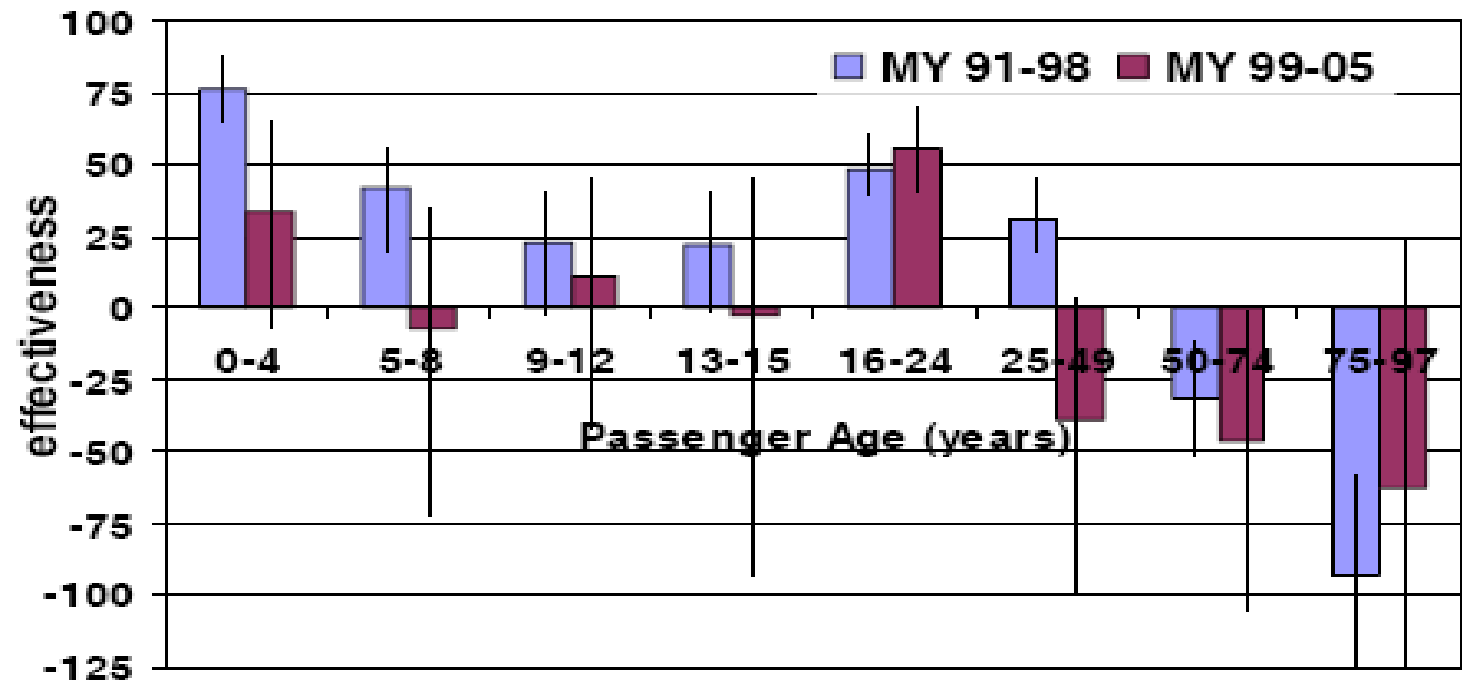


Figure 3. Effectiveness of outboard rear seats compared to front outboard passenger seats in mitigating fatalities for restrained occupants in MY 1991-1998 and MY 1999-2005 vehicles (all vehicles equipped with air bags).

Recent Studies of Rear Seat Safety

- **Huang and Reed U. of Michigan (2006)** noted that the seat cushion length in the rear seat is longer than the buttock-to-popliteal (BPL) length of much of the population in the rear seat.
- In other words, rear seats too long.



Recent Studies of Rear Seat Safety

- **Huang and Reed U. of Michigan (2006)** estimated the cumulative probability of rear seat occupants
- Approximately 50% of rear-seat occupants of cars, SUVs, and minivans are less than 12 years old.

