



Additional Analysis of National Child Restraint Use Special Study: Child Restraint Misuse

Summary

The National Child Restraint Use Special Study (NCRUSS), conducted in 2011, recorded the use of car seats and belt-positioning booster seats in children from birth to 8 years old in 4,167 vehicles. Observers approached vehicles that carried at least one child. They interviewed the drivers and recorded observations of the restraint of one child per vehicle.

Observers collected detailed information on drivers, vehicles, the restraint status of the child, the child's car seat (if present), the installation of the car seat, and specific use of the car seat to restrain the child (e.g., harness placement and tightness). This included each driver's self-reported confidence in the correct installation of the car seat.

"Misuse" was defined as a characteristic of installation or use of a car seat/booster seat that may reduce the protection of the child in a crash. Installation did not have to be perfect. Only deviations that might compromise the protective function were defined as misuses for the purposes of the NCRUSS.

Descriptive results can be found in Greenwell (2015a, 2015b), including descriptions of the single most common misuse for each car seat type (Greenwell, 2015b). Research Notes using this data set further investigated installation decisions, driver characteristics, and lateral movement (Raymond, Searcy, Miller, & Redden, 2018) and the characteristics of unrestrained vehicle occupants (Raymond, Searcy, Findley, Miller, & Redden, 2017). This analysis reports the further examination of the misuse of car seats and booster seats and those who misuse those devices.

Multiple misuses (two or more) were common in car seats, appearing in 23.9 percent of rear-facing infant seats, 21.9 percent of rear-facing convertible seats, and 31.3 percent of forward-facing seats. Only 3.8 percent of booster seats had multiple misuses. Each seat type was examined separately

to determine the most common misuses and the most common co-occurring misuses.

As in Greenwell (2015a), in rear-facing infant and rear-facing convertible seats, the most common misuses were an incorrect seat angle for a child under 1 year old, less than or equal to 30 degrees; loose car seat installation, where the car seat could be moved more than 2 inches laterally; and harness slack over 2 inches. In forward-facing car seats, the most common misuses were loose car seat installation, harness slack, and one or more harness straps behind the child's arm, back, or leg. In highback and backless booster seats, the most common misuses were the lap belt across child's abdomen and/or ribcage and an improperly placed shoulder belt behind the child's arm or back.

In both rear-facing and forward-facing car seats, harness slack appeared in combination with several other common misuses. In fact, harness slack was observed in combination with other misuses more often than it was observed as the sole misuse.

A given case may have more than one misuse: the presence of one or more misuses categorizes the case as "Misuse Present." Car seats were more likely to be misused by Hispanic or Latino drivers than non-Hispanic/non-Latino drivers, by Black or African-American drivers more than White drivers, and by young drivers (under 30) more than middle-age drivers (30 to 50 years old).

Some driver behaviors were related to Misuse Present as well. Drivers who were very confident in their use were less likely to have Misuse Present than drivers who were less confident, though even "Very Confident" drivers had Misuse Present 38.4 percent of the time. Car seats that were installed using seat belts were more likely to have Misuse Present than car seats installed using the lower anchors and tether system.

Background

The NCRUSS was a nationally representative survey, with data collected at 24 primary sampling units (PSUs) across the country. The PSUs were established previously by a separate ongoing survey, the National Automotive Sampling System. The PSUs are defined geographically and can be thought of as cities, counties, or groups of adjacent counties. The PSUs include urban, rural, and suburban environments and are located in 17 States (Greenwell, 2015a).

The NCRUSS survey offers field observations of car seats installed by people without expectation of inspection. That is, drivers did not plan or expect inspection, and the installation of the observed car seats was not biased by any expectation, desire for self-presentation, or other contaminating behavior.

Observers were child passenger safety technicians (CPSTs) who approached vehicles that carried at least one child. They interviewed the drivers and conducted detailed observations of the restraint use of one child per each vehicle. Observers collected information on drivers, vehicles, restraint status of the child, the child's car seat (if present), installation methods used, the specific use of each seat's features (e.g., harness placement and tightness), and any misuses.

Specific details of data collection can be found in the 2011 National Child Restraint Usage Special Study User's Coding Manual (Barron, Doyle, & Radja, 2011). Descriptive information is reported in Greenwell (2015a, 2015b), which did not report inferential testing. Research Notes using this data set further investigated installation decisions, driver characteristics, and lateral movement (Raymond, Searcy, Findley, Miller, & Redden, 2017) and the characteristics of unrestrained vehicle occupants (Raymond, Searcy, Miller, & Redden, 2018).

The NCRUSS investigated misuse of car seats. An internal panel of subject matter experts identified misuse as characteristics of installation or usage that may reduce the safety of the car seat or booster seat for the child occupant. Details of the specific operationalization of the definition can be found in Greenwell (2015a).

The NCRUSS data set offers the opportunity to further investigate the misuse and co-occurring misuses of child restraint devices and to examine those who misuse those devices.

Research Questions

- When misuse is present, what types of misuses are seen?
- When multiple misuses are present, what are the most common combinations?
- Who is most likely to misuse car seats?
- Are there demographic characteristics or behaviors that are associated with misuse?

Analysis

Defining and Measuring Misuse

"Misuse" was defined as a characteristic of installation or use of a car seat/booster seat that may reduce the protection of the child in a crash. Installation did not have to be perfect. Only deviations that might compromise the protective function were defined as misuses for the purposes of the NCRUSS. For example, loose installation was measured by pushing the seat side to side and measuring lateral movement. The "best practice" is 1 inch of movement or less – but a seat only was coded as misused if it moved more than 2 inches laterally.

In the NCRUSS observations, 3,814 cases represented the use of car seats or booster seats. In any data collection effort, there are missing or unknown values for some observations. In the NCRUSS, 431 cases (weighted 14%) were missing some or all of the observations relevant to defining misuse.

In Greenwell (2015a, 2015b), cases with unknown values were excluded from analysis for the calculation of single misuse rates. That is, Greenwell examined single misuse rates using different denominators for each single misuse: all cases with observations for that specific misuse contributed to the calculation of that single misuse rate. Cases with missing cells for other misuse observations were not excluded from the calculation of the single misuse rate as long as the observation for that single misuse was present.

For the current detailed investigation of types of misuse and predictors of misuse, only the 3,383 complete cases are included for analysis. Cases with missing data (with one or more defined misuses with unknown values) are excluded from analysis. Because the purpose of this analysis is to investigate multiple misuses, the denominator for these misuses must be the same across specific misuses. By including only the cases with complete misuse observations, a consistent denominator allows rates of misuse and multiple misuses to be illustrated graphically in Euler diagrams.

