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

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Research Engineer
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Texas Child Passenger Safety Conference
Introduction

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

• **CRS-specific factors**
  – Tether storage method (Hook on shell [83%]; compartment [63%]; pouch [50%])
  
• **Vehicle-specific factors**
  – Anchor location (rear deck, seat back, floor, or roof)
  – Locations with no confusing hardware nearby

• **Non-significant factors**
  – Hardware characteristics, label readability, instruction manual factors, standard marking techniques, QR codes


Images: Klinich et al.
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

**Instruction manuals**
- 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 one installation
    - Assigned to specific tether conditions
  - Primary outcome measure:
    - Attachment of top tether
  - $10 cash incentive
Results: Subject Info

Have you ever installed a child seat in a vehicle?

- 46% No
- 44% Yes, but not FF
- 10% Yes, including FF
Results: Tether outcomes

- Correct tether: 50/96 subjects (52.1%)
  - Identified tether
  - Correct anchor
  - Correct routing
  - Tension $\geq 2$ 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 top
    - 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

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  – Left tether where it was (n=17)
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  – Tucked into seat bight
Results: Tether outcomes

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

### Acceptable (66)

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<tr>
<th>No errors (50)</th>
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</tr>
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<td>Tension ✓</td>
<td>Over folded HR (1)</td>
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### Unacceptable (30)

<table>
<thead>
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</thead>
<tbody>
<tr>
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<td>Attached to lower anchor (3)</td>
<td>Draped over seating area (1)</td>
</tr>
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<td>Routed in front of seat back (2)</td>
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</tr>
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<td>Attached to seat stow handle (1)</td>
<td>Tucked into seat bight (1)</td>
</tr>
</tbody>
</table>
Results: Outcomes v. conditions

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color</strong></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>80%</td>
</tr>
<tr>
<td>Red</td>
<td>60%</td>
</tr>
<tr>
<td>Unlabeled</td>
<td>40%</td>
</tr>
<tr>
<td>Labeled</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Tether label</strong></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>80%</td>
</tr>
<tr>
<td>Red</td>
<td>60%</td>
</tr>
<tr>
<td>Unlabeled</td>
<td>40%</td>
</tr>
<tr>
<td>Labeled</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td></td>
</tr>
<tr>
<td>Bundle</td>
<td>40%</td>
</tr>
<tr>
<td>Belt path</td>
<td>60%</td>
</tr>
<tr>
<td>Unlabeled</td>
<td>30%</td>
</tr>
<tr>
<td>Labeled</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Vehicle labels</strong></td>
<td></td>
</tr>
<tr>
<td>Unlabeled</td>
<td>60%</td>
</tr>
<tr>
<td>Labeled</td>
<td>40%</td>
</tr>
</tbody>
</table>

P-values:
- Color: p=0.66
- Tether label: p=0.38
- Storage: p=0.66
- Vehicle labels: p=0.38
Results: Other predictors

Pearson’s chi-square test: $p = 0.0335$
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: $p = .6966$  

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: $p=0.0494$
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.

*continued on next page*
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:

Study 2:
Non-standard lower anchor spacing
• 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
Background

- Dedicated set of center LATCH anchors
• “Borrow” outboard anchors to create “simulated” center LATCH position
Background

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

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

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

6 axis load cell
Methods

6 axis load cell
Methods

Anchors clearly visible and easy to access

Lower anchors (shown at 11”)
Anchors clearly visible and easy to access

Lower anchors (shown at 23”)
• 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
• 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
• 6 Child Passenger Safety Technicians (CPSTs) recruited
• Installed each CRS (x3) in each spacing condition (x4)  
  – 12 installations each
• Tightened strap until CRS \textit{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)

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

CPSTs (n=6)
Results: FF Convertible

No significant differences in tension with respect to lower anchor spacing.
## Results: Summary

<table>
<thead>
<tr>
<th></th>
<th>General Subjects (n=30)</th>
<th>CPSTs (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infant base</strong></td>
<td>Subjects produced more tension at 15” and 23” compared to standard 11”.</td>
<td>Greater tension required for each wider-than-standard configuration (15”, 19”, and 23”)</td>
</tr>
<tr>
<td><strong>Rear-facing convertible</strong></td>
<td>No significant differences.</td>
<td>No significant differences.</td>
</tr>
<tr>
<td><strong>Forward-facing convertible</strong></td>
<td>No significant differences.</td>
<td>No significant differences.</td>
</tr>
</tbody>
</table>
Results: 1-inch test

Did general subjects “pass” the 1-inch test?

- Infant Base
- RF Convertible
- FF Convertible

Pass

Fail
Results: 1-inch test

Did general subjects “pass” the 1-inch test?

<table>
<thead>
<tr>
<th>Lower anchor spacing (inches)</th>
<th>Infant Base</th>
<th>RF Convertible</th>
<th>FF Convertible</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>15</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>19</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>23</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Forward-facing convertible had highest overall pass rate.
- Passing the 1-inch test does not appear to correlate with anchor spacing variations.
“Please describe any difficulties and/or positive aspects of this installation.” (write-in responses)

- 14/30 subjects: Wider spacing was more difficult to tighten
  - “More movement,” “Seemed less secure,” “Seemed less stable,” “Didn’t seem safe.”

- 7/30 subjects: Wider spacing was easier to tighten
  - “Easier to tighten,” “More space to angle/maneuver strap to pull better,” “Wider spacing seemed safer.”

- 9/30 subjects: Wider spacing was easier to access 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!
(Center for Child Injury Prevention Studies)
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Thank you!

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Injury Biomechanics Research Center:
www.ibrc.osu.edu

Center for Child Injury Prevention Studies (CChIPS)
www.cchips.research/chop.edu

Buckle Up with Brutus (Caregiver-oriented):
www.buckleup.osu.edu
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