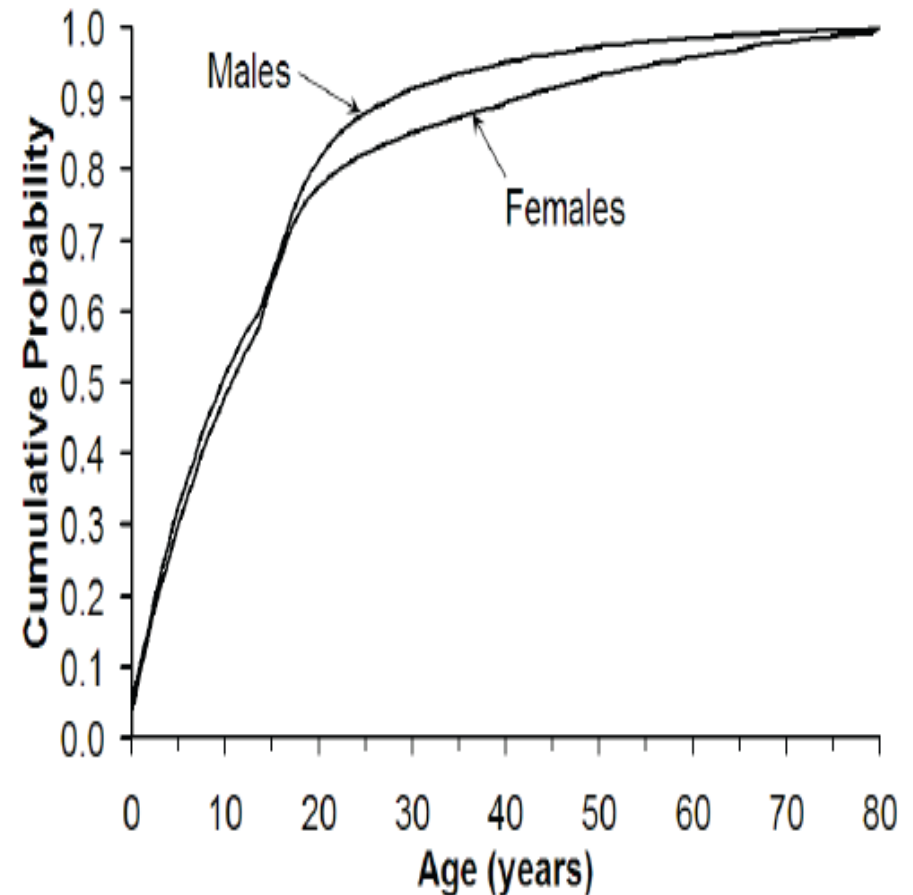


Figure 9. Cumulative probability of rear seat occupant age in passenger cars, SUVs, and minivans from NASS-GES.

10 year-old Child Hybrid III Dummy

Features

- ≡ Instrumented shoulders with more realistic shape
- ≡ Thoracic instrumentation optional to chest ball-slider mechanism
- ≡ Lumbar spine is rubber cylinder with center cable



Specification

	Standing Height (cm)		Weight (kg)	
	Hybrid III	Human	Hybrid III	Human
5 th Female	149.9	144.8/149.9/154.9	49.0	41.7/48.1/53.1
10 year-old	129.5	127.0/137.2/144.8	35.3	23.6/32.9/50.8
6 year-old	114.3	109.2/119.4/129.5	23.4	16.9/21.4/34.3

10 Year-Old Child Hybrid III Dummy

- The 10 Year Old Child Hybrid III is available from both FTSS and Denton ATD.
- **Stammen of NHTSA (2003)** found the dummy to be within SAE-proposed response corridors for impacts to head, neck, thorax, knees, and torso flex.
- **Stammen** found the 10 year old dummy met reasonable requirements for repeatability and reproducibility.

USA NCAP Tests for Rear Seat Safety

- From 2004 to 2005, **NHTSA did twenty-eight tests**: 10-Year-Old Child Hybrid III dummy in rear seat.
- 50th% male Hybrid III dummies seated on front seat.
- Some 10-Year-Old Child Hybrid III dummies seated on a booster seat and some on the vehicle seat.
- We will look at child dummy performance in four NCAP tests: **Car A, Car B, Minivan C, and SUV D**

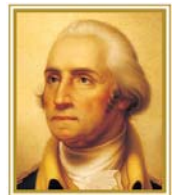
NCAP Test – 10-Year-Old Child – No Booster – Car A - 4 Star Car