A variable called “Misuse Present” was created to indicate whether a case was observed to have at least one defined misuse. A given case may have more than one misuse: the presence of one or more misuses categorizes the case as Misuse Present.

Statistical Methods

The NCRUSS (2011) data collection and weighting plan was designed to represent the restraint use of children 8 and younger. That is, sampling and weighting adjusted the data to represent the use of the types of car seats. Each case is the restraint (or non-restraint) used by a sampled child, and the information collected in association with that child.

SAS survey methods for subgroup analyses use only cases defined by the subgroup in the calculation of point estimates, but use the entire sample in the variance estimation, including the calculation of standard errors to account for variability resulting from subgroup creation that is unrelated to the survey design. Since the NCRUSS sampling weights are relative to the sampled child in the vehicle, reporting of results related to drivers must be in reference to the sampled children.

Descriptive statistics report weighted frequencies, with standard errors (SE), 95 percent confidence intervals (CI), and design effects. All reported percentages are weighted percentages.

Sample sizes are small for many of the subgroups. As the subgroup sample size decreases, the confidence we have in our point estimates decreases. The corresponding weighted percentages may become less reliable (Greenwell, 2015a) as reflected in larger confidence intervals, and conclusions become less advisable.

Particularly for weighted percentages with large confidence intervals, it should be emphasized that the results are estimates and that there exists uncertainty about the true difference in proportion between subgroups. While a difference between subgroups may be found to be statistically significant, its practical significance must also be thoroughly evaluated.

In some of these groups that form the larger context, some cells are too small for analysis. Therefore, some subgroups may be combined. For example, too few people in the “Native Hawaiian/Other Pacific Islanders” category appear in the sample for analysis. Rather than exclude these cases, they are recoded with those who self-identified as “American Indian/Alaska Native” or “Other” to form an “All Other Races” group for analysis.

For inferential statistics, the Rao-Scott chi-square test, a design-adjusted version of the Pearson chi-square test appropriate for handling complex survey data, was used to test for association and differences in frequencies. In some comparisons (e.g., when comparing restrained and unrestrained groups) cell sizes differ greatly. The second-order Rao-Scott (design-adjusted) chi-square is appropriate when cell design effects vary substantially, as they do when cell sizes vary markedly. When testing associations and differences of frequencies between greatly unequal cell sizes, the second-order Rao-Scott (design-adjusted) chi-square is used. Throughout, the significance level was $p < .05$ for analyses.

Results

Descriptive Statistics

Car Seats and Booster Seats With Defined Misuses

Table 1 shows the List of Defined Misuses, which can also be found in Appendix D and Tables 12 and 13 of Greenwell (2015a). These are the misuses previously defined as detrimental to the protective function of the child restraint device.

Of the 3,383 complete cases in the NCRUSS observations, 1,866 cases (weighted 49%) had at least one misuse. The remaining 1,517 cases (weighted 51%) had no misuse.

Table 1
List of Defined Misuses

Car Seat to Vehicle Installation
Car seat's direction is incorrect
Loose installation: Moves >2 inches laterally (includes all cases with more than 2 inches of lateral movement)
Other method of attachment of car seat to vehicle (method is not seat belt or lower anchors and tether)
Car seat not attached to vehicle
Car seat not against vehicle back
Child less than 1 year old and car seat is upright
Child less than 1 year old and car seat angle is less than or equal to 30 degrees
Recline of more than 45 degrees
For seat installed with lower anchors: Both lower anchor connectors attached to something other than anchors
For seat installed with lower anchors: One of the connectors not attached to anything or attached to something other than anchor
For seat installed with lower anchors: Multiple car seats or boosters attached to lower anchors used by inspected car seat
For seat installed with lower anchors: Incorrect lower anchor strap routing
For seat installed with seat belt: Seat belt is not buckled
For seat installed with seat belt: Vehicle model years prior to 1996 and locking clip used on lap/shoulder; greater than 1 inch; used only on lap; used only on shoulder
For seat installed with seat belt: ELR mode and latch plate is not switchable—locked or locking
For seat installed with seat belt: Car seat lock-off is available and not in use and seat belt is in ELR mode and latch plate is not switchable—locked or locking
For seat installed with seat belt: Incorrect seat belt routing
Restraining a Child in Car Seat
Child seated in front row, with an active air bag
Car seat is cracked/broken shell
Car seat has broken/frayed harness
Car seat uses non-regulated product, such as a belt tightener
Location of car seat not on vehicle seat
Harness not in use
Given harness in use, harness strap not buckled
Given harness in use, one or more harness straps behind arm/back/leg
Given harness in use, harness slack is greater than 2 inches
Given direction is rear-facing, both harness slots positioned above the child's shoulder by more than 2 inches
Given direction is forward-facing, both harness slots positioned below the child's shoulder by more than 2 inches
Child's head is above the top of car seat
Restraining a Child in Booster Seat
Child seated in front row, with an active air bag
Location of booster seat not on vehicle seat
Booster seat is cracked/broken shell
Booster seat has broken/frayed harness
Booster seat uses non-regulated product, such as a belt tightener
Seat belt is not buckled
Child's head above vehicle seat back
Shoulder belt behind arm or back
Lap belt across abdomen/ribcage
Lap belt not used

These misuses were used to identify car seat and booster seats where misuse was present. In any case with complete usage data, the presence of one or more of these misuses was sufficient to categorize a car seat or booster seat as misused.

When misuse is present, what types of misuse are seen?

Tables 2, 3, and 4 show proportions of each misuse as it contributes to the cases with complete usage observations. These tables are similar conceptually to Tables 10 to 13 in Greenwell (2015a) but are calculated with a single denominator for each seat type (cases with complete observations for all usage measures) rather than different denominators for each single misuse (cases with complete observations for that specific misuse). The use of complete cases and a single denominator for each seat type allows the more direct comparison of misuse and the illustration of multiple misuses in Euler diagrams. The patterns of misuse proportions are consistent with Greenwell (2015a, 2015b).

Table 2 shows the list of defined misuses, with the weighted proportions for each seat type as they contribute to the cases with complete observations of usage. For this table, the defined misuses include only those misuses that do not apply to specific installation methods (e.g., incorrect lower anchor strap routing, incorrect seat belt routing). Note that a given case may have more than one observed misuse, so proportions will not sum to 100 percent. The sample size

listed in the header shows the number of complete cases for that seat type. Sample size reported in the body of the table shows the number of cases with that particular misuse.

