Exploring interventions to reduce misuse: Top tether features and lower anchor spacing

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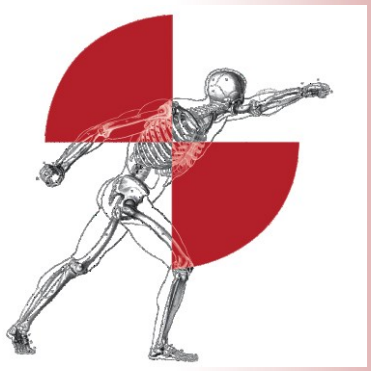
July 30, 2019

Texas Child Passenger Safety Conference



INJURY BIOMECHANICS RESEARCH CENTER

THE OHIO STATE UNIVERSITY

Introduction

- CRS misuse rates are high
- Misuse is not always predictable
  - Who has seen an installation technique that surprised you?

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- Misuse is not always predictable
  - Who has seen an installation technique that surprised you?

Image: Buckle Up for Life
(Staged for a promotional video, thank goodness)

Introduction

- Manufacturers and educators are always trying new things to reduce misuse.
  - Innovative features
  - Better educational techniques
  - Improved resources
- How can we be sure these efforts/interventions are working?
  - Avoid wasting time/money on ineffective changes
  - Avoid making the problems worse



Study 1:
Top tether usability

Background

- Top tether usage improves injury outcomes for children in Forward-Facing Child Restraint Systems (FF CRS)
  - Reduces head excursion
    - (Hauschild et al. 2016; Kang et al. 2018)
  - Reduces risk of head strikes

Image: Buckle Up with Brutus

Background

- Problem: Top tethers are attached in only about 50% of FF CRS installations
  - 33% for seat belt installations; 71% for LATCH installations
  - 41% of FF CRS users knew the CRS had a top tether
- Main question: Are there specific CRS and vehicle features that improve top tether attachment rates?

Sources: Jermakian and Wells 2011; Eichelberger et al. 2013

Background: Significant factors

- <u>CRS-specific factors</u>
  - Tether storage method (Hook on shell [83%]; compartment [63%]; pouch [50%])
- <u>Vehicle-specific factors</u>
  - Anchor location (rear deck, seat back, floor, or roof)
  - Locations with no confusing hardware nearby
- <u>Non-significant factors</u>
  - Hardware characteristics, label readability, instruction manual factors, standard marking techniques, QR codes

Sources: Jermakian et al. 2014; Cicchino and Jermakian 2015; Eichelberger et al. 2013; Klinich et al. 2012, 2014

Images: Klinich et al.

Goals

Broad Goal: Improve top tether attachment rates by making the top tether and associated hardware more obvious and intuitive.

Specific Aims:

Investigate the following specific factors in relation to top tether attachment in a factorial experiment:

- Color of tether hardware
- Labeling of tether on CRS
- Storage location of tether on CRS
- Labeling of tether route and anchor in vehicle

Methods: Conditions

- Tether hardware color

Red Black

Methods: Conditions

- Tether labeling

“Tether: Use for forward-facing” or unlabeled

Methods: Conditions

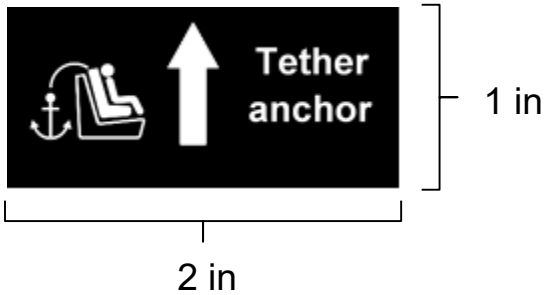
- Tether storage location

Rubber band
(back, center)

Over FF belt path
(Velcro, inboard and outboard)