Additional Camera View-01



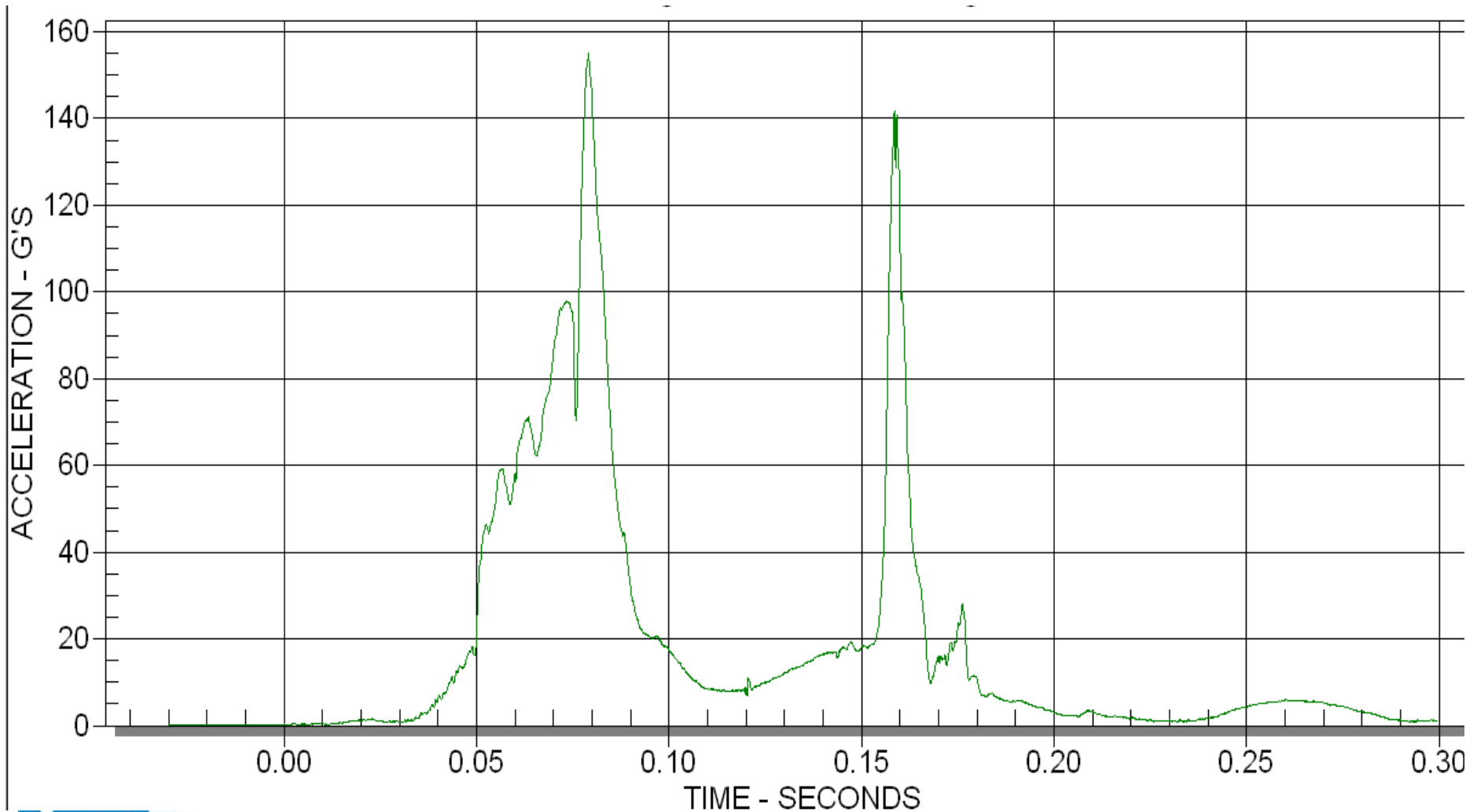
Frame # - 10

Time -0.0100

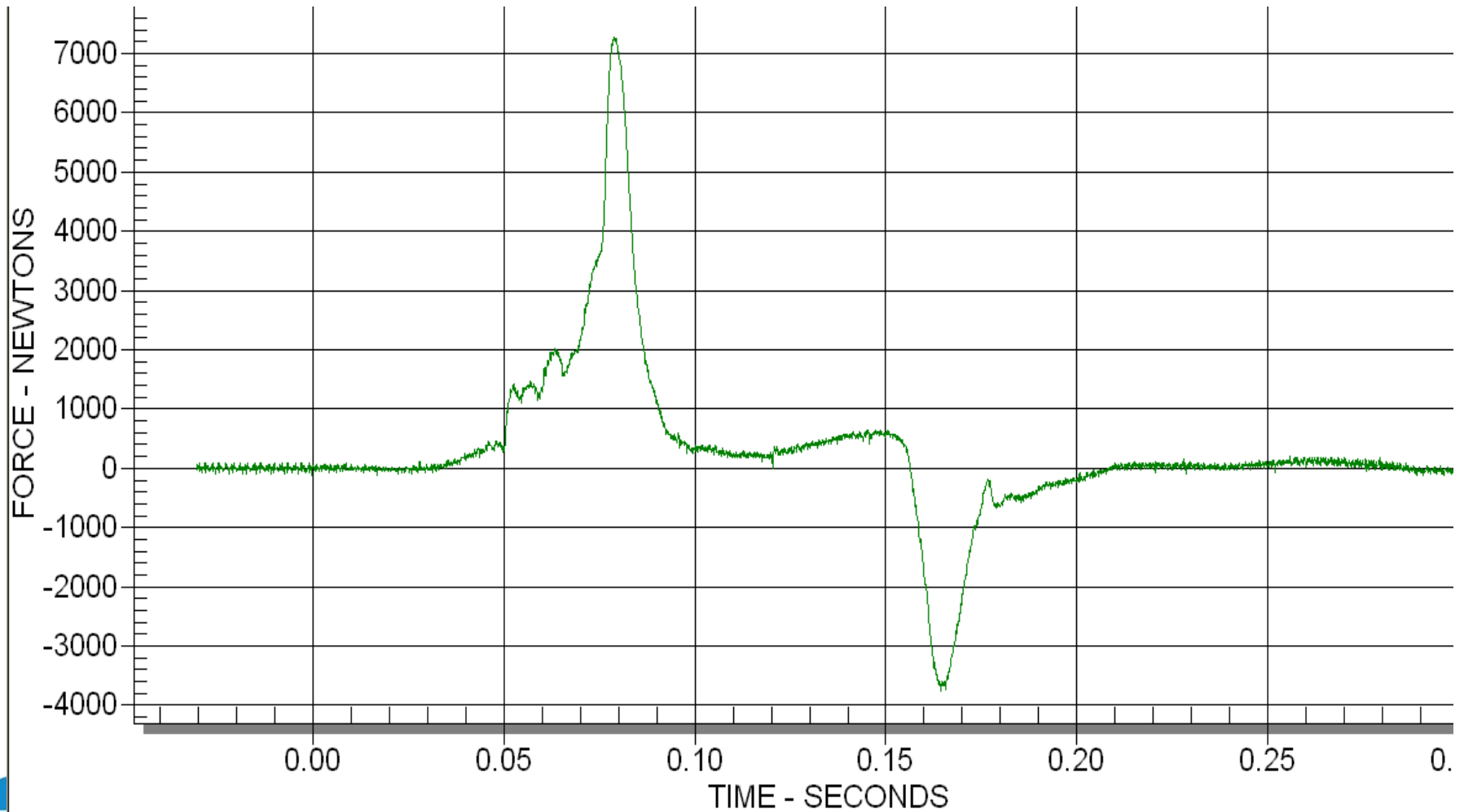


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In Car A, 10YO Child Dummy Has Two Peaks of Resultant Head Acceleration with a HIC of 1,785 – Second HIC 15 = 681



