**Supplemental Materials for** ***Age-based variability in the association between restraint use and injury type and severity in multi-occupant crashes***

**SUMMARY**

This document contains supplemental tables and analyses for the manuscript *Age-based variability in the association between restraint use and injury type and severity in multi-occupant crashes*. First, we provide summary statistics about linkage probabilities for each data set (**Table S1**). Next, we assess the potential for unmeasured confounding to impact our study conclusions using the E-value of Vanderweele and Ding [1] (**Table S2**).

**LINKAGE PROBABILITIES**

**Table S1** contains summary statistics about the linkage probabilities in the site- and outcome-specific data sets. Kentucky and Utah exhibited similar patterns, in that the great majority (>75%) of observations had linkage probabilities at or very near 1.00. On the other hand, a greater proportion of Ohio and Maryland data had probabilities that deviated somewhat from 1.00. Most of the data consisted of high-probability links.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Percentile | Ohio | | | Kentucky | | | Utah | | | Maryland | | |
| Fatal | MAIS3+ | Torso | Fatal | MAIS3+ | Torso | Fatal | MAIS3+ | Torso | Fatal | MAIS3+ | Torso |
| 100th (Max) | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 75th | 0.999 | 0.999 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 50th | 0.998 | 0.998 | 0.998 | 1.000 | 1.000 | 0.999 | 1.000 | 1.000 | 1.000 | 0.992 | 0.993 | 0.991 |
| 25th | 0.920 | 0.923 | 0.971 | 0.997 | 0.997 | 0.994 | 1.000 | 1.000 | 1.000 | 0.857 | 0.849 | 0.824 |
| 0 (Min) | 0.003 | 0.003 | 0.002 | 0.029 | 0.012 | 0.004 | 0.067 | 0.039 | 0.041 | 0.001 | 0.001 | 0.001 |

**Table S1:** Summary statistics (minimum, maximum, median, and first and third quartiles) of linkage probabilities for each data set used in the study.

**ASSESSING UNMEASURED CONFOUNDING:**

This section contains information about potential unmeasured confounding and how failure to control for unmeasured variables could have impacted our study conclusions. An example of such of variable is seating position relative to impact location, which we could not include in our model due to pertinent information not existing in the CODES data. For seating position relative to impact location to confound the association between belt use and injury, it would have to be associated with both injury and seat belt use, after controlling for all matching and regression variables. More rigorous definitions of confounding, especially how it pertains to causal relationships between the variables, is available in Greenland and Morgenstern (2001) [2].

As we have already somewhat controlled for seating position (driver, front passenger, rear passenger) in the model, and matched on vehicle impact location, confounding could occur if passengers’ location on the right of left side of the vehicle relative to the impact was associated with their seat belt use or non-use. For example, perhaps front passengers are more to be unbelted than drivers, and are more likely to be on the near side of a crash due to driver blind spots. To estimate how robust our study conclusions are against unmeasured confounding, we performed a sensitivity analysis using the E-value of VanderWeele and Ding [1]. The E-value is the minimum strength of association (measured via risk ratio) between an unmeasured confounder (seating position relative to impact) and both exposure (seat belt) and outcome (injury) needed to explain away the association between belt-use and injury, i.e. for the relative risk to be equal to one. We also include the lower limit of the E-value, which in practical terms is the minimum strength of association between an unmeasured confounder and both exposure and outcome for our study conclusions to change, i.e. for the confidence interval to contain one.

Results pertaining to the E-value are presented in Table R1 below and are included in a supplemental table. For fatal injuries, the lower limits of the E-value range from 2.97 (oldest age group) to 5.91 (youngest age group). Hence, seating position relative to impact location would have to be associated with belt use at a magnitude of 2.97 or greater to impact our conclusions. We believe that this is not plausible. For MAIS3+ injuries, in which the E-value lower limit was as low as 1.50 for the oldest age group, which in many epidemiological applications would lead us to conclude that there was moderate concern that unmeasured confounding could have impacted the study conclusions. However, for our application, we find it unlikely that seating position relative to impact location and belt use would exhibit an association of this magnitude (e.g., being on the near side of an impact is associated with 50% higher risk of being unbelted).

The smallest E-value was for torso injury for those aged 50-64 (E-value = 1.53; lower limit = 1.11). While this value suggests sensitivity to unmeasured confounding, the fact that this association was “statistically significant” (likely not practically so), was not paramount to our study conclusions. Rather, the critical finding with respect to torso injury was that belt protection attenuates with age. For both MAIS3+ and torso injury, we believe that our conclusions about associations attenuating with age are robust to unmeasured confounding. To change these conclusions, an unmeasured confounder would have to associate with belt use, and do so differentially for certain age groups. We expect that this is not the case.

We have presented these results with a focus on a specific potential confounder, seating position relative to impact location, whose exclusion from the study was a limitation. While we believe it is unlikely that confounding from this variable would have impacted our results, it does not mean that our results are similarly robust to *any* unmeasured confounding.

We did not include E-values for null results.

|  |  |  |  |
| --- | --- | --- | --- |
| Outcome | Age Group | Adjusted RR: belted vs. unbelted | E-value (Lower limit) |
| Fatal Injury | All | 0.26 (0.23, 0.30) | 7.15 (6.12) |
| 16-30 | 0.26 (0.21, 0.31) | 7.15 (5.91) |
| 31-49 | 0.25 (0.19, 0.31) | 7.46 (5.91) |
| 50-64 | 0.27 (0.19, 0.37) | 6.87 (4.85) |
| 65-74 | 0.28 (0.17, 0.44) | 6.60 (3.97) |
| 75+ | 0.36 (0.24, 0.56) | 5.00 (2.97) |
| MAIS3+\* | All | 0.36 (0.33, 0.39) | 5.00 (4.57) |
| 16-30 | 0.34 (0.31, 0.39) | 5.33 (4.57) |
| 31-49 | 0.36 (0.31, 0.42) | 5.00 (4.19) |
| 50-64 | 0.37 (0.31, 0.45) | 4.85 (3.87) |
| 65-74 | 0.45 (0.33, 0.61) | 3.87 (2.66) |
| 75+ | 0.64 (0.47, 0.89) | 2.50 (1.50) |
| Torso Injury | All | 0.84 (0.80, 0.89) | 1.67 (1.50) |
| 16-30 | 0.81 (0.76, 0.87) | 1.77 (1.56) |
| 31-49 | 0.81 (0.75, 0.88) | 1.77 (1.53) |
| 50-64 | 0.88 (0.79, 0.99) | 1.53 (1.11) |
| 65-74 | 0.94 (0.76, 1.17) | NA |
| 75+ | 1.08 (0.85, 1.37) | NA |

**Table S2:** Adjusted relative risks of fatal, MAIS3+, and torso injury associated with belt use for the full samples and broken up by age groups. E-values are provided in the right-most column, along with lower limits (the upper limit is infinity). Asterisks denote that there is age-based variability in the association between restraint use and the outcome.

**REFERENCES**

1. VanderWeele, T.J. and P. Ding, *Sensitivity Analysis in Observational Research: Introducing the E-Value.* Annals of Internal Medicine, 2017. **167**(4): p. 268-274.

2. Greenland, S. and H. Morgenstern, *Confounding in Health Research.* Annual Review of Public Health, 2001. **22**(1): p. 189-212.