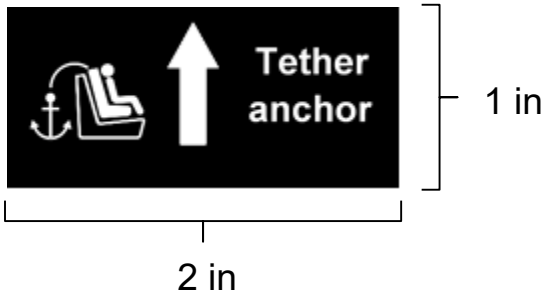
Methods: Conditions

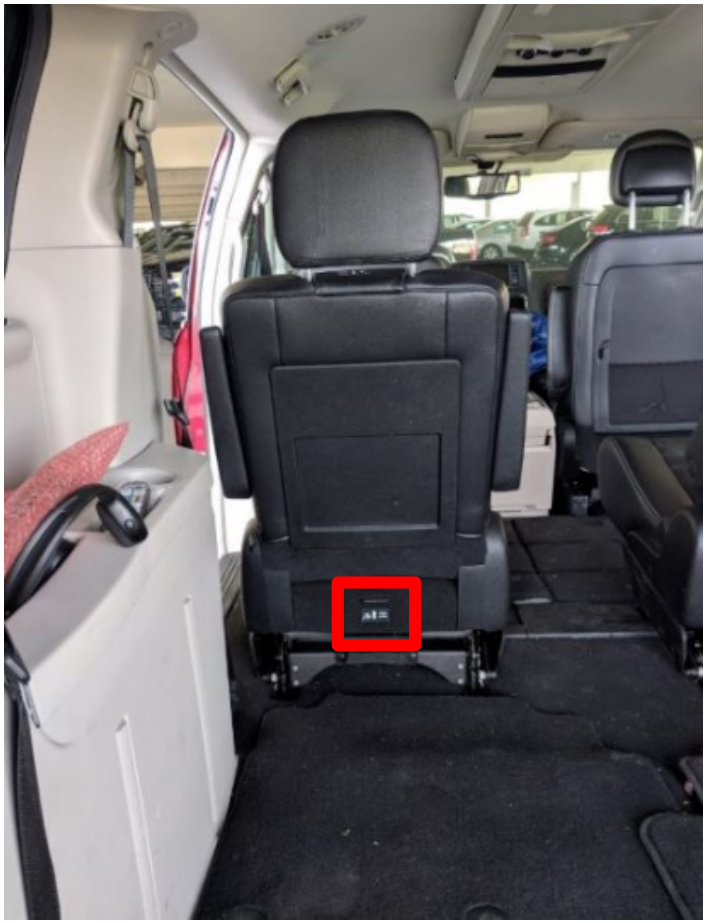
- Vehicle: Labeling of tether anchor



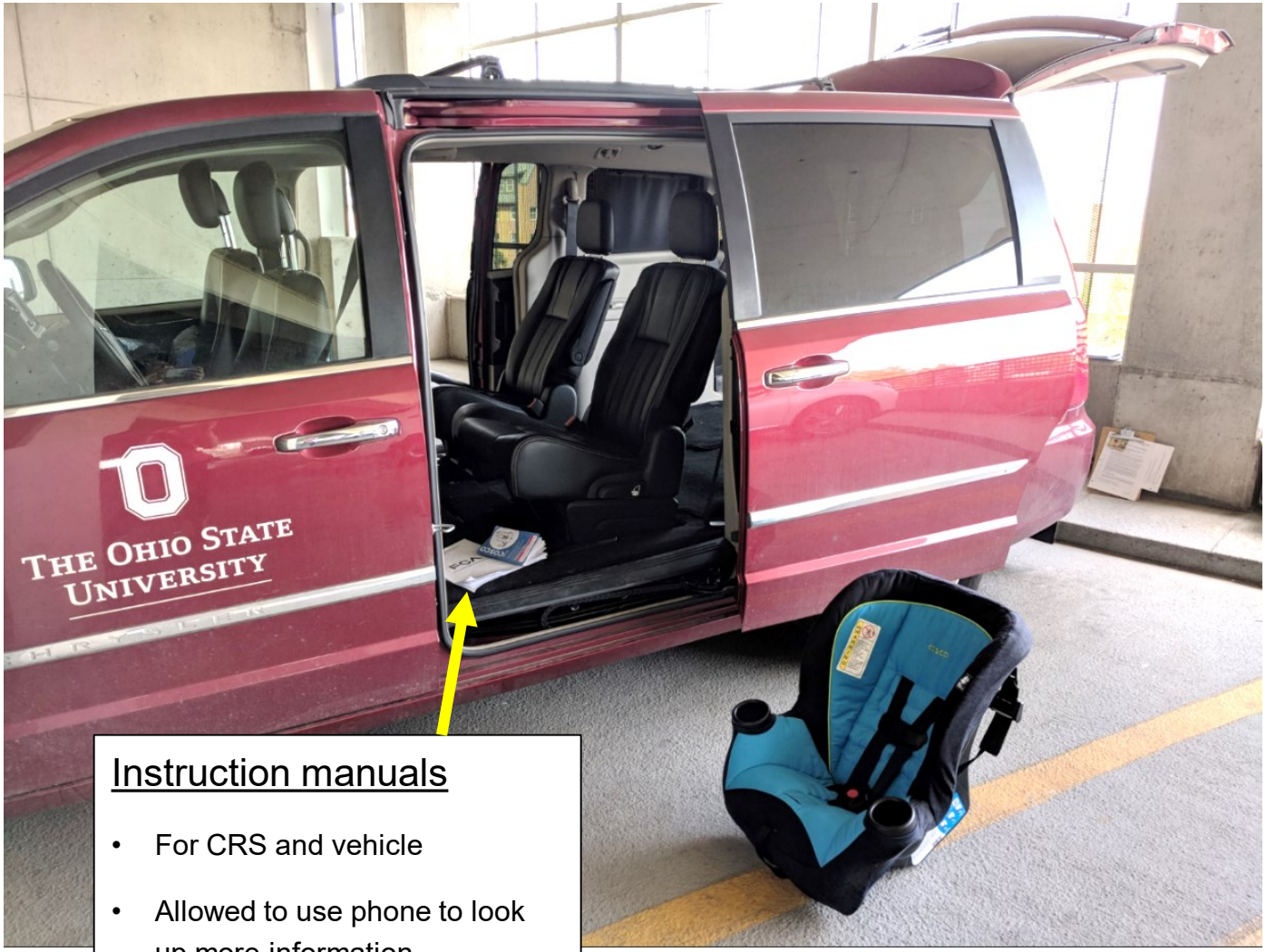
Methods: Conditions

- Vehicle: Labeling of tether anchor





Methods: Set-up



Instruction manuals

- For CRS and vehicle
- Allowed to use phone to look up more information

Methods: Set-up

<u>Instruction manuals</u>

- For CRS and vehicle
- Allowed to use phone to look up more information

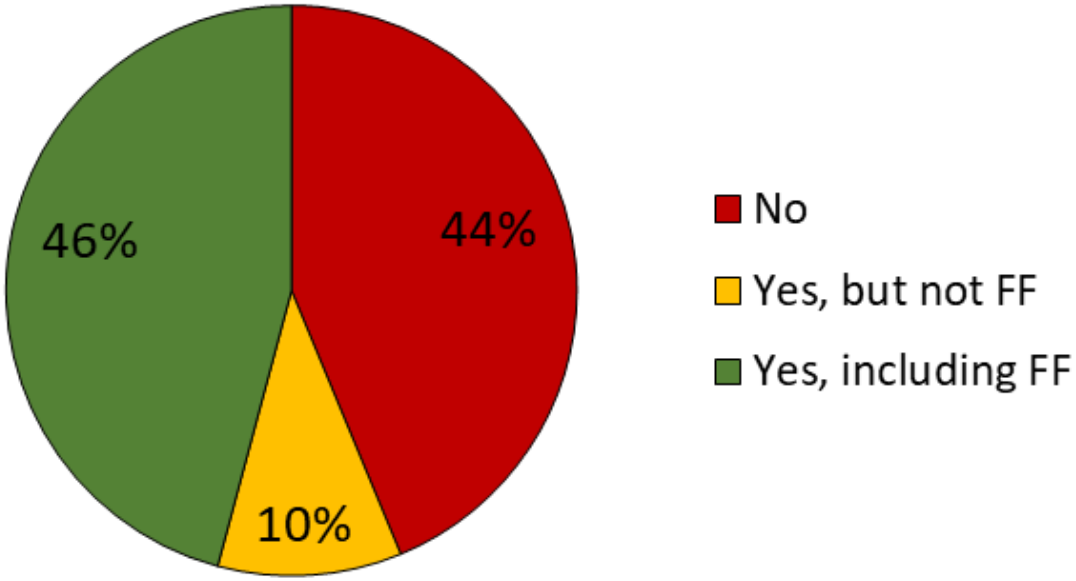
Methods: Study Design

- Factorial experiment (~Randomized controlled trial)
  - 96 subjects
  - Each completed <u>one</u> installation
    - Assigned to specific tether conditions
  - Primary outcome measure:
    - Attachment of top tether
  - $10 cash incentive

Color?	Tether Label?	Vehicle Label?	Storage Location?
Red (48)	Tether Label (24)	Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
		No Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
	No Tether Label (24)	Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
		No Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
Black (48)	Tether Label (24)	Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
		No Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
	No Tether Label (24)	Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)
		No Vehicle Label (12)	Rubber Band (6)
			Over belt path (6)

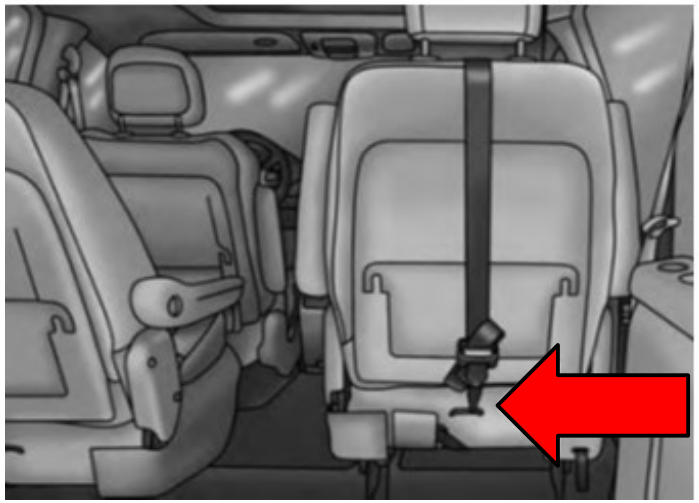
Results: Subject Info

Have you ever installed a child seat in a vehicle?



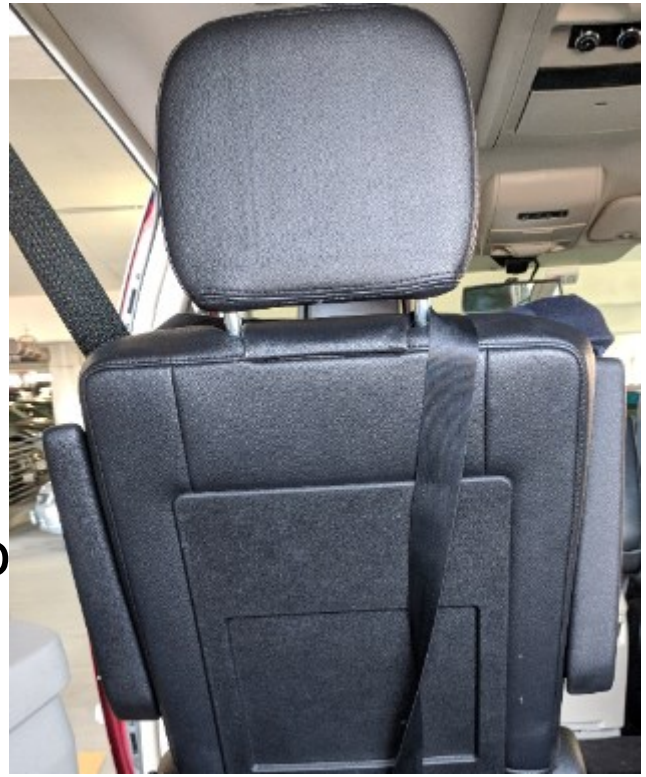
Results: Tether outcomes

- Correct tether: 50/96 subjects (52.1%)
  - Identified tether
  - Correct anchor
  - Correct routing
  - Tension ≥ 2 lbs



Results: Tether outcomes

- Minor tether errors: 16/96 subjects (16.7%)
  - Identified tether ✓
  - Correct anchor ✓
  - – Mistakes such as:
    - Routed around HR posts
    - Webbing twisted
    - Folded HR and routed over to
    - Tension loose < 2 lbs (n=11)
      - – Legault et al. 1997



Results: Tether outcomes

- Major tether errors: 10/96 subjects (10.4%)
  - Attached to lower anchor (n=3)

Typically happened when tether was stored on side (over belt path).

Results: Tether outcomes

- Major tether errors: 10/96 subjects (10.4%)
  - Attached to lower anchor (n=3)
  - Attached to back of CRS
  - Attached to seat stow handle
  - Routed through seat bight

Typically happened when tether was stored on side (over belt path).

Results: Tether outcomes

- Tether not attached (20/96 subjects = 20.8%)
  - Left tether where it was (n=17)
  - Draped over seating area
  - Tucked into belt path
  - Tucked into seat bight

Results: Tether outcomes

- Tether not attached (20/96 subjects = 20.8%)
  - Left tether where it was (n=17)
  - Draped over seating area
  - Tucked into belt path
  - Tucked into seat bight

Results: Tether outcomes

No errors (50)	Minor errors (16)	Major errors (10)	Not used (20)
Identified tether ✓	Loose (11)	Attached to back of CRS (4)	Left in storage (17)
Correct anchor ✓	Twisted (2)	Attached to lower anchor (3)	Draped over seating area (1)
Route under HR ✓	Around HR post (1)	Routed in front of seat back (2)	Tucked into belt path (1)
Flat webbing ✓	Around HR post and twisted (1)	Attached to seat stow handle (1)	Tucked into seat bight (1)
Tension ✓	Over folded HR (1)		

Results: Tether outcomes

Acceptable (66)		Unacceptable (30)	
No errors (50)	**Minor errors (16)**	**Major errors (10)**	**Not used (20)**
Identified tether ✓	Loose (11)	Attached to back of CRS (4)	Left in storage (17)
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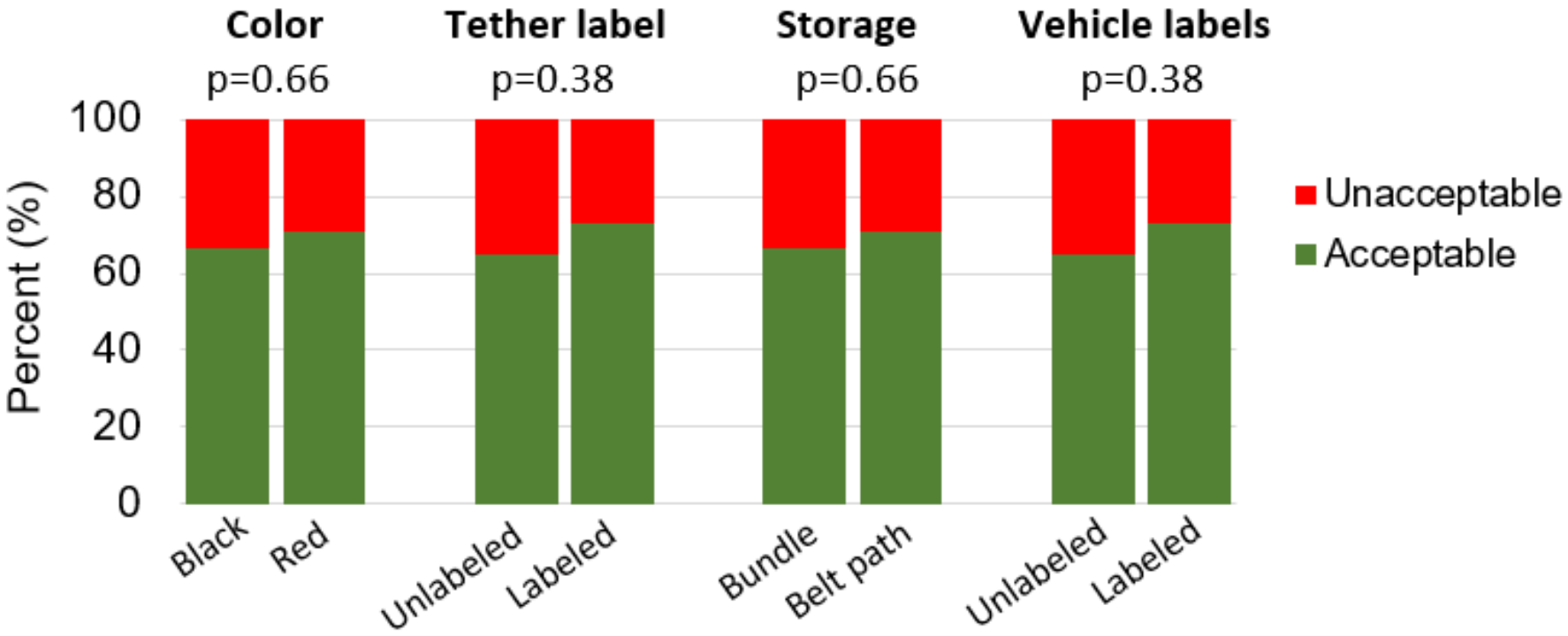
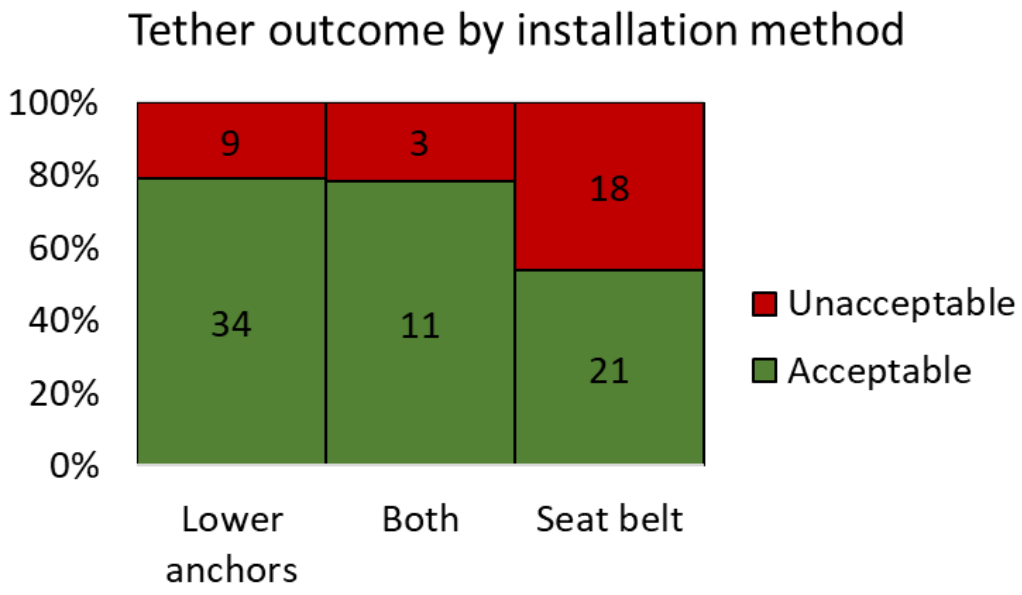
Flat webbing ✓	Around HR post and twisted (1)	Attached to seat stow handle (1)	Tucked into seat bight (1)
Tension ✓	Over folded HR (1)		