10YO Child Has Neck Tension and Compression Greater than IARV of 2,290 N (tension) and 2,200 N (compression) - Mertz, Irwin, and Prasad, 2003



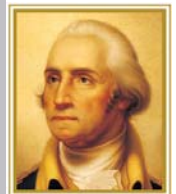
NCAP Tests for Rear Seat Safety – Booster Seat - HIC 15 = 951 – Car B – 5 Star Car

Camera View DSP-03



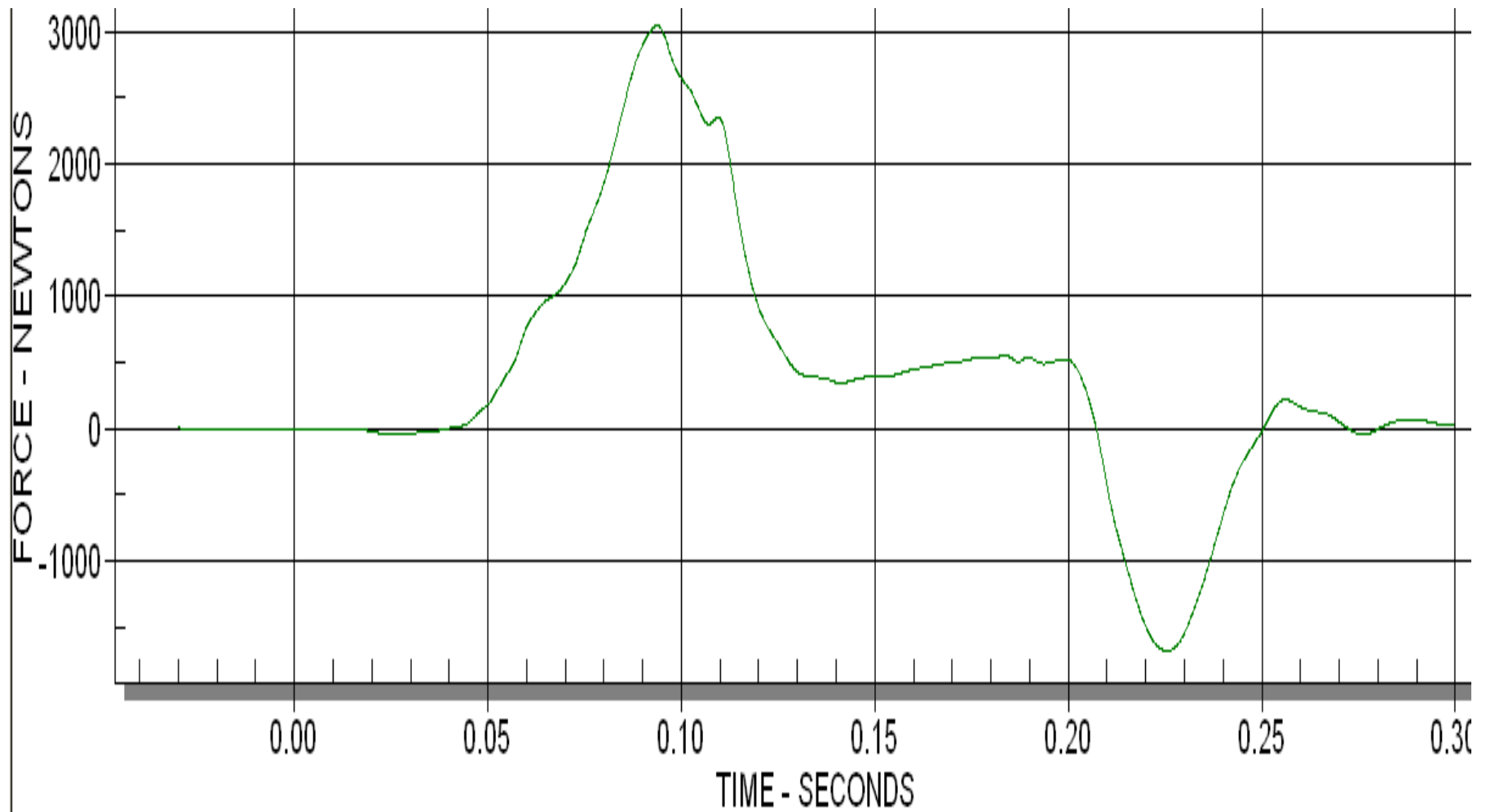
Frame # - 10

Time -0.0100



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10YO Child Has Neck Tension Greater than IARV of 2,290 N and Compression Approaching 2,200 N



Ready

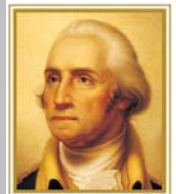
NCAP Test – Booster Seat – HIC 15 = 351 – Minivan C – 5 Star Vehicle