Misuses for rear-facing infant seats and rear-facing convertible seats showed similar patterns (see also Greenwell, 2015a, 2015b). For misuses unrelated to a specific installation method, the most common misuse in rear-facing seats was an incorrect angle of recline, where a child less than 1 year old rode in a seat at an angle less than or equal to 30 degrees. The next most common misuse was loose installation, where the seat moved more than 2 inches laterally (side to side). The third most common misuse was harness slack of more than 2 inches. Seats that did not show misuse would exhibit an angle of recline from 30 to 45 degrees, less than 2 inches of lateral movement, and less than 2 inches of harness slack.

Forward-facing seats are subject to many of the same possible misuses as rear-facing seats. They differ from rear-facing seats in their need to be against the back of the vehicle seat and in the lack of need for a specific angle of recline. Consistent with Greenwell (2015a, 2015b), among forward-facing car seats, the most frequently observed misuse was loose installation. The second most common misuse was harness slack of more than 2 inches, followed by one or more harness straps behind the child's back, arm, or leg.

Table 2

Weighted Proportions of Defined Misuses by Seat Type, Excluding Those Related to Specific Installation Method

Defined Misuses	Rear-Facing Infant (n=248)	Rear-Facing Convertible (n=122)	Forward-Facing (n=1,819)
Car Seat to Vehicle Installation			
Car seat's direction is incorrect	6.4% (n=11)	0.0% (n=0)	0.3% (n=6)
Loose installation: Moves >2 inches laterally	12.6% (n=59)	5.7% (n=10)	17.0% (n=358)
Other method of attachment of car seat to vehicle	0.1% (n=1)	0.7% (n=1)	0.5% (n=10)
Car seat not attached to vehicle	0.9% (n=7)	0.0% (n=0)	3.2% (n=71)
Car seat not against vehicle back	n/a	n/a	3.4% (n=74)
Child less than 1 year old and car seat is upright	2.9% (n=7)	0.0% (n=0)	n/a
Child less than 1 year old and car seat angle is up to 30 degrees	16.1% (n=32)	14.0% (n=9)	n/a
Recline of more than 45 degrees	3.3% (n=9)	1.6% (n=3)	n/a
Restraining a Child in Car Seat			
Child seated in front row, with an active air bag	0.4% (n=1)	0.0% (n=0)	0.2% (n=5)
Car seat is cracked/broken shell	0.0% (n=0)	0.0% (n=0)	0.3% (n=12)
Car seat has broken/frayed harness	3.3% (n=1)	0.0% (n=0)	1.0% (n=24)
Car seat uses non-regulated product	0.0% (n=0)	1.5% (n=1)	0.4% (n=4)
Location of car seat not on vehicle seat	0.0% (n=0)	0.0% (n=0)	0.0% (n=0)
Harness not in use	3.4% (n=3)	1.6% (n=2)	2.0% (50)
Given harness in use, harness strap not buckled	1.4% (n=7)	0.0% (n=0)	1.6% (n=40)
Given harness in use, one or more harness straps behind arm/back/leg	0.6% (n=4)	0.9% (n=1)	5.4% (n=85)
Given harness in use, harness slack is greater than 2 inches	6.8% (27)	2.3% (n=5)	10.2% (n=267)
Given direction is rear-facing, both harness slots positioned above the child's shoulder by more than 2 inches	0.2% (n=2)	0.6% (n=2)	0.0% (0)
Given direction is forward-facing, both harness slots positioned below the child's shoulder by more than 2 inches	0.0% (n=0)	0.0% (n=0)	2.9% (n=81)
Child's head is above the top of car seat	0.1% (n=2)	0.0% (n=0)	0.0% (n=0)

Table 3 shows the other defined misuses that are related to the specific installation method, broken down by seat type, with weighted proportions as the misuses contribute to cases with complete usage observations. These other defined misuses are those that depend upon the installation method. For example, incorrect seat belt routing can be seen in a seat that is installed using the seat belt, but not in a seat that is installed using the lower anchors and tether. The most common installation-specific misuses are the following:

- Installed with seat belt and ELR mode and latch plate is not switchable—locked or locking: seen most often in rear-facing infant seats and forward-facing seats.
- Installed with lower anchors and incorrect lower anchor strap routing: seen most often in rear-facing convertible seats and forward-facing seats.
- Installed with seat belt and incorrect seat belt routing: seen most often in forward-facing seats but also in rear-facing convertible seats.

Table 3

Weighted Proportions of Other Defined Misuses Related to Specific Installation Method by Seat Type

Defined Misuses	Rear-Facing Infant (n=248)	Rear-Facing Convertible (n=122)	Forward-Facing (n=1,819)
Other Defined Misuses			
Installed with seat belt and incorrect seat belt routing	n/a	9.8% (n=19)	18.3% (n=524)
Installed with seat belt and seat belt is not buckled	2.3% (n=5)	1.0% (n=1)	2.7% (n=25)
Installed with seat belt and vehicle model years prior to 1996 and locking clip used on lap/shoulder; greater than 1 inch; used only on lap; used only on shoulder	0% (n=0)	0.0% (n=0)	0.2% (n=4)
Installed with seat belt and ELR mode and latch plate is not switchable—locked or locking	25.5% (n=70)	8.9% (n=13)	25.8% (493)
Installed with seat belt and car seat lock-off is available and not in use; seat belt in ELR mode and latch plate is not switchable—locked or locking	1.3% (n=4)	0.0% (n=0)	0.5% (n=23)
Installed with lower anchors and incorrect lower anchor strap routing	n/a	28.6% (41)	15.5% (n=396)
Installed with lower anchors and both lower anchor connectors attached to something other than anchors	0.5% (n=4)	0.3% (n=1)	0.5% (n=11)
Installed with lower anchors and one of the connectors not attached to anything or attached to something other than anchor	0.05% (n=1)	0.0% (n=0)	0.5% (n=11)
Installed with lower anchors and multiple car seats or boosters attached to lower anchors used by inspected car seat	2.8% (n=7)	0.2% (1)	2.0% (24)

Booster seats are designed to position the seat belt correctly against a child's frame, and are subject to different potential misuses than rear-facing infant seats, rear-facing convertible seats, and forward-facing seats. Table 4 shows weighted proportions of defined misuses in booster seats as they contribute to cases with complete usage observa-

tions. Consistent with Greenwell (2015a, 2015b), among booster seats (both highback and backless types), the most frequently observed misuse was the lap belt positioned across the child's abdomen or ribcage. The second-most common misuse was the shoulder belt behind the child's arm or back.