Results: Outcomes v. conditions

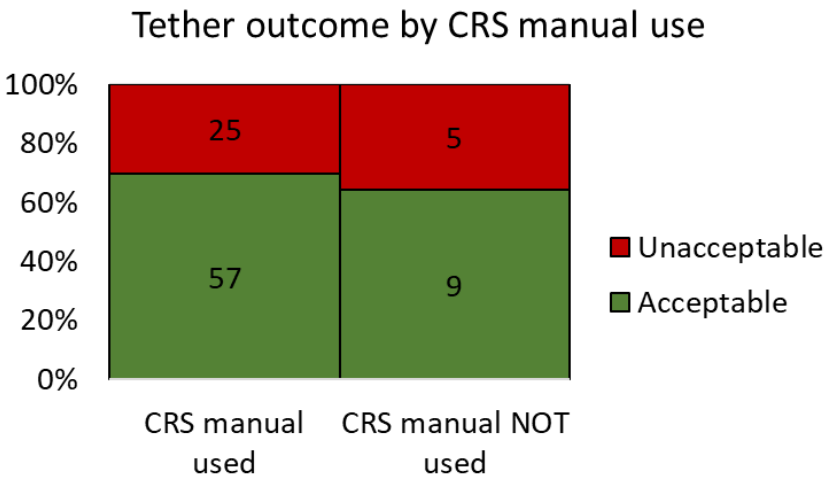


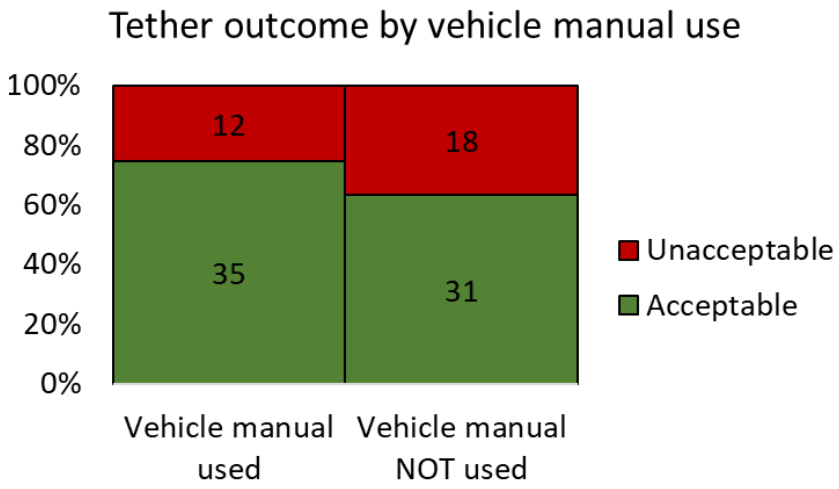
Results: Other predictors



Pearson's chi-square test: **p=.0335**

Results: Other predictors

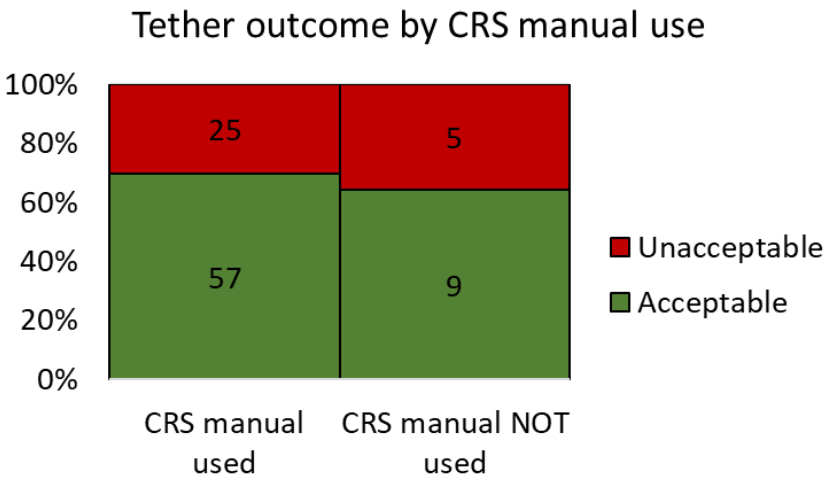


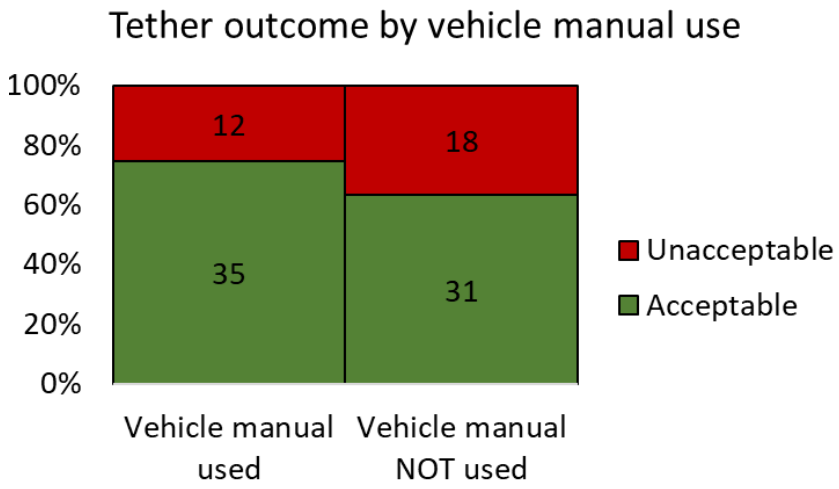


Pearson's chi-square test: p=.6966

Pearson's chi-square test: p=.2365

Results: Other predictors



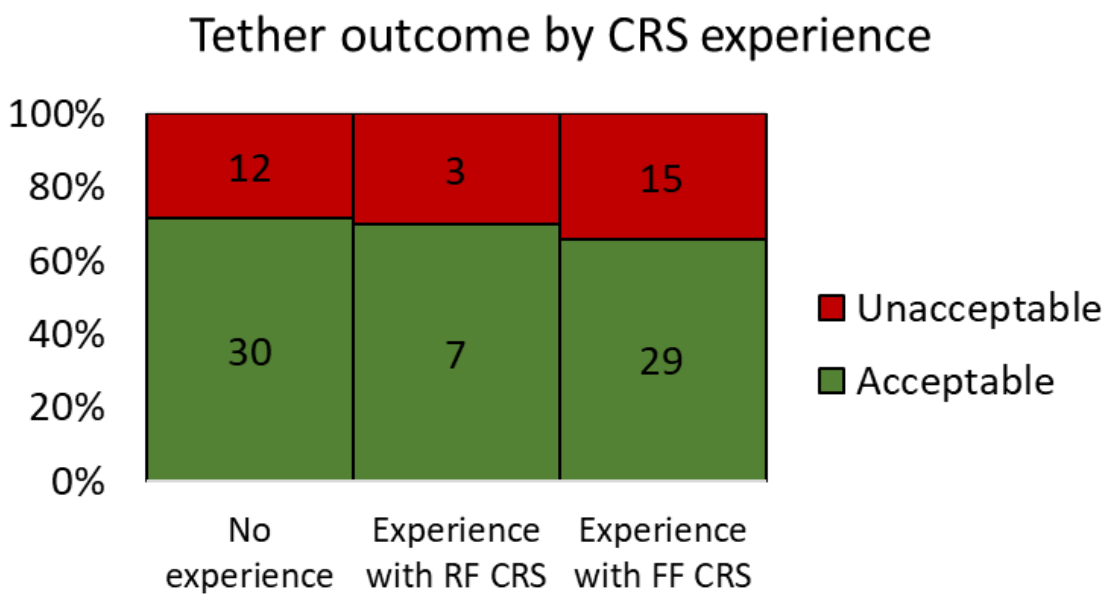


Pearson's chi-square test: p=.6966

Pearson's chi-square test: p=.2365

Only 2 subjects used their phone to look up more information!