Camera View DSP-04



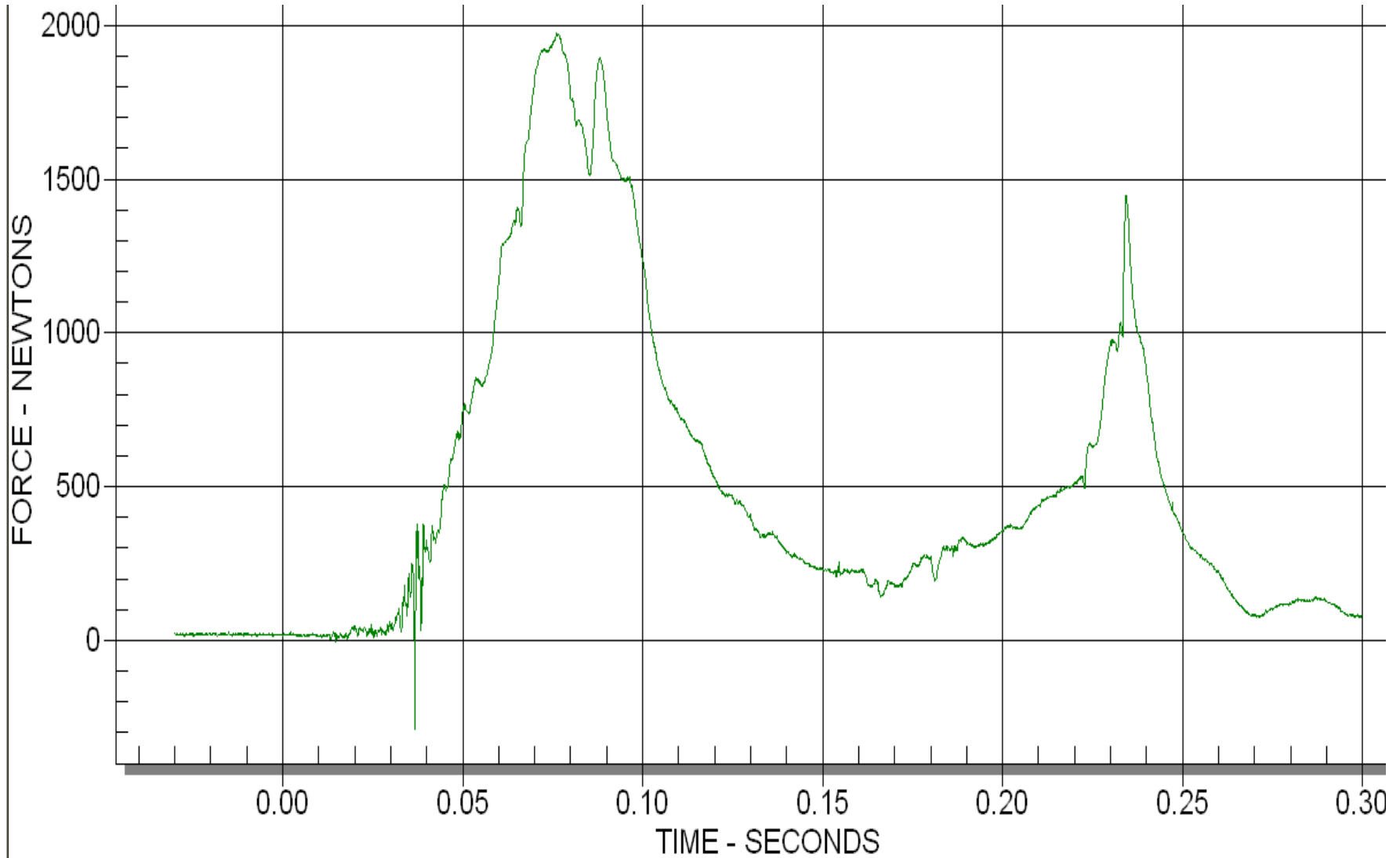
Frame # - 10

Time -0.0100



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10YO Child Has Neck Tension Less than IARV of 2,290 N - Minivan C