Table 4

Weighted Proportions of Defined Misuses for Booster Seats

Defined Misuses	Highback Booster (n=627)	Backless Booster (n=567)
Child seated in front row, with an active air bag	0.2% (n=3)	1.9% (n=11)
Location of booster seat not on vehicle seat	0.05% (n=1)	0.0% (n=0)
Booster seat is cracked/broken shell	0.4% (n=2)	0.1% (n=1)
Booster seat has broken/frayed harness	0.7% (n=4)	0.0% (n=0)
Booster seat uses non-regulated product	0.0% (n=0)	0.0% (n=0)
Seat belt is not buckled	1.8% (n=19)	4.0% (n=31)
Child's head above vehicle seat back	2.6% (n=9)	3.8% (n=33)
Shoulder belt behind arm or back	4.1% (n=34)	5.9% (n=44)
Lap belt across abdomen/ribcage	9.6% (n=55)	12.1% (n=45)
Lap belt not used	0.9% (n=12)	2.1% (n=16)

Misuse and Multiple Misuse by Seat Type

When multiple misuses are present, what are the most common combinations?

Each seat type was examined separately to determine the most common co-occurring misuses. Euler diagrams show the ways that the more common misuses appear in combination. For each car seat or booster seat type, a diagram shows the misuses that represent 5 percent or more of the complete cases with misuse present.

Each diagram illustrates only complete cases with at least one misuse. Each misuse that represents more than 5 percent of these cases (complete cases with at least one misuse) is shown as a circle.

Multiple misuses are shown when they represent 1 percent or more of the cases. Cases with multiple misuse are shown where the circles overlap. When circles do not overlap, that combination of misuses either (a) does not appear in the data set or (b) does not represent 1 percent or more of complete cases with misuse present.

Following Greenwell (2015b), misuses shown are those that are not subjected to specific types of installation method of car seat/booster seat to the vehicle. That is, misuses unique to lower anchor use or to seat belt use are excluded in this first set of diagrams. The denominator therefore comes from complete cases only, where at least one misuse is present, and at least one misuse is not installation-specific.

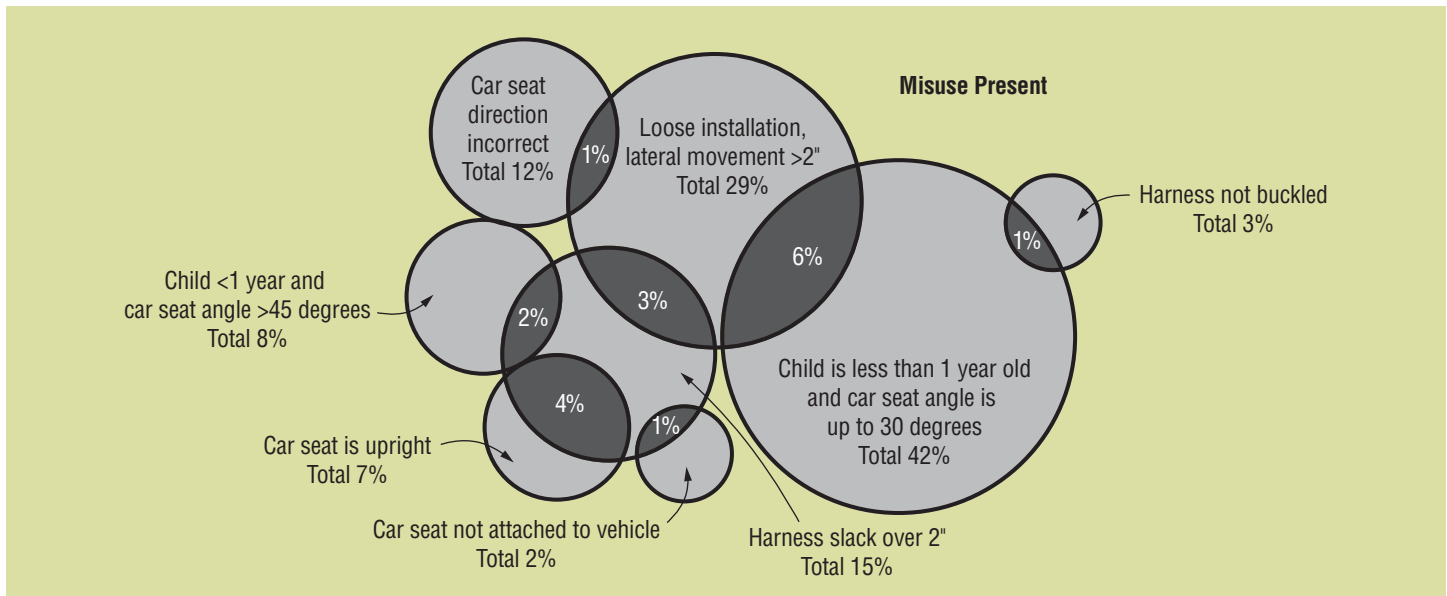
Rear-facing infant and rear-facing convertible seats

Multiple misuses were common, appearing in 23.9 percent of rear-facing infant seats ($n=76$; SE of percent=6.24%; 95% CI=10.3%, 37.5%; design effect=5.30) and 21.9 percent of rear-facing convertible seats ($n=24$; SE of percent=5.29%; 95% CI=10.3%, 33.4%; design effect=1.98).

When examining cases which show at least one misuse, 44.1 percent ($n=100$; SE of percent=6.49%; 95% CI=30.0%, 58.2%; design effect=3.87) of misuse cases in rear-facing infant and convertible seats show multiple misuses.

Figure 1

Rear-Facing Infant and Convertible Seats With Observed Misuses, Specific Installation Methods Excluded



Rear-facing infant and rear-facing convertible seats have been combined and can be seen in Figure 1, which shows frequent combinations of observed misuses. The most frequently seen misuse is the incorrect seat angle (42% of misuse cases), where the child is less than 1 year old and the car seat angle is less than 30 degrees. Loose installation is the next-most common misuse, seen in 29 percent of misuse cases. Six percent of the misuse cases include both these misuses. The next most common co-occurring misuses are, in order, harness slack over 2" *with* loose installation (3%), the car seat installed in incorrect direction *with* loose installation (1%), incorrect car seat angle where the

child is less than 1 year old and the car seat angle is more than 45 degrees *with* harness slack over 2" (2%), harness not buckled *with* the car seat angle less than 30 degrees (1%), and the car seat not attached to vehicle *with* harness slack over 2" (1%).

Harness slack was observed in combination with four other common misuses (loose installation, car seat angle over 45 degrees, upright car seat, and car seat not attached to vehicle). In fact, two-thirds of the harness slack cases are combined with another common misuse. Misuses that overlap by less than 1 percent are not shown in the diagram,

and when all combinations are taken into account, including those not illustrated, harness slack was observed as the sole misuse in less than 2 percent of misuse cases: over 13 percent of harness slack misuses were in combination with one or more other misuses.