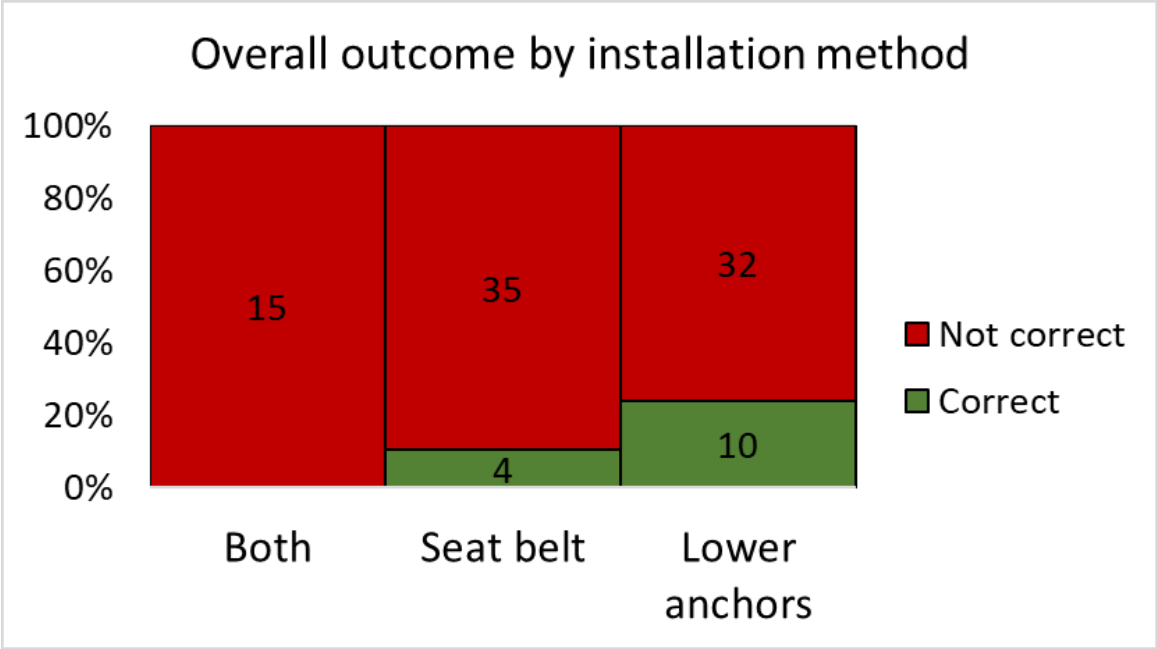
Results: Other predictors



Pearson's chi-square test: p=.6175

Results: Other outcomes

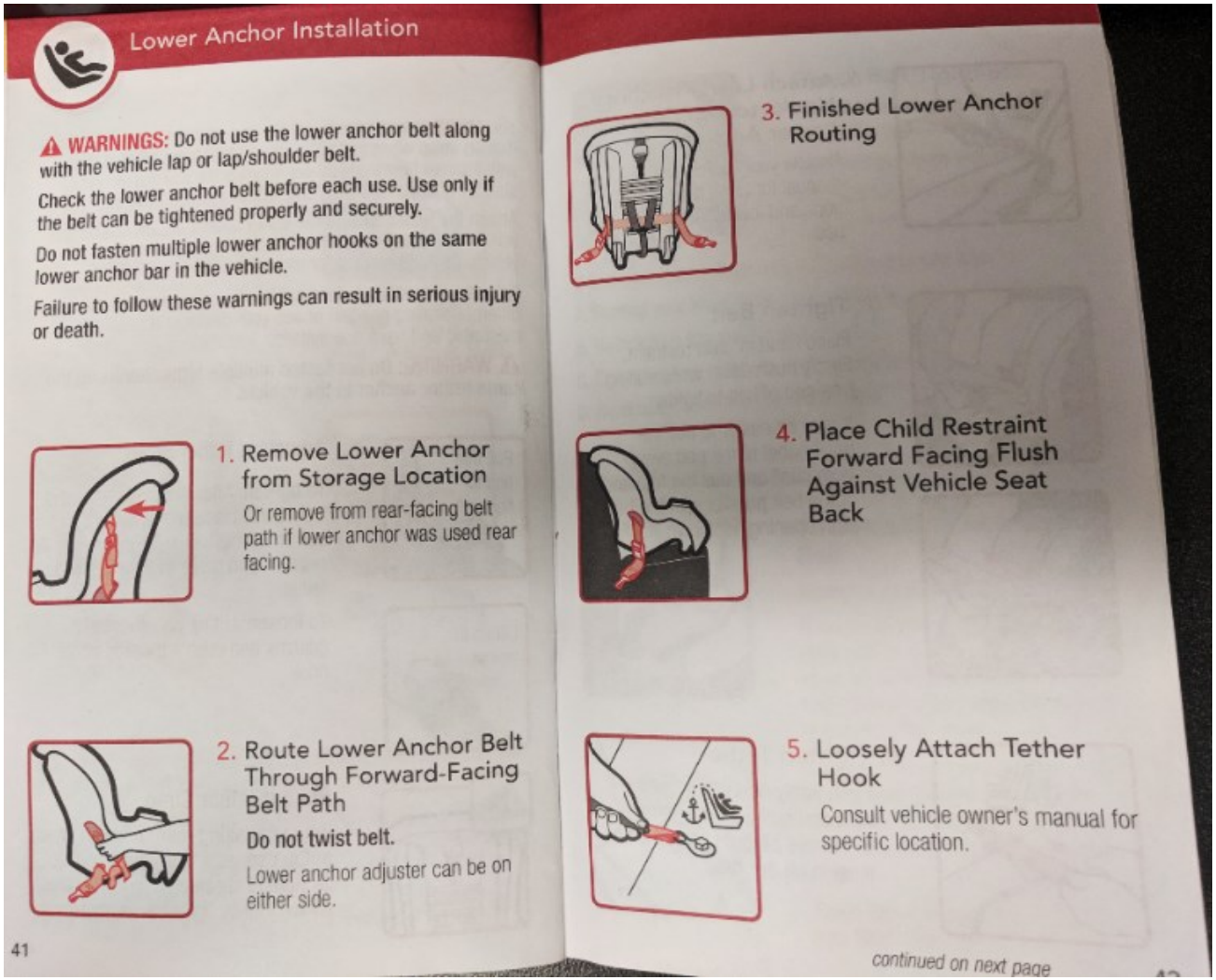
14/96 completely right! (14.6%)



Note: All subjects who used “both” methods failed the 1” test.

Pearson’s chi-square test: **p=.0494**

Results: Feedback



Lower Anchor Installation

WARNINGS: Do not use the lower anchor belt along with the vehicle lap or lap/shoulder belt.

Check the lower anchor belt before each use. Use only if the belt can be tightened properly and securely.

Do not fasten multiple lower anchor hooks on the same lower anchor bar in the vehicle.

Failure to follow these warnings can result in serious injury or death.

1. Remove Lower Anchor from Storage Location

   Or remove from rear-facing belt path if lower anchor was used rear facing.

2. Route Lower Anchor Belt Through Forward-Facing Belt Path

   Do not twist belt.

   Lower anchor adjuster can be on either side.

3. Finished Lower Anchor Routing

4. Place Child Restraint Forward Facing Flush Against Vehicle Seat Back

5. Loosely Attach Tether Hook

   Consult vehicle owner's manual for specific location.

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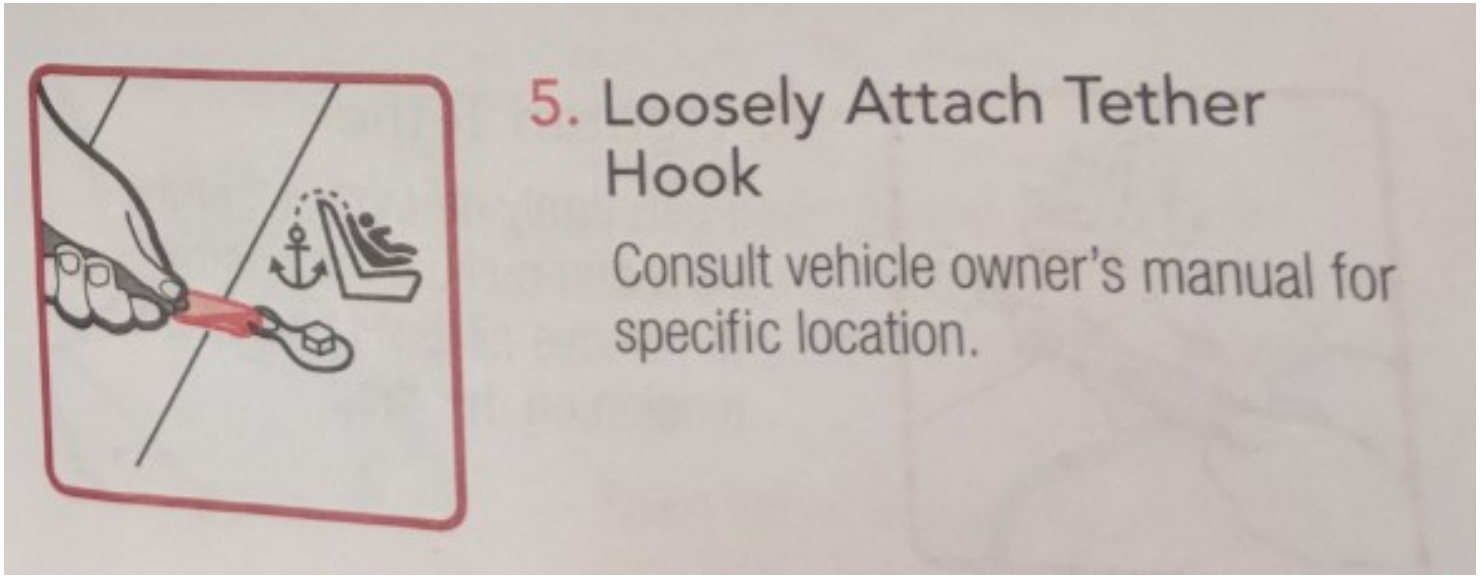
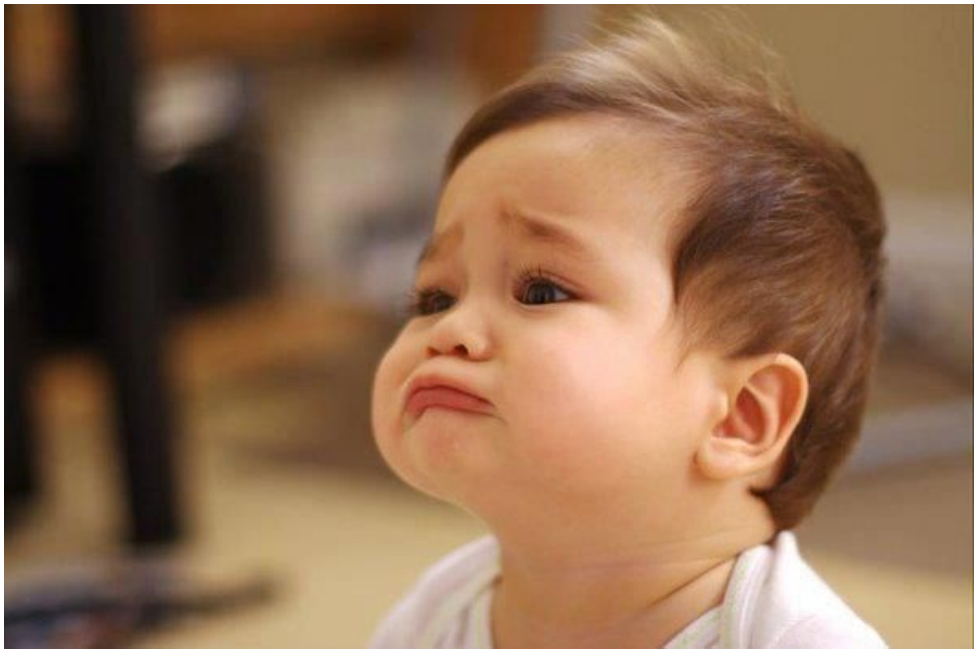
Results: Feedback



Where is this?
What is this?
Need bigger frame of reference.

Conclusions

- None of our interventions were successful!
  - Potentially caused more confusion when stored on side of CRS
    - Tendency to attach to nearest lower anchor



Limitations

- Sample size
  - One vehicle → One tether anchor location
  - One CRS model
  - 96 subjects → Many conditions
- Study setting vs. real life
  - Being watched
    - High percentage used CRS manual, but not vehicle manual
  - No children in danger

FOR MORE INFORMATION:

- Mansfield JA, Zaragoza-Rivera YN, Baker GH, Bolte JH IV. Evaluation of interventions to make top tether hardware more visible during child restraint system (CRS) installations. *Traffic Injury Prevention*. 2019; 20(5):534-539.