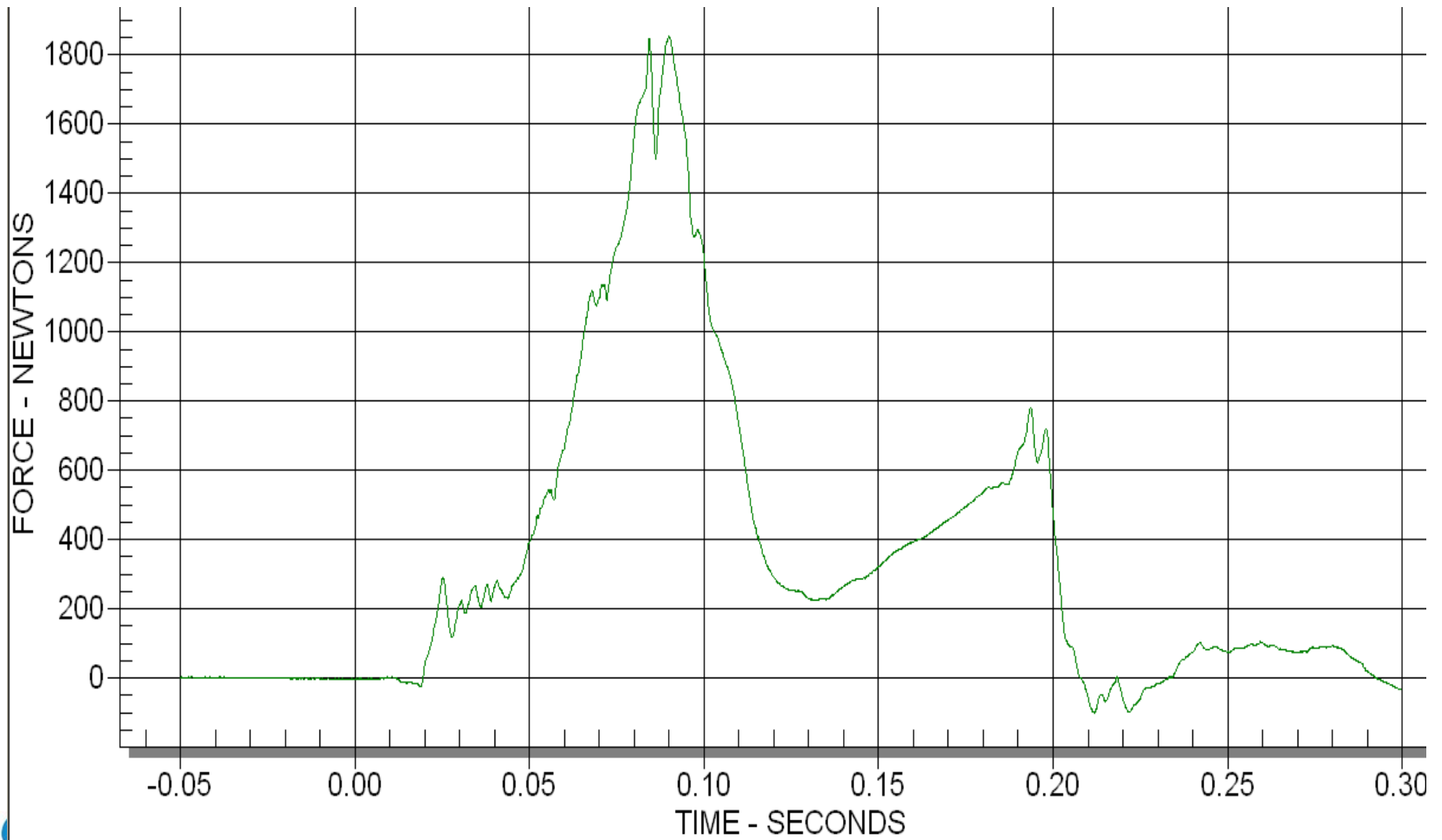
Ready

NCAP Test – No Booster in Right Rear – HIC 15 = 343 – SUV D – 5 Star Vehicle

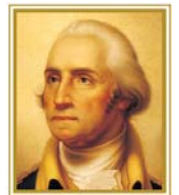
500 fps • Frame: 1



10YO Child Has Neck Tension Lower than IARV of 2,290 N for SUV D



**The New Car Assessment
Program (NCAP) uses a 5
Star Rating System
for Adults in the Front Seat**



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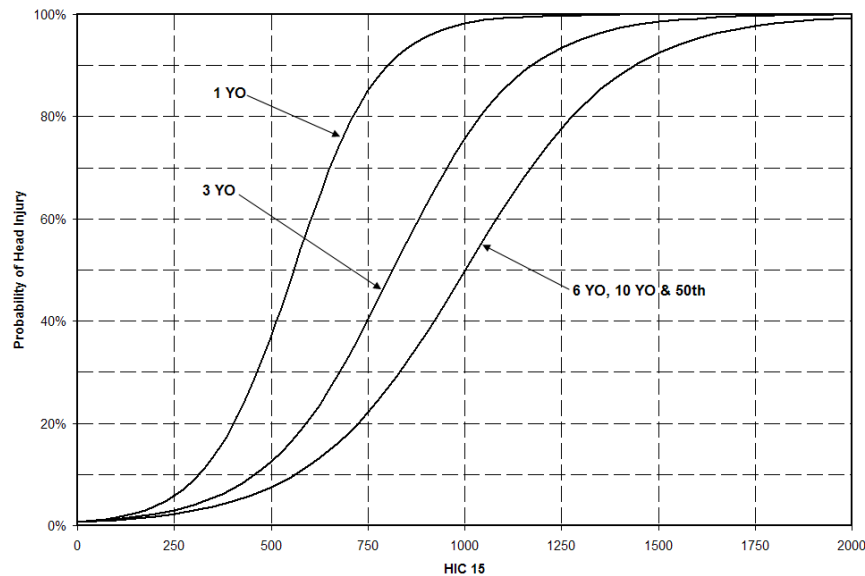
Using NHTSA Published Study of Trauma, Scale NCAP Injury Risk Function Curves to 10YO

NCAP uses Injury Probability of AIS ≥ 4 Head, Chest

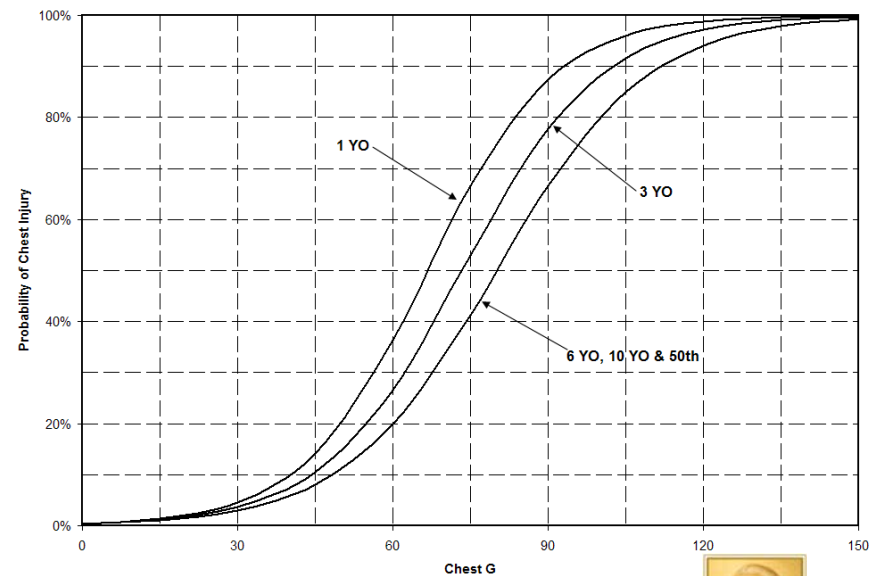
$$P_{head} = \{1 + \exp[5.02 - 0.00351 \times HIC_{36}]\}^{-1} \quad \text{For } HIC_{36}$$