Forward-facing seats

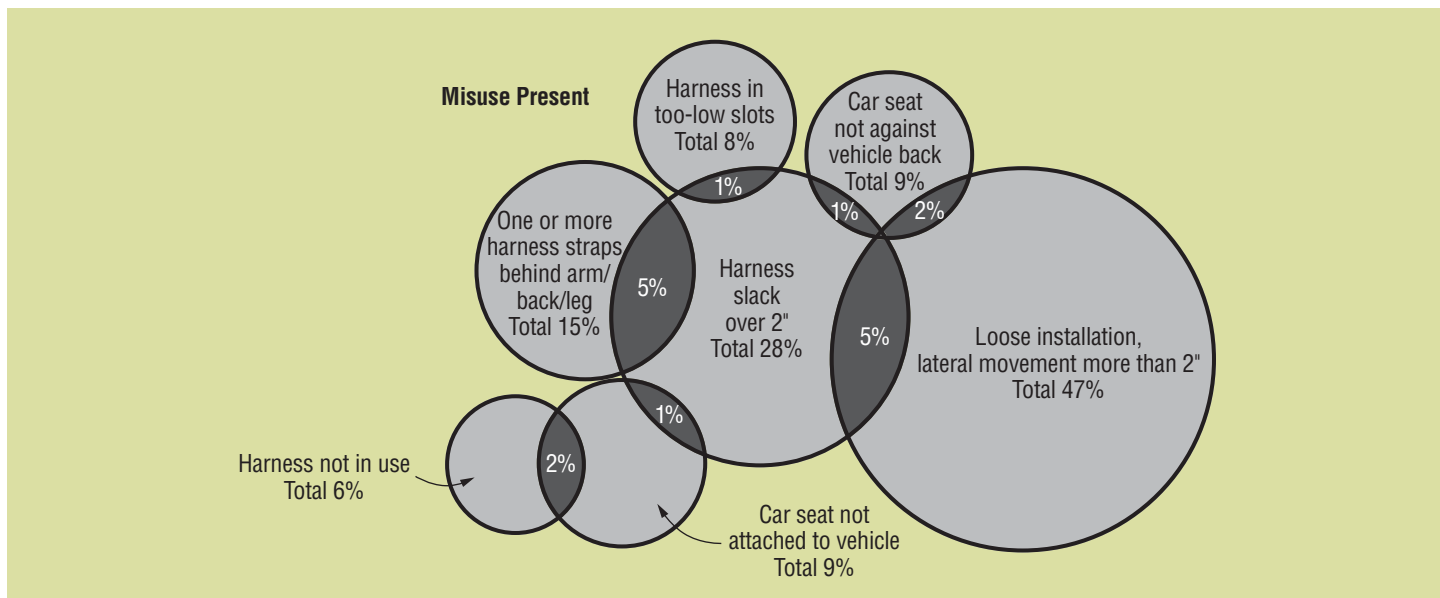
Overall, multiple misuses appeared in 31.3 percent of forward-facing seats ($n=736$; SE of percent=4.71%; 95% CI=21.1%, 41.6%; design effect=18.76). When examining

cases that show at least one misuse, 47.5 percent ($n=736$; SE of percent=4.56%; 95% CI=37.6%, 57.5%; design effect=11.49) of misuse cases in forward-facing seats show multiple misuses.

Forward-facing seats are shown in Figure 2. The most common misuse, loose installation, was seen combined with harness slack (5% of misuse cases had both these misuses) and with the car seat not against the vehicle back (2% of misuse cases with both these misuses).

Figure 2

Forward-Facing Car Seats With Observed Misuses, Specific Installation Methods Excluded



Harness slack over 2 inches was often seen in combination with other misuses. Harness slack was most often seen in combination with loose installation, as mentioned, or a misplaced strap (one or more harness straps behind the child's arm, back or leg) (5%) but was also seen in combination with the car seat not against the vehicle back (1%), with the harness in too-low slots (1%), and with the car seat not being attached to the vehicle (1%). Though other misuses were seen in multiple-misuse combinations, harness slack overlapped substantially (1% or more) with five other common misuses. Misuses which overlap by less than 1 percent are not shown in the diagram, and when all misuse combinations are taken into account, harness slack appears as the sole misuse in only 12 percent of misuse cases – 16 percent are in combination with one or more other misuses.