Study 2:

Non-standard lower anchor spacing

Background

- Center position (rear row)
  - Statistically safest position (Kallan et al., 2008)
  - One third of CRS installations utilize it (Safe Kids, 2011)
    - Includes families who only transport one child
- Problem: Most vehicles do not provide LATCH option in center position

Relevance to Industry

IIHS
Insurance Institute for Highway Safety

NHTSA
www.nhtsa.gov

Background

- Dedicated set of center LATCH anchors

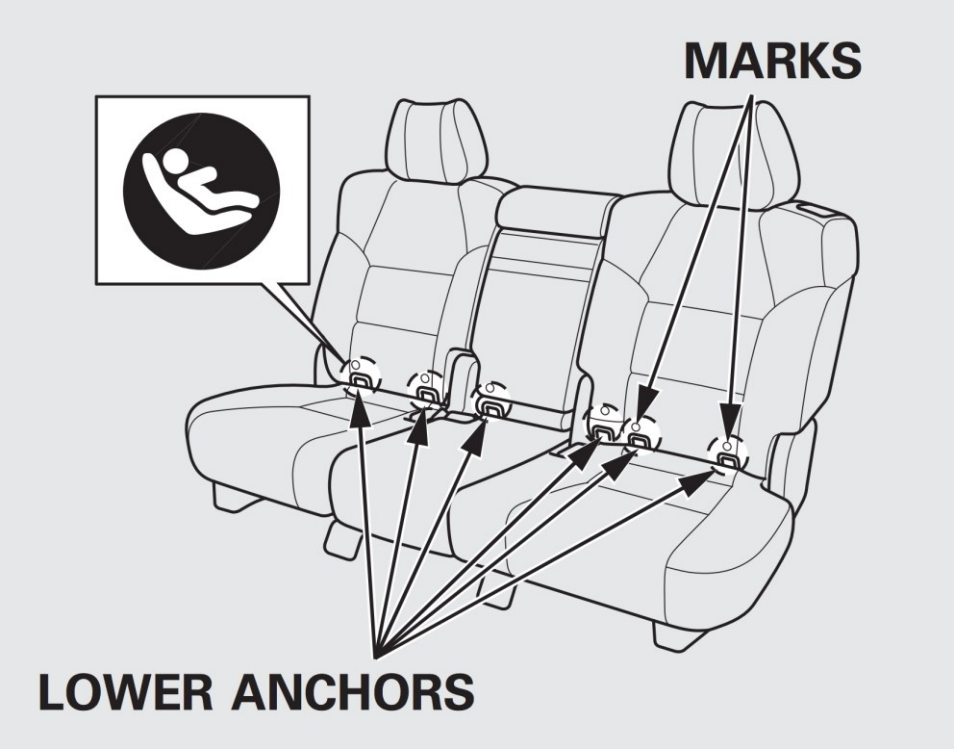


Photo: 2011 Acura MDX, http://carseatblog.com/31033/borrowing-latch-anchors/

Background

- “Borrow” outboard anchors to create “simulated” center LATCH position

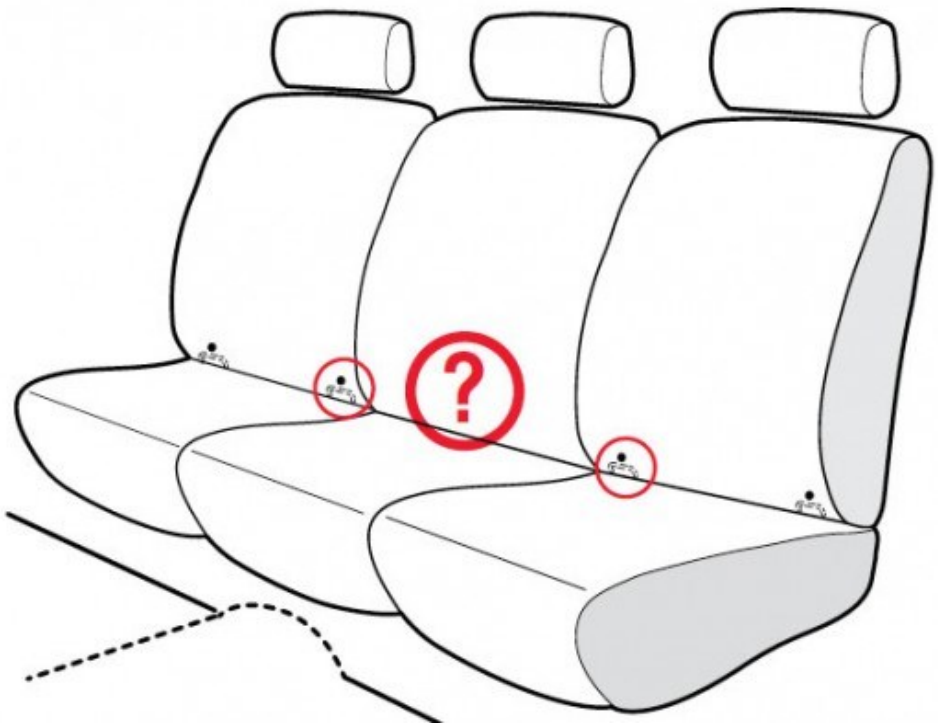


Image credit: Cybex, from http://www.babygearlab.com/Best-Car-Seat

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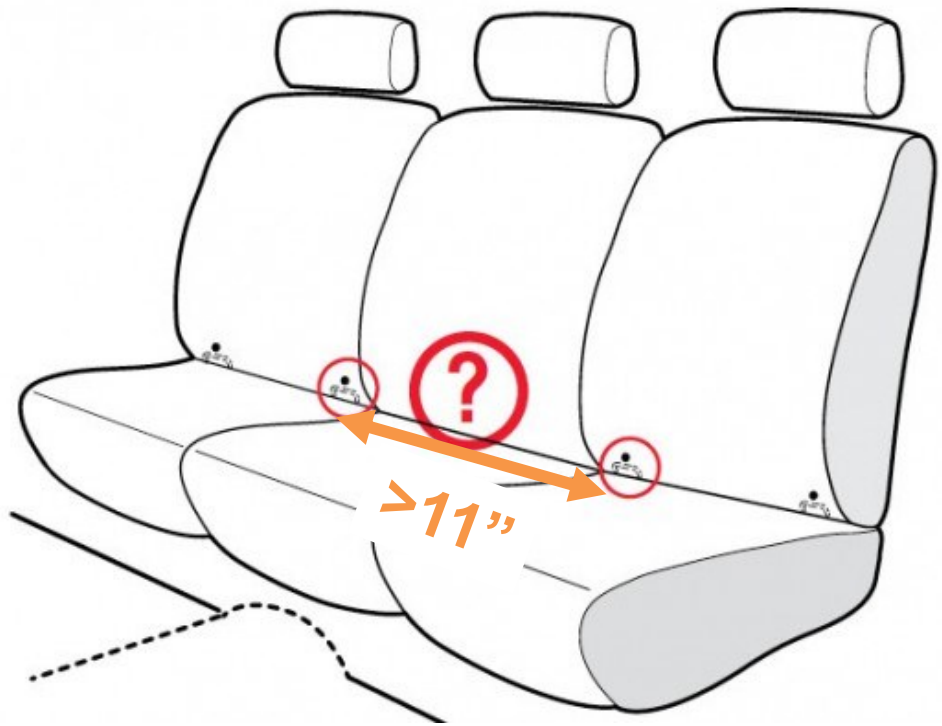

Problem: Lower anchors are often spaced much further apart than 11 inch standard.

Image credit: Cybex, from http://www.babygearlab.com/Best-Car-Seat

Background

Two main considerations:

1. Dynamic performance
   - Will CRS provide adequate protection with wider-than-standard lower anchor installations?

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   - Will consumers be able to install the CRS tightly enough?

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Two main considerations:

1. Dynamic performance
   - Will CRS provide adequate protection with wider-than-standard lower anchor installations?
   - Dr. Aditya Belwadi (CHOP) / Each manufacturer

2. Usability
   - Will consumers be able to install the CRS tightly enough?
   - Topic of this study

Objective

Determine whether wider-than-standard lower anchors can be used effectively by caregivers by:

- Measuring the tension produced
- Comparing to CPST installations

Methods

Evenflo Embrace

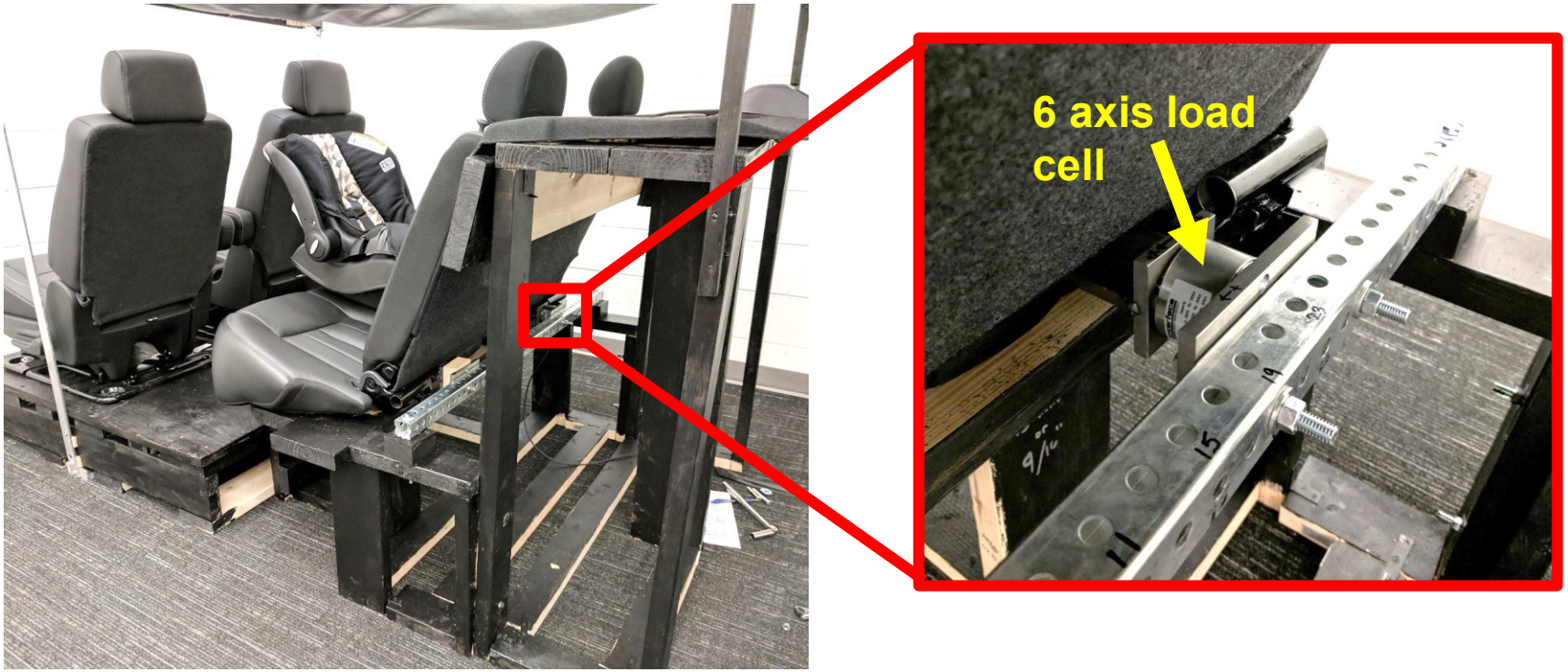
Evenflo Sure Ride, RF

Evenflo Sure Ride, FF

*These models have also been selected for dynamic sled testing (Belwadi et al).