$$P_{head} = \{1 + \exp[5.02 - 0.005014 \times HIC_{15}]\}^{-1} \quad \text{For } HIC_{15}$$

$$P_{chest} = \{1 + \exp[5.55 - 0.0693 \times ChestG]\}^{-1}$$

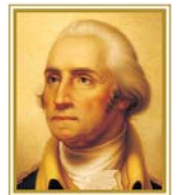


Head Injury



Chest Injury

**Following NHTSA Logic of 5 Star
Rating System for 50th% Male,
Develop 5 Star Rating Format for
10 year-old Child Dummy**



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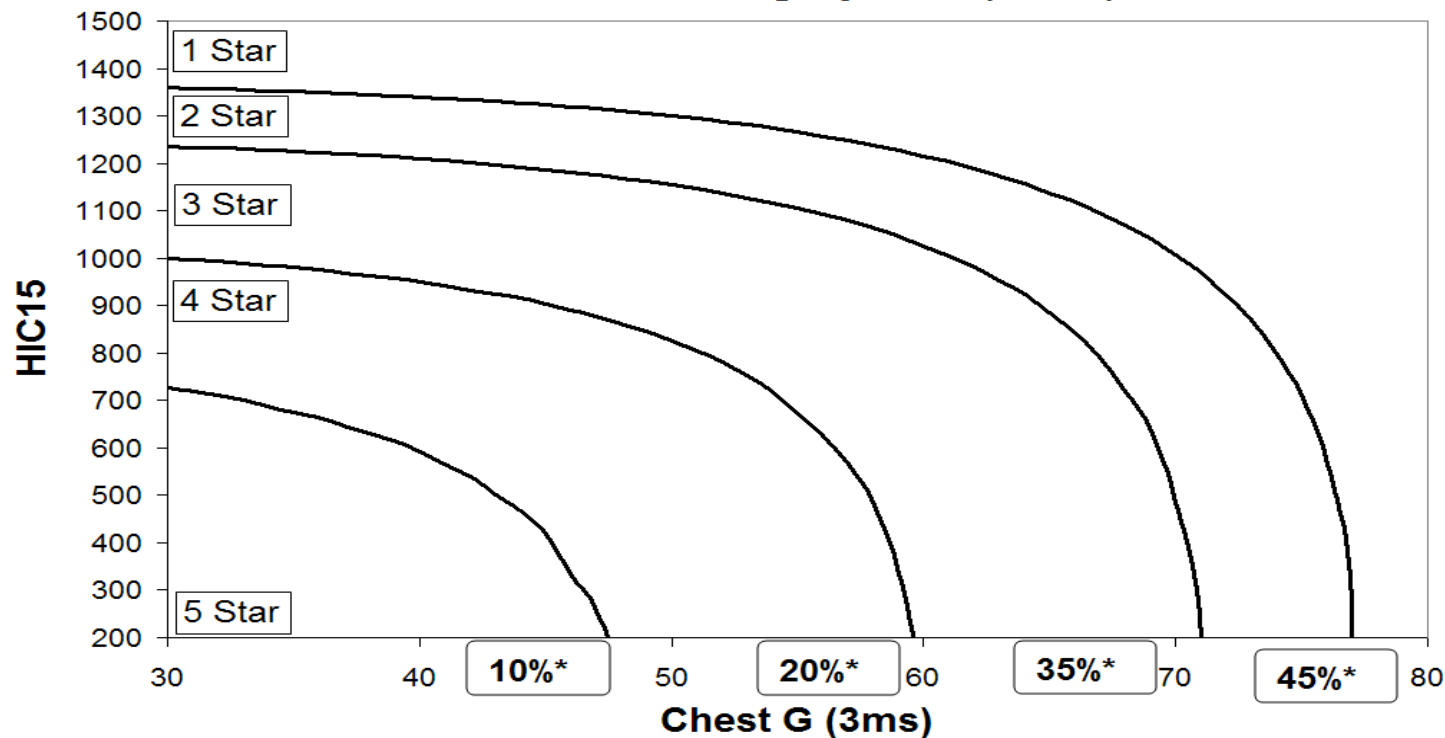
5 Star Rating System for 10YO - Details in SAE Paper 2008-01-0511

5 Star rating system is based on Injury Risk Function Curve using HIC 15 and Chest G's

Combined probability is defined for 5 Star rating in accordance with:

$$P_{combined} = P_{head} + P_{chest} - P_{head} \times P_{chest}$$

NCAP Five Star Rating System (10YO)