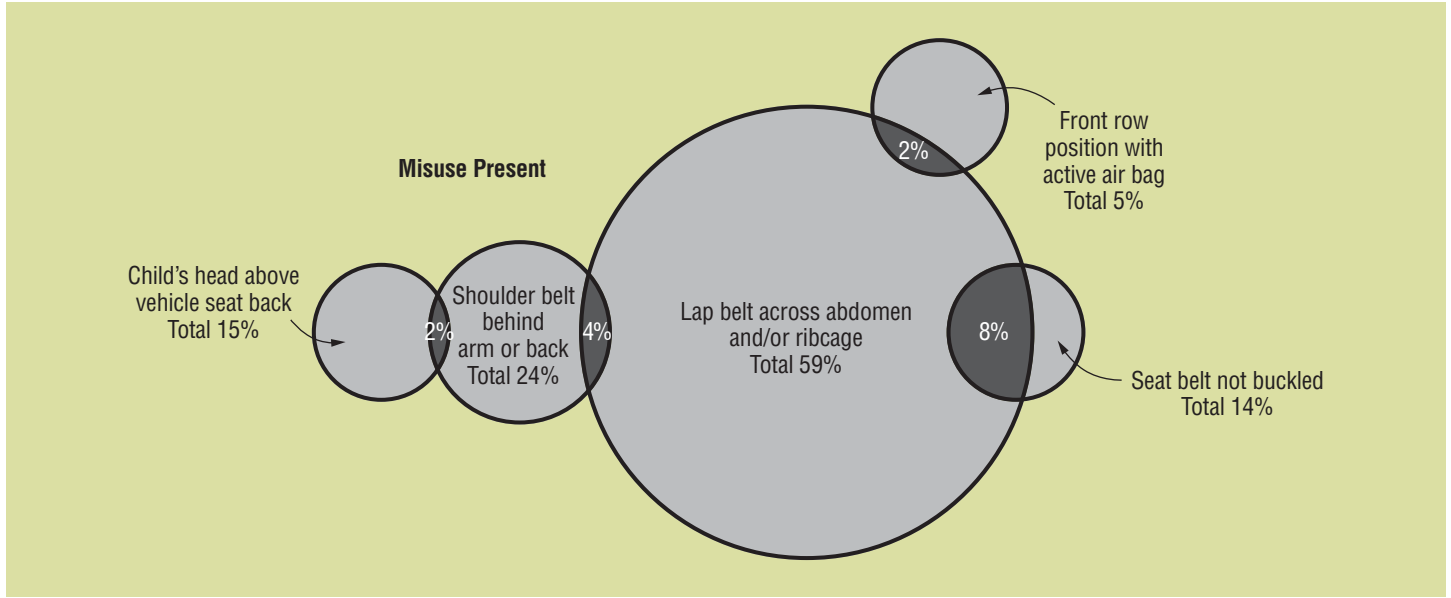
Booster seats

Overall, 3.8 percent of highback and backless booster seats ($n=57$; SE of percent=1.26%; 95% CI=1.0%, 6.5%; design effect=5.25) showed multiple misuses. Narrowing the field of interest down to cases which exhibit at least one misuse, 18.1 percent ($n=57$; SE of percent=5.79%; 95% CI=5.5%, 30.7%; design effect=5.82) of misuse cases in booster seats show multiple misuses.

Booster seats have 10 possible defined misuses, compared to the 23 possible misuses for car seats (excluding misuses specific to the type of installation method.) The Euler diagram (Figure 3) is correspondingly simpler, showing the five misuses that occur in 5 percent of misuse cases or more.

Figure 3

Highback and Backless Booster Seats With Observed Misuses, Specific Installation Methods Excluded



The most common misuse was improper lap belt position, where the lap belt was observed across the abdomen and/or ribcage in 59 percent of misuse cases. When part of multiple misuses, it was paired most commonly with an unbuckled seat belt (8% of misuse cases showed both these misuses) or with a shoulder belt behind the child's arm or back (4%).

When the shoulder belt was positioned behind the child's arm or back, the child's head also was observed above the vehicle seat back in 2 percent of misuse cases.

Characteristics of Those Who Misuse Car Seats and Booster Seats

Who is most likely to misuse car seats and booster seats? Are there demographic characteristics and behaviors that are related to misuse?

The calculation of the "Misuse Present" variable allows the investigation of demographic characteristics and behaviors that may be associated with the presence or absence of misuse. Recall that the absence of misuse does not imply correct use – it merely denotes the absence of the defined misuses expected to reduce the protection of the child in a crash.

Demographics

Overall descriptive statistics for demographics of drivers by misuse present or absent appear in Table 5. Gender, Hispanic/Latino Ethnicity, Race, and Age Group are shown with the number of complete cases, the weighted percentages, and 95 percent confidence intervals, all by Misuse Present status. Because of the weights applied, sample sizes and weighted percentages do not have a simple arithmetic relationship.

Comparisons between groups can be made. For example, drivers were male in 19.8 percent of Misuse Present cases and in 20.8 percent of Non-Misuse Present cases. An examination of the confidence intervals reveals that the difference between the Misuse Present and Non-Misuse Present male proportions are not expected to be significantly different.

Table 5
Descriptive Statistics for Demographics of Drivers by Misuse Present or Absent

	Driver Characteristics	Misuse Present		Misuse Absent	
		(n)	Weighted Percentage [95% CI]	(n)	Weighted Percentage [95% CI]
Gender	Male	396	19.8% [15.1% – 24.4%]	323	20.8% [19.1% – 22.5%]
	Female	1,470	80.2% [75.6% – 84.9%]	1,194	79.2% [77.5% – 80.9%]
Ethnicity	Not Hispanic or Latino	1,481	89.7% [86.6% – 92.7%]	1,325	94.1% [90.4% – 97.9%]
	Hispanic or Latino	310	10.3% [7.3% – 13.4%]	157	5.9% [2.1% – 9.6%]
Race	White	1,297	67.7% [53.0% – 82.5%]	1,248	85.5% [79.4% – 91.5%]
	Black or African-American	325	25.8% [11.5% – 40.1%]	139	8.8% [3.3% – 14.2%]
	Asian	100	4.8% [1.2% – 8.3%]	62	5.1% [1.7% – 8.5%]
	Native Hawaiian/Other Pacific Islander	10	0.4% [0.03% – 0.8%]	2	0.1% [0.0% – 0.2%]
	American Indian/Alaska Native	10	0.2% [0.003% – 0.4%]	3	0.03% [0.0% – 0.1%]
	Other	31	1.0% [0.1% – 1.9%]	17	0.5% [0.1% – 1.0%]
Driver Age Group	Age >50 years old	128	6.0% [3.4% – 8.6%]	99	4.3% [2.0% – 6.6%]
	Age 30–50 years old	1,190	68.7% [63.9% – 73.4%]	1,100	80.7% [74.9% – 86.6%]
	Age <30 years old	437	25.4% [20.0% – 30.8%]	225	15.0% [11.0% – 18.9%]

Rao-Scott (design-adjusted) chi-square tests were used to investigate potential relationships of Misuse Present with Driver Gender, Hispanic or Latino ethnicity, Race, and Age, along with Child Gender.

Misuse Present was unrelated to Driver Gender (second-order Rao-Scott chi-square: $F(1,12)=0.25$, $p=0.63$,

design correction=2.30), and Child Gender (second-order Rao-Scott chi-square: $F(1,12)=0.04$, $p=0.84$, design correction=2.15), as shown in Tables 6 and 7. That is, misuse was no more likely to be present with a particular gender of driver or child.

Table 6
Misuse Present by Driver Gender

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Male Drivers	719	396	47.6%	5.17%	36.3%, 58.9%	7.70
Female Drivers	2,664	1,470	49.2%	3.85%	40.8%, 57.6%	15.82

Table 7
Misuse Present by Child Gender

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Male Children	1,736	957	48.7%	4.26%	39.4%, 57.9%	12.62
Female Children	1,606	886	49.2%	3.89%	40.7%, 57.7%	9.73

Drivers with Hispanic or Latino ethnicity were more likely to misuse car seats or booster seats, as shown in Table 8

(second-order Rao-Scott chi-square: $F(1,12)=5.48$, $p < .05$, design correction=4.00).

Table 8

Misuse Present by Drivers With Hispanic or Latino Ethnicity

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Hispanic or Latino Drivers	467	310	62.4%	6.68%	47.8%, 76.9%	8.86
Non-Hispanic/Non-Latino Drivers	2,806	1,481	47.3%	4.17%	38.2%, 56.4%	19.59

Driver race was associated with Misuse Present (see Table 9). Driver race was recoded into four categories: White, Black or African-American, Asian, and All Other Races, shown in Table 9. The overall F statistic was significant (second-order Rao-Scott chi-square: $F(1,12)=9.15$, $p < .05$, design correction=6.54), allowing pairwise comparisons.