Methods

Methods



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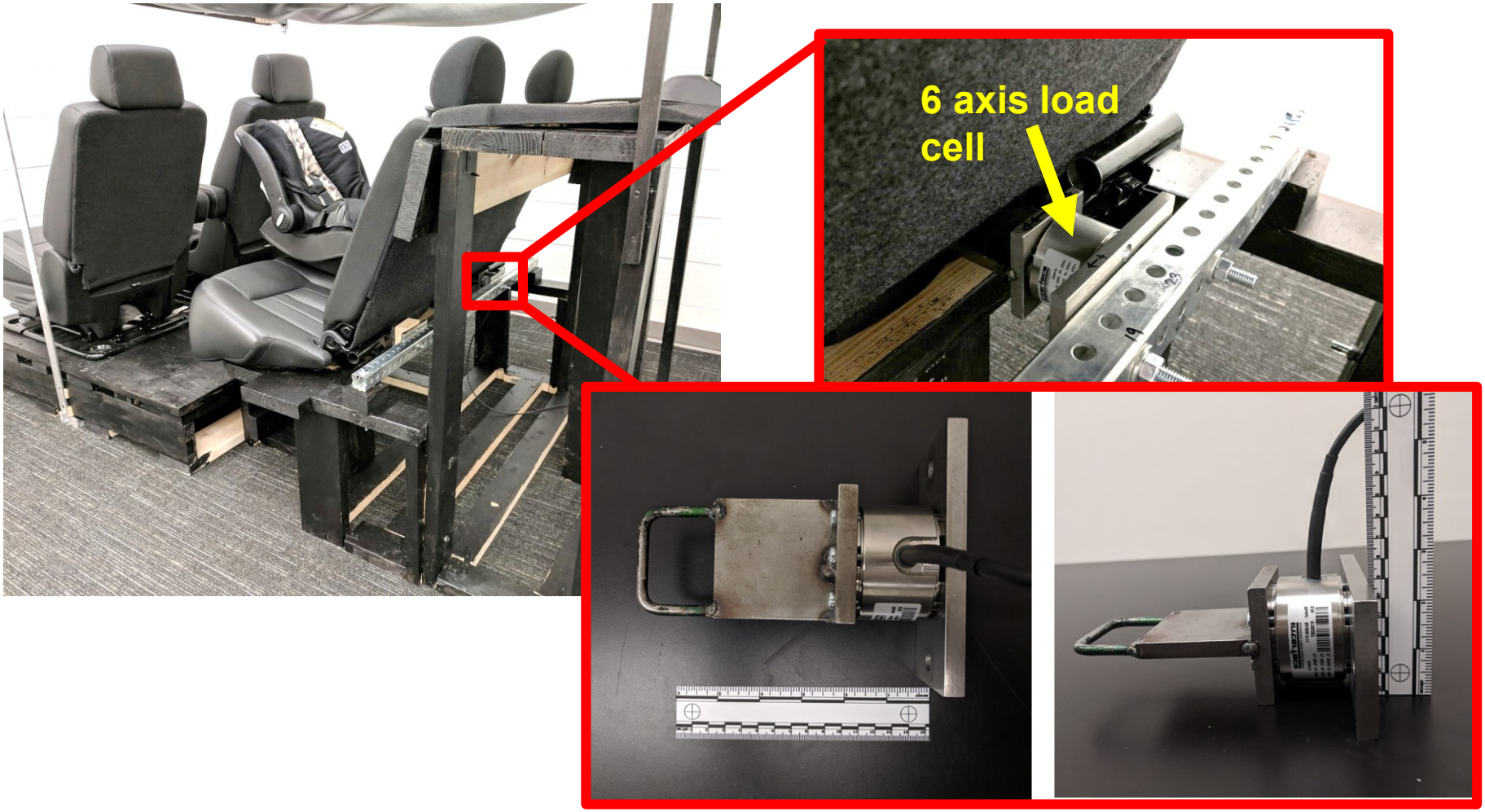

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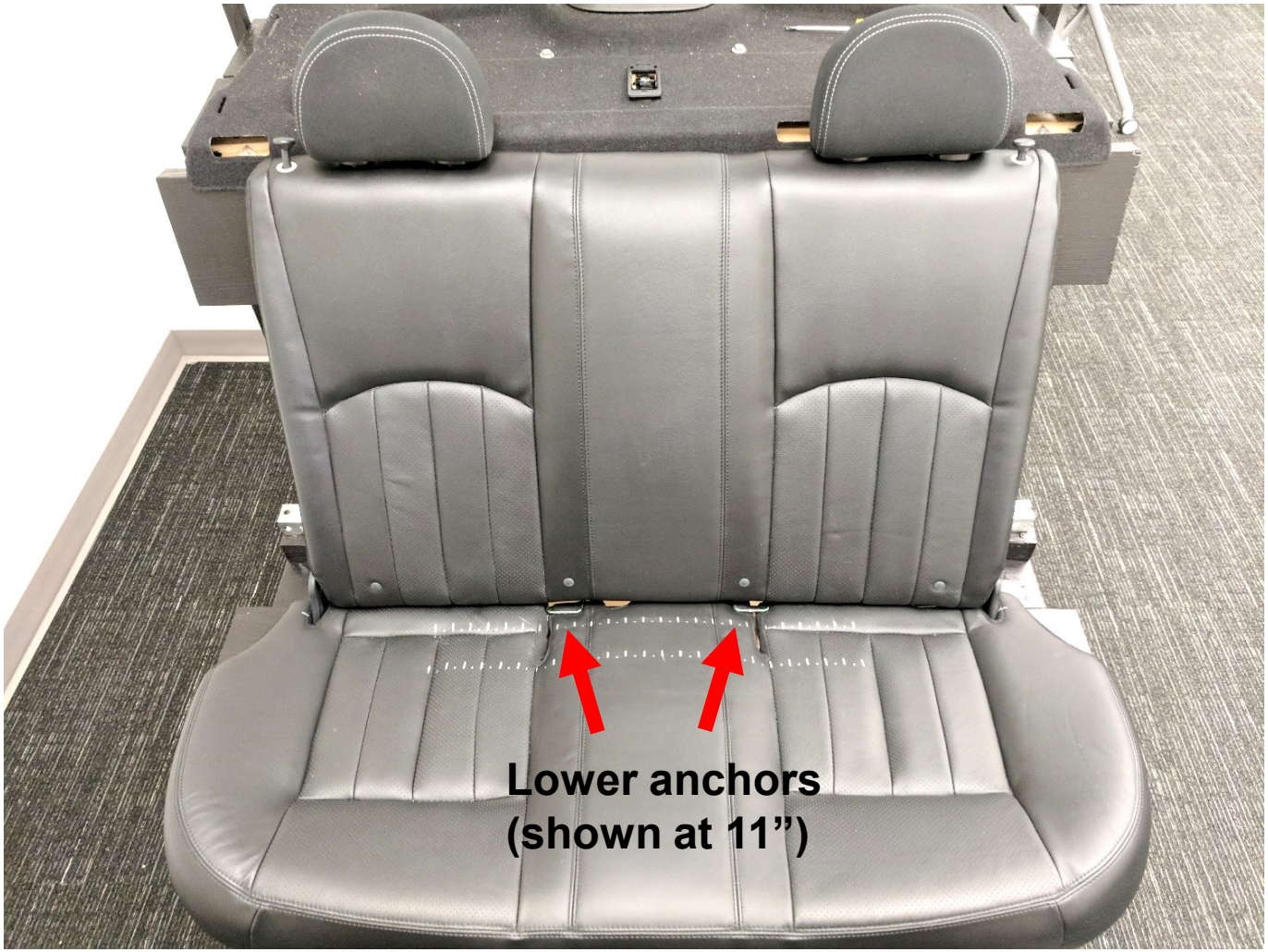
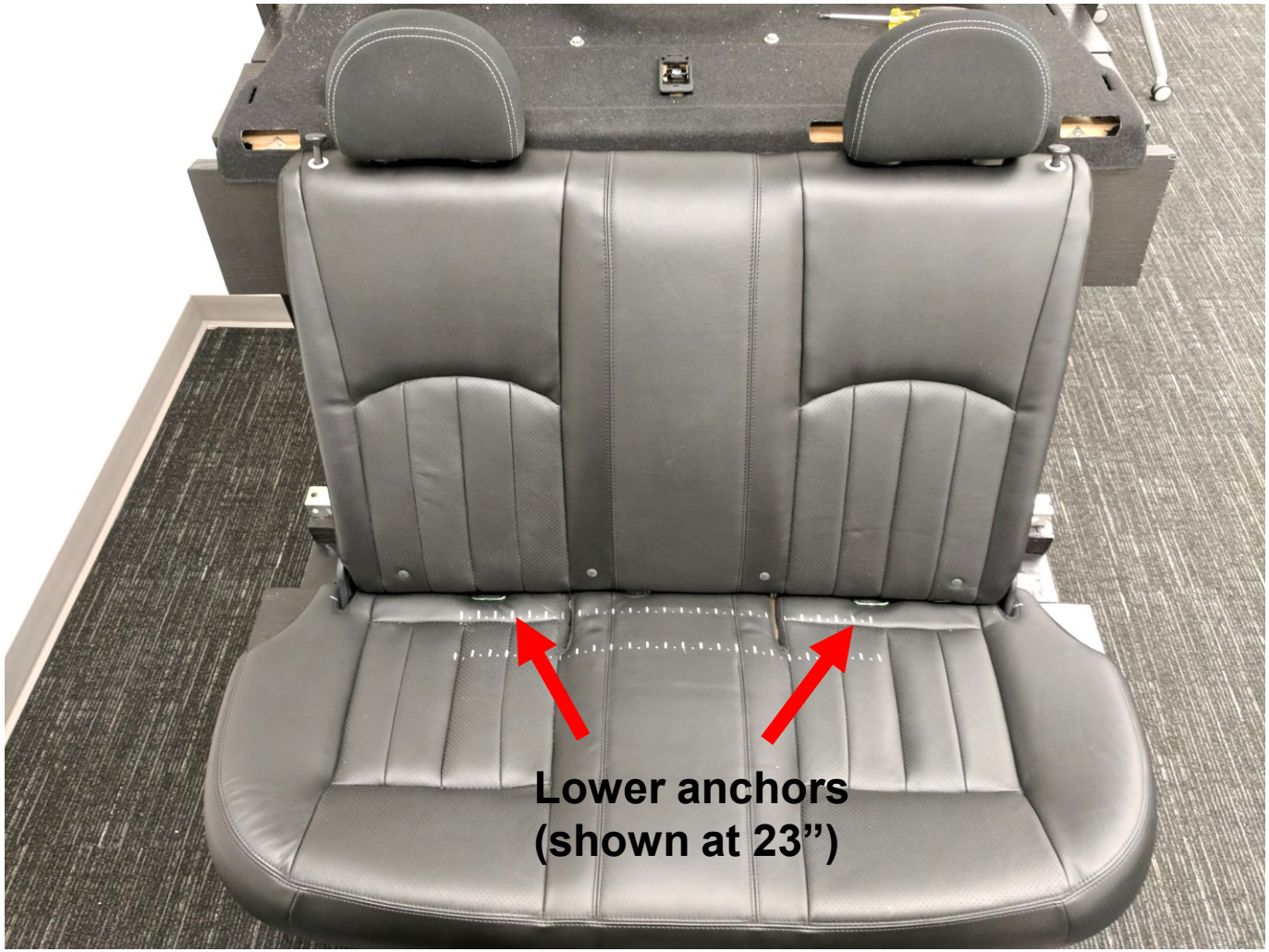