*Combined Probability of Serious Injury



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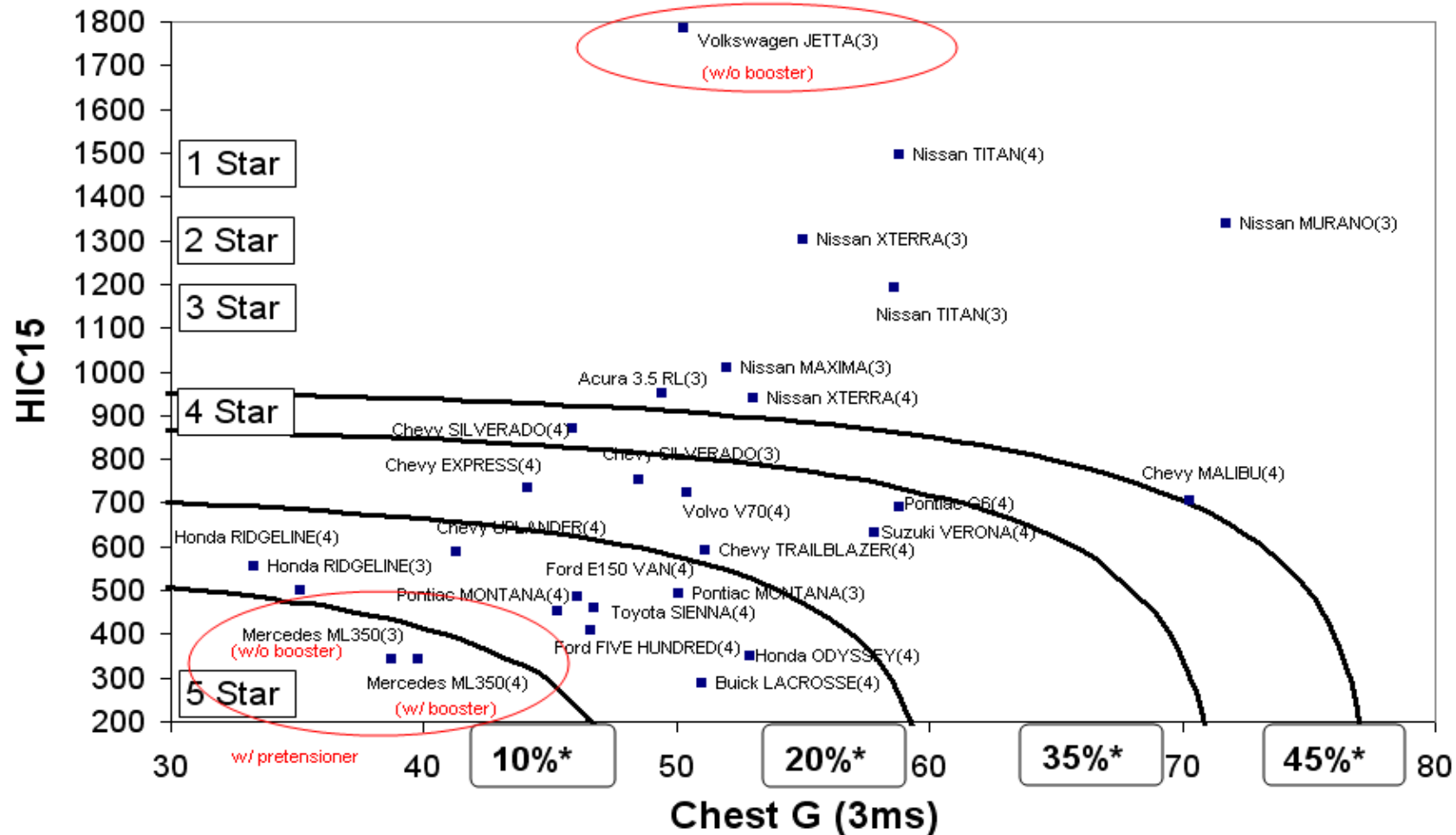
Apply 5 Star Rating System to 10 Year Old Dummy in 4 Exemplar Vehicles

	HIC (15)	Tension (N)	Compression (N)	Chest G's
Allowable	700	2,290	2,200	60
Car A	1,785	7,200	3,600	50
Car B	951	3,010	1,800	49
Minivan C	351	1,980	NA	53
SUV D	343	1,825	NA	39



28 10YO Dummies in Rear Seat in NCAP – Rating for 10YO Stretches from 1 to 5 Stars – Almost All Front Seat Adults Got 4 or 5 Stars

NCAP Five Star Rating System (10YO)

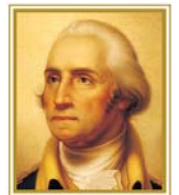


*Combined Probability of Serious Injury



Conclusion One

- Over the past ten years, various researchers around the world have studied rear seat safety in frontal crashes. **Crash dummies in the rear seat have higher readings (relative to IARVs) than the front seat dummies.** For adults about 50 years old or older, **the rear seat is not as safe in real-world crashes as the front seat.**

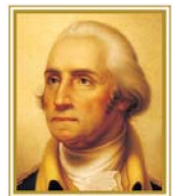


Conclusion Two

- In 2004 — 2005, USA NCAP tested the 10-Year-Old Child Hybrid III dummy in the rear seat of frontal tests. In these NCAP tests, almost all the front seat adults had low IARVs. In contrast, many of the 10-Year-Old Child dummies saw violent head motion, high HIC, high tension or compression in the neck, and high chest accelerations. In a few vehicles, the 10-Year-Old Child dummy saw much smoother head motion, lower HIC, lower tension, and lower chest acceleration.

Conclusion Three

- In the NCAP tests, almost every front-seated adult got 4 or 5 Stars. Following the logic of the original NCAP risk curves for adults, a Star rating system was suggested for the 10-Year-Old Child dummy in the rear seat. When applied to the twenty-eight 10-Year-Old Child dummies in the rear seat of the NCAP vehicles, the child dummies got a wide rating spread all the way from 1 Star to 5 Stars.



Acknowledgement

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The authors are appreciative to NHTSA for making the NCAP data available to the entire safety community through the public domain.

Thank You for Your Attention