Black or African-American drivers were more likely to have a Misuse Present than White drivers (second-order Rao-Scott chi-square: $F(1,12)=12.27$, $p < .05$, design correction=13.84), 73.2 percent of Black or African-American drivers misused car seats or booster seats, compared to 42.4 percent of White drivers.

Black or African-American drivers were more likely to have a Misuse Present than Asian drivers (second-order Rao-Scott chi-square: $F(1,12)=4.96$, $p < .05$, design correction=7.20), 73.2 percent of Black or African-American drivers misused car seats or booster seats, compared to 46.4 percent of Asian drivers.

Misuse Present did not differ significantly between White drivers and Asian drivers (second-order Rao-Scott chi-square: $F(1,12)=0.19$, $p=0.67$, design correction=5.25), 46.4 percent of Asian drivers misused car seats or booster seats, compared to 42.4 percent of White drivers.

Drivers of All Other Races were more likely to have a Misuse Present than White drivers (second-order Rao-Scott chi-square: $F(1,12)=7.25$, $p < .05$, design correction=1.71). Similarly, drivers of All Other Races were more likely to have a Misuse Present than Asian drivers (second-order Rao-Scott chi-square: $F(1,12)=5.23$, $p < .05$, design correction=1.62). However, Misuse Present did not differ significantly between Drivers of All Other Races and Black or African-American drivers (second-order Rao-Scott chi-square: $F(1,12)=0.09$, $p=0.77$, design correction=1.00).

Table 9

Misuse Present by Driver Race

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Black or African-American Drivers	464	325	73.2%	3.98%	64.5%, 81.9%	3.74
White Drivers	2,545	1,297	42.4%	3.74%	34.2%, 50.5%	14.57
Asian Drivers	162	100	46.4%	10.11%	24.4%, 68.4%	6.61
All Other Races	73	51	70.9%	7.28%	55.0%, 86.7%	1.85

Driver Age was related to Misuse Present as well. Driver Age was recoded into three categories: over 50, 30 to 50, or under 30. Age group was associated with Misuse Present (second-order Rao-Scott chi-square: $F(1,12)=9.89$, $p < .05$, design correction=3.18), shown in Table 10.

Misuse Present did not differ significantly between younger drivers (under 30) and older drivers (over 50) (second-order Rao-Scott chi-square: $F(1,12)=0.31$, $p=0.59$,

design correction=4.57). Misuse Present also did not differ significantly between middle-age drivers (30 to 50) and older drivers (over 50) (second-order Rao-Scott chi-square: $F(1,12)=2.49$, $p=0.14$, design correction=3.63).

Younger drivers (under 30) were more likely to have a Misuse Present than middle-age drivers (30 to 50) (second-order Rao-Scott chi-square: $F(1,12)=28.32$, $p < .05$, design correction=2.01).

Table 10

Misuse Present by Driver Age

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Under Age 30	662	437	61.8%	3.12%	55.0%, 68.5%	2.72
Age 30-50	2,290	1,190	44.7%	4.01%	36.0%, 53.5%	14.90
Over Age 50	227	128	56.9%	7.90%	39.7%, 74.1%	5.76

Behaviors

Driver restraint use (whether using the lap and shoulder belt or not using the seat belt) was not related to Misuse Present (second-order Rao-Scott chi-square: $F(1,12)=2.84$, $p=0.12$, design correction=3.68), shown in Table 11. In addition,

a history of having driven with an unrestrained child was not related to Misuse Present (second-order Rao-Scott chi-square: $F(1,12)=1.19$, $p=0.30$, design correction=3.84) as seen in Table 12.

Table 11

Misuse Present by Driver Restraint Use

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Unrestrained	60	43	67.5%	7.59%	51.0%, 84.1%	1.55
Lap and Shoulder Belt	2,616	1,442	48.4%	4.47%	38.6%, 58.1%	20.96

Table 12

Misuse Present by History of Driving With an Unrestrained Child

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Drove With Unrestrained Child	466	239	53.6%	5.82%	40.9%, 66.3%	6.34
Never Drove With Unrestrained Child	2,808	1,563	48.0%	4.22%	38.8%, 57.1%	20.03

Drivers rated their confidence in the seat's correct installation on a 1 (Not Confident) to 5 (Very Confident) scale. Driver confidence was associated with lower rates of misuse based on the overall F statistic (second-order Rao-Scott chi-square: $F(2.56,30.67)=5.57$, $p < .05$, design correction=5.50), with Very Confident drivers showing the least likelihood

(38.4%) of a Misuse Present, as shown in Table 13. Consistent with Greenwell (2015b), this is still a substantial proportion with misuse, and these Very Confident drivers may be less likely to seek out additional information about correct restraint usage.

Table 13

Misuse Present by Driver Confidence in Seat's Correct Installation

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
(1) Not Confident	76	59	62.3%	12.3%	35.5%, 89.1%	4.84
(2)	85	61	70.6%	10.6%	47.5%, 93.7%	4.55
(3)	463	318	63.7%	3.7%	55.7%, 71.7%	2.70
(4)	1,053	597	52.5%	6.4%	38.6%, 66.4%	17.17
(5) Very Confident	1,416	664	38.4%	5.3%	26.8%, 50.1%	17.05

Observers recorded the total number of occupants in the vehicle as well as the number of child passengers under age 9. Total number of occupants in the vehicle was recoded into two categories (three or fewer total occupants in the vehicle,

more than three total occupants in the vehicle), shown in Table 14. Misuse Present was not related to the total number of occupants in the vehicle (second-order Rao-Scott chi-square: $F(1,12)=1.93$, $p=0.19$, design correction=2.47).

Table 14

Misuse Present by Number of Occupants in the Vehicle

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Three or Fewer Occupants	2,890	1,589	48.6%	4.08%	39.7%, 57.4%	19.25
More Than Three Occupants	402	238	53.7%	3.95%	45.1%, 62.3%	2.51

When looking at all rear-facing and forward-facing car seats, Installation Method (whether the seat was installed with the lower anchors and tether or with the seat belt) was related to Misuse Present (second order Rao-Scott chi-

square: $F(1,12)=195.70$, $p < .05$, design correction=1.58) (see Table 15). Cases installed using both methods simultaneously were excluded; use of both methods concurrently is a misuse. Car seats installed using seat belts were more

likely to be misused than car seats installed using lower anchors and tethers. This effect holds true when examining all car seats by installation method, as described, and also holds true when examining only those cases where either

installation method is equally possible (the vehicle seating position has both a seat belt and lower anchors, and the car seat has the capability to be installed using either the seat belt or lower anchors and tethers).