Anchors clearly visible and easy to access

Methods



Anchors clearly visible and easy to access

Methods: Subjects

- Each subject assigned to one CRS
  - Install same CRS in each of 4 lower anchor spacing conditions
  - Random order
- CRS presented in proper settings
  - Instruction manuals and internet access available
- Instructions:
  - Install the CRS to the best of your ability
- Filled out feedback survey between each installation

Results: Subjects

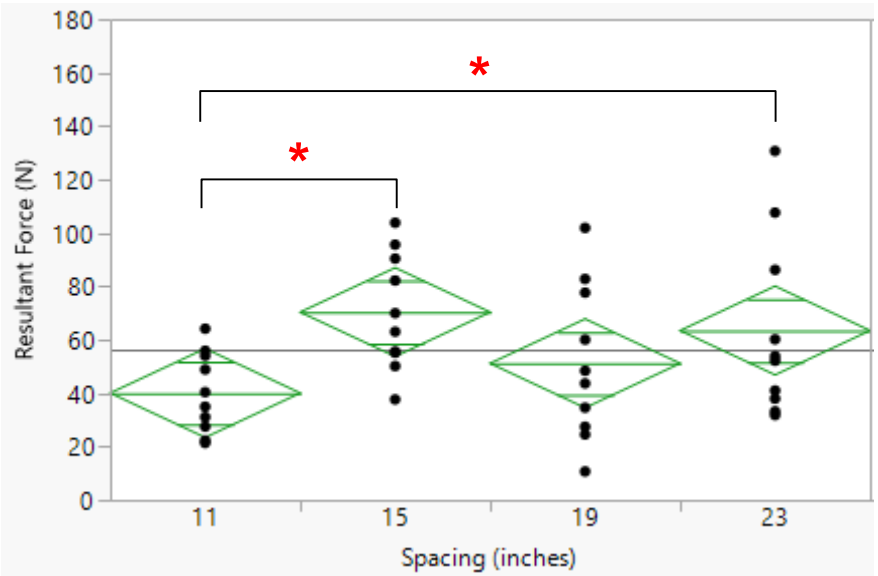
- 30 subjects from general population
  - 18 females and 12 males
  - 35.2 ± 8.4 years old (min=18; max=56)
- Experience:
  - 18 had installed a CRS before
  - 12 had never installed a CRS before

Methods

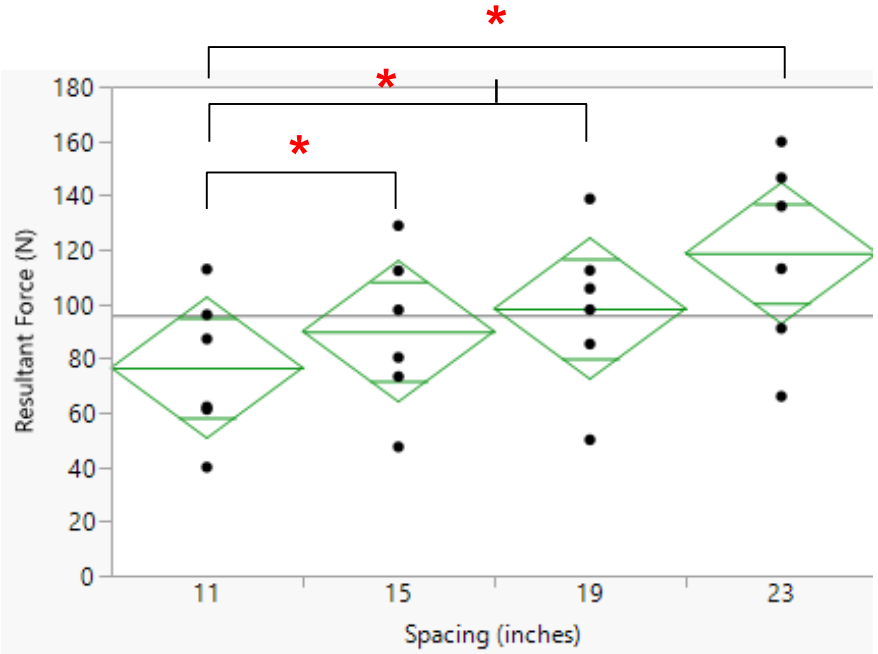
- 6 Child Passenger Safety Technicians (CPSTs) recruited
- Installed each CRS (x3) in each spacing condition (x4)
  - 12 installations each
- Tightened strap until CRS ***just*** passes one inch test
- Use these data as a reference threshold for pass/fail

Results: Infant Base

General Subjects (n=10)



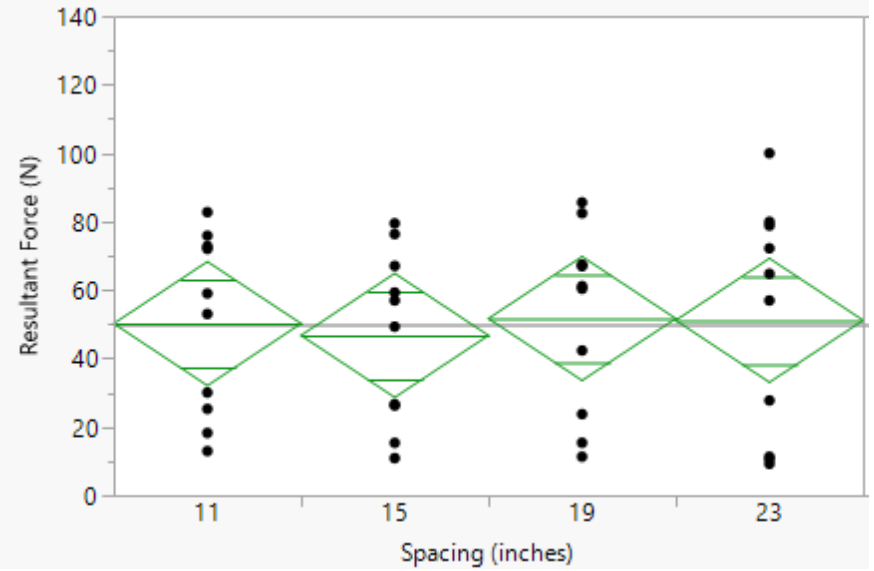
CPSTs (n=6)



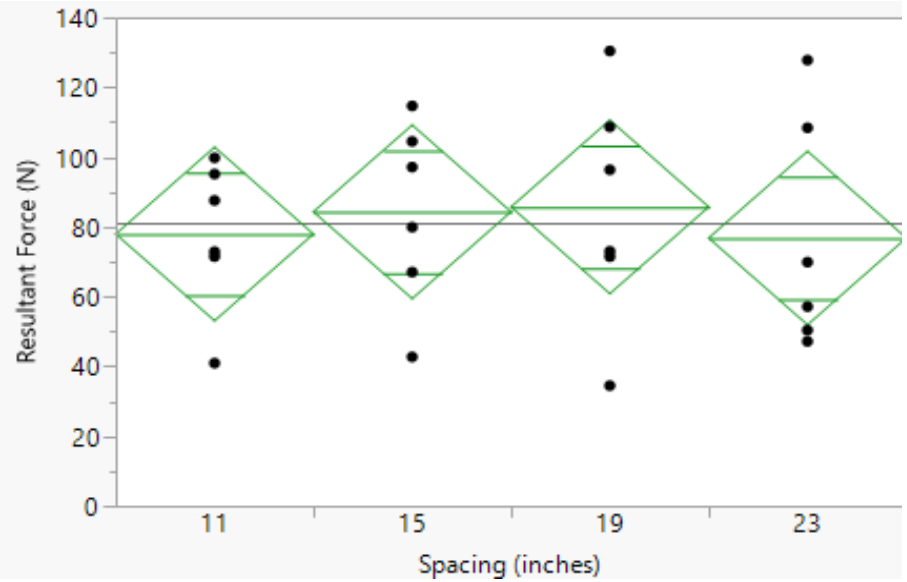
* p<.05, matched pair t-test

Results: RF Convertible

General Subjects (n=10)



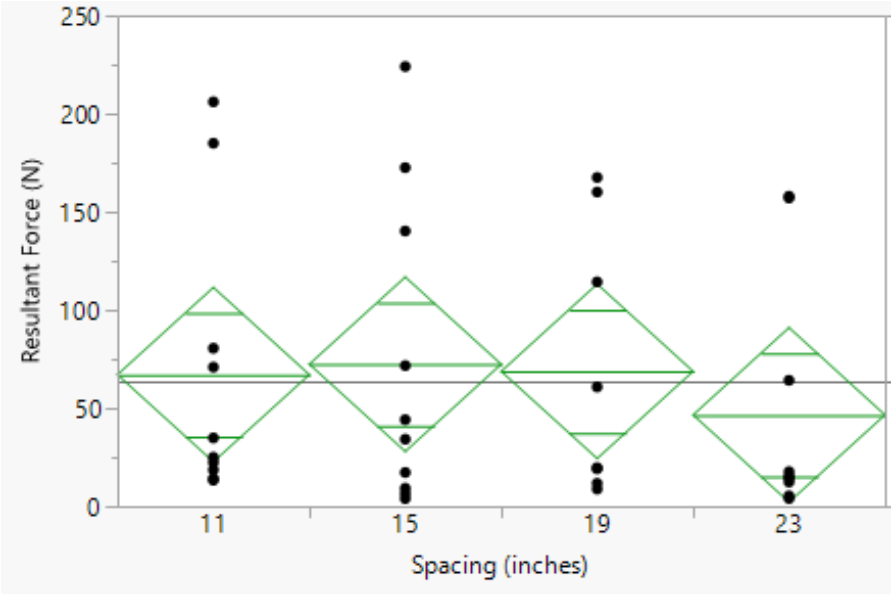
CPSTs (n=6)



No significant differences in tension with respect to lower anchor spacing.