Table 15

Misuse Present by Installation Method

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Lower Anchors or Lower Anchors/Tether	876	489	42.0%	5.42%	30.2%, 53.8%	10.54
Seat Belt Only	867	747	83.4%	2.71%	77.5%, 89.3%	4.61

It is important to note that seat belt installation is associated with excessive lateral movement (Raymond et al., under agency review), which is one of the defined misuses included in the definition of Misuse Present.

The number of child passengers under 9 was recoded into four categories (One Child Passenger <9 years old, Two

Child Passengers <9 years old, Three Child Passengers <9 years old, and Four or More Child Passengers <9 years old), see Table 16. Misuse Present was not related to the number of child passengers under age 9 (second-order Rao-Scott chi-square: $F(2.31, 27.68) = 2.54, p = 0.09, \text{design correction} = 2.37$).

Table 16

Misuse by Number of Child Passengers Under 9

Subgroup	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
One Child Passenger <9 Years Old	2,292	1,240	48.8%	4.08%	39.9%, 57.7%	15.29
Two Child Passengers <9 Years Old	916	512	47.1%	4.32%	37.7%, 56.5%	6.86
Three Child Passengers <9 Years Old	135	86	60.2%	6.02%	47.1%, 73.3%	2.03
Four or More Child Passengers <9 Years Old	20	12	36.5%	7.98%	19.1%, 53.9%	0.52

Drivers described their perception of car seat and booster seat efficacy for young children. They compared child safety seats to seat belts for children under 2, and made

the same comparison for children 2 to 4 years old. Though cell sizes are not appropriate for inferential analysis, these groups can be seen in Tables 17 and 18.

Table 17

Misuse by Driver Perception of Car Seat and Booster Seat Efficacy Relative to Seat Belt Use for Children Less Than 2 Years Old

Subgroup for Children <2 Years Old	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Not As Good?	8	4	19.5%	14.09%	0.0%, 50.2%	0.88
The Same?	76	45	63.4%	5.44%	51.6%, 75.2%	0.96
Better Than Seat Belts?	3,200	1,753	48.2%	3.97%	39.5%, 56.8%	20.23

Table 18

Misuse by Driver Perception of Car Seat and Booster Seat Efficacy Relative to Seat Belt Use for Children Ages 2-4

Subgroup for Children 2-4 Years Old	(n)	(n) of Subgroup With Misuse Present	% of Subgroup With Misuse Present	Standard Error of the Percentage	Confidence Intervals	Design Effect
Not As Good?	9	7	71.7%	14.37%	40.4%, 100.0%	0.81
The Same?	96	57	48.1%	11.96%	22.1%, 74.2%	5.44
Better Than Seat Belts?	3,172	1,734	48.3%	3.88%	39.9%, 56.8%	19.16

Limitations

Causality cannot be inferred from this data. For example, we cannot conclude that the use of lower anchors and tether prevents misuse: we know only that lower anchor and tether use is associated with lower misuse rates.

In some cases, observers were unable to code relevant misuse variables. These cases with missing usage data were excluded from analysis. In Greenwell (2015a), the cases with missing data were assumed to be drawn from the same distributions as those with observed data, and missing data was imputed in order to calculate a rate of overall misuse. In the current investigation, incomplete cases were excluded, and multiple misuses were examined in the context of cases with complete data. Under either method, the actual distributions of the missing data cannot be examined.

Caution must be used when interpreting results. The sampling plan was designed to represent the restraint use of children under 9. It was not designed to create a representative sample of racial, ethnic, or linguistic groups. Observers did not collect socioeconomic data, such as family income or education levels. Though results are reported here, interpretation should be made with awareness of these factors.

Sample sizes are small for many of the subgroups. As the subgroup sample size decreases, the confidence we have in our point estimates decreases. The corresponding weighted percentages may become less reliable (Greenwell, 2015a), and conclusions become less advisable.

Conclusions

Multiple misuses were common in car seats, appearing in 23.9 percent of rear-facing infant seats, 21.9 percent of rear-facing convertible seats, and 31.3 percent of forward-facing seats. Only 3.8 percent of booster seats were misused. Each seat type was examined separately to determine the most common misuses and the most common co-occurring misuses.

In rear-facing infant and convertible seats, the most common misuses (excluding those specific to installation method) were the following:

- Child is less than 1 year old and the angle of the seat is less than or equal to 30 degrees (42% of misuse cases).
- Loose installation, where the car seat could be moved more than 2 inches laterally (29% of misuse cases).
- Harness slack over 2 inches (15% of misuse cases).

In forward-facing car seats, the most common misuses were the following:

- Loose installation, where the car seat could be moved more than 2 inches laterally (47% of misuse cases).
- Harness slack over 2 inches (28% of misuse cases).
- One or more harness straps behind the child's arm, back, or leg (15% of misuse cases).

In highback and backless booster seats, the most common misuses were the following:

- Lap belt across child's abdomen and/or ribcage (59% of misuse cases).
- Shoulder belt behind the child's arm or back (24% of misuse cases).

In both rear-facing and forward-facing car seats, harness slack appeared in combination with several other common misuses. In fact, harness slack was observed in combination with other misuses more often than it was observed as the sole misuse. Manufacturers may note this phenomenon and its implications for the development of child restraint devices. CPSTs may find this knowledge useful in the course of their duties.

A given case may have more than one misuse: the presence of one or more misuses categorizes the case as Misuse Present. Categorizing cases relative to the presence of any defined misuse allowed the analysis of demographic characteristics and behaviors that might be related to misuse.

Car seats were more likely to be misused by Hispanic or Latino drivers than non-Hispanic/non-Latino drivers; by Black or African-American drivers more than White drivers or Asian drivers; by drivers of All Other Races more than White drivers or Asian drivers; and by young drivers (under 30) more than middle-age drivers (30 to 50 years old). Outreach efforts should continue to try to reach these groups.

Drivers who were very confident in their use were less likely to have Misuse Present than drivers who were less confident. However, these very confident drivers still had substantial rates of Misuse Present (38.4%) and furthermore might be unlikely to seek out information regarding correct usage of child restraints.

Car seats that were installed using seat belts were more likely to have Misuse Present than car seats installed using lower anchors and tethers.

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This research note and other general information on highway traffic safety may be accessed at: <https://crashstats.nhtsa.dot.gov/>.



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