Results: FF Convertible

General Subjects (n=10)



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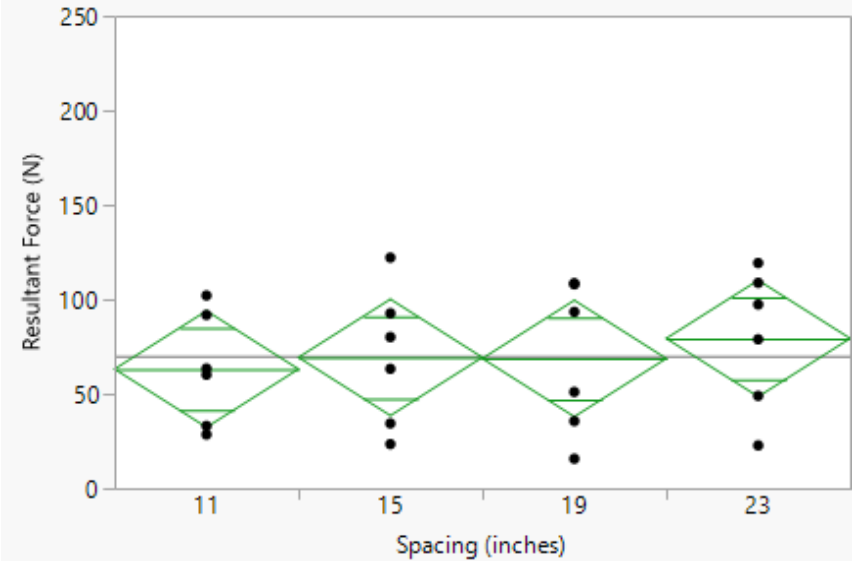


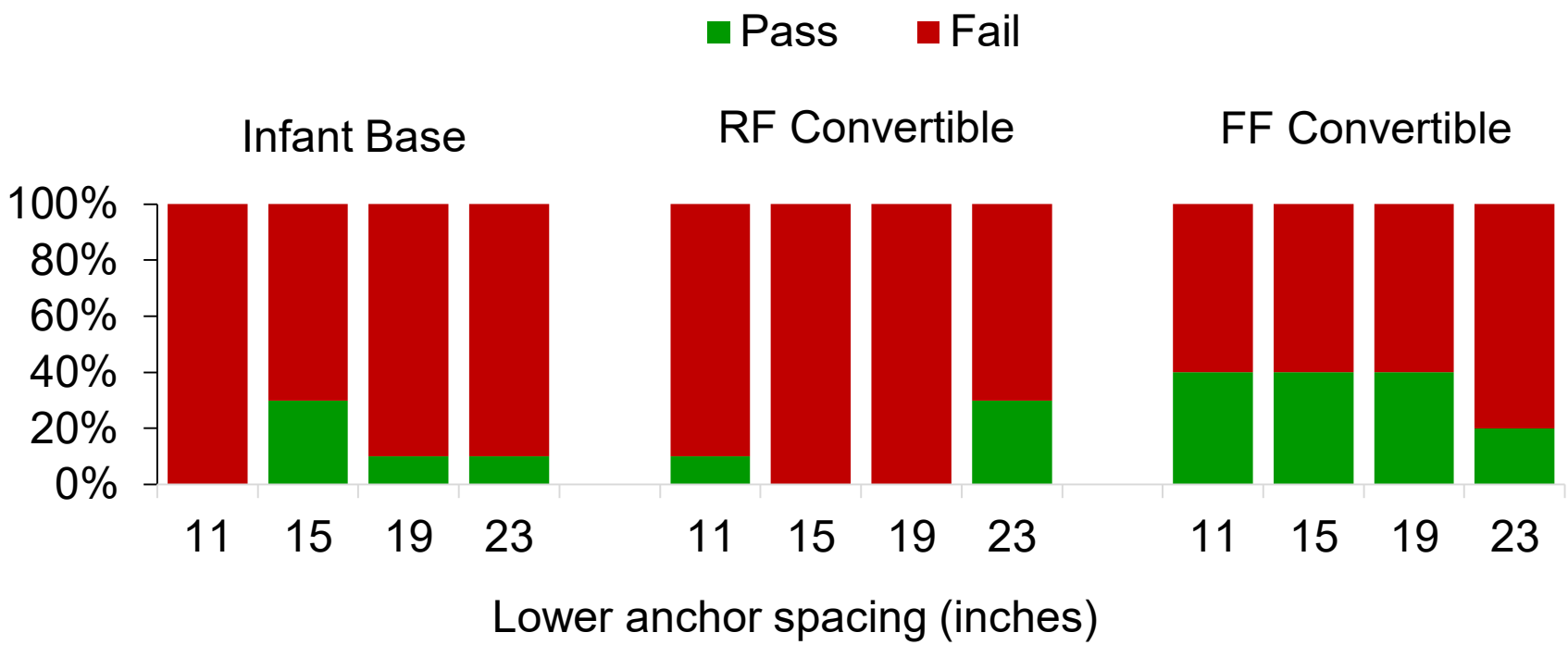
No significant differences in tension with respect to lower anchor spacing.

Results: Summary

	General Subjects (n=30)	CPSTs (n=6)
Infant base	Subjects produced more tension at 15” and 23” compared to standard 11”.	Greater tension required for each wider-than-standard configuration (15”, 19”, and 23”)
Rear-facing convertible	No significant differences.	No significant differences.
Forward-facing convertible	No significant differences.	No significant differences.

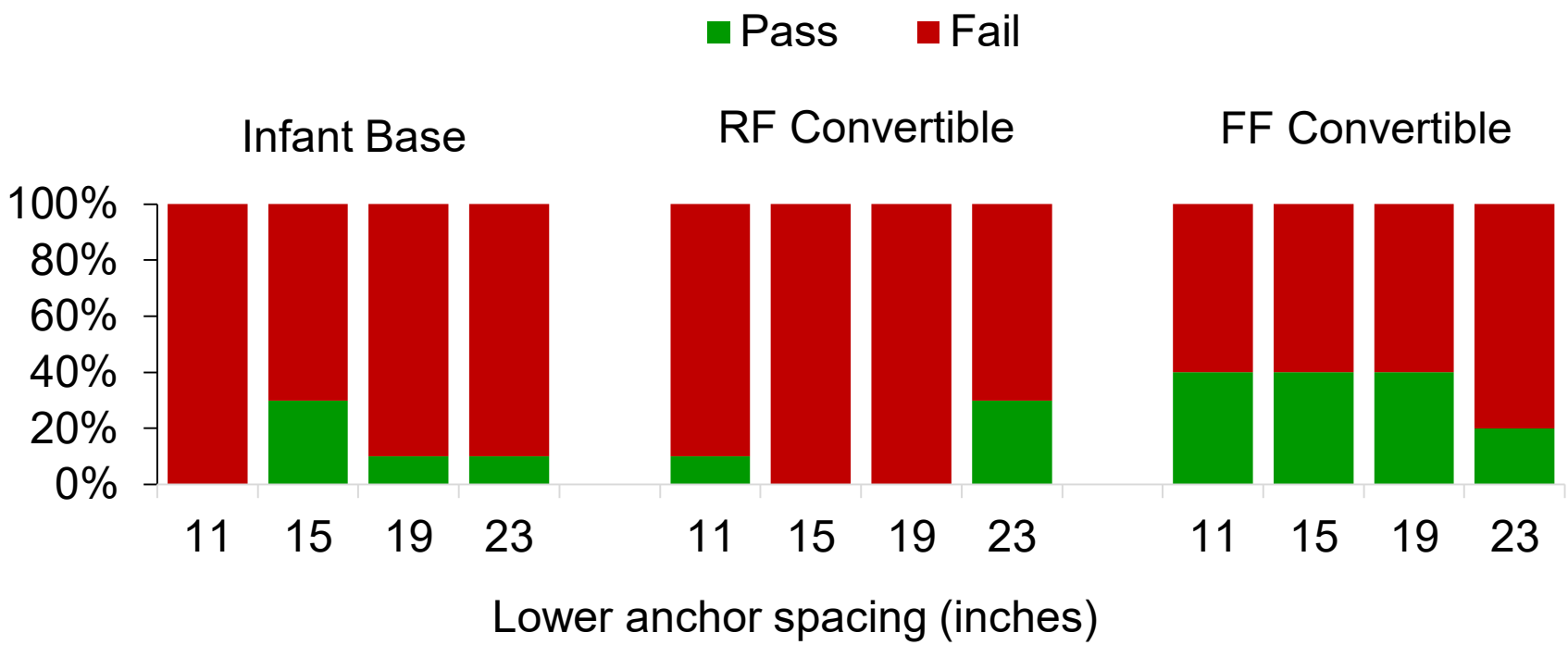
Results: 1-inch test

Did general subjects "pass" the 1-inch test?



Results: 1-inch test

Did general subjects "pass" the 1-inch test?



- Forward-facing convertible had highest overall pass rate.
- **Passing the 1-inch test does not appear to correlate with anchor spacing variations.**

Results: Subject Feedback

"Please describe any difficulties and/or positive aspects of this installation." (write-in responses)

- 14/30 subjects: Wider spacing was <u>more difficult to tighten</u>
  - "More movement," "Seemed less secure," "Seemed less stable," "Didn't seem safe."
- 7/30 subjects: Wider spacing was <u>easier to tighten</u>
  - "Easier to tighten," "More space to angle/maneuver strap to pull better," "Wider spacing seemed safer."
- 9/30 subjects: Wider spacing was easier to <u>access</u> anchors/attach connectors
- 9/30 did not address anchor spacing in their responses

Limitations

- Vehicle seat fixture ≠ real vehicle
  - Seat belts removed
  - Ample space behind front row
- Small sample size
  - 3 CRS models
  - 1 vehicle seat
- Population not representative
  - Education and income levels above average, mostly white

Conclusions

- From these data, adults appear to be able to install CRS with widely spaced lower anchors about as well as standard 11” spacing.
- These results should be considered in tandem with dynamic test results.

Always follow manufacturers’ instructions!

Thank you CChIPS!

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Acknowledgements

The authors would like to acknowledge the National Science Foundation (NSF) Center for Child Injury Prevention Studies at the Children's Hospital of Philadelphia (CHOP) for sponsoring this study and its Industry Advisory Board (IAB) members for their support, valuable input and advice. The views presented are those of the authors and not necessarily the views of CHOP, the NSF, or the IAB members.

Special thank you to:

- John Combest (Nissan)
- Eric Dahle (Evenflo)
- Charlie Vits (IMMI)

Students: Gretchen Baker, Yadetsie Zaragoza-Rivera, Sydney VerDow, Kat Sikiric, Laura Jurewicz, Jon Blank

Thank you!

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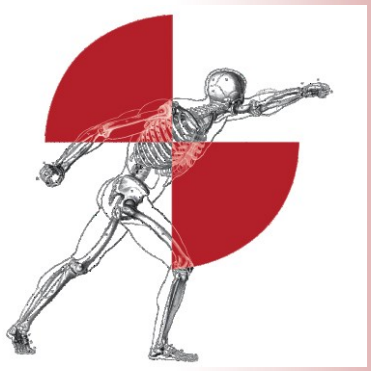
Exploring interventions to reduce misuse: Top tether features and lower anchor spacing

Julie Mansfield, PhD
Research Engineer

July 30, 2019

Texas Child Passenger Safety Conference



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