INTRODUCTION
Booster seats are recommended for children who have outgrown a forward-facing child restraint but do not yet properly fit an adult seat belt. All jurisdictions in Canada and the US require child restraints for infants and toddlers, but requirements for booster seats are not similarly universal.

Our goal is to compile the available frontal crash test data for booster seats and to examine the effectiveness of booster seats in reducing severe to catastrophic neck injury risk in moderate and high-speed collisions. As a first step, we are focusing on the peak tensile force that develops in the upper neck.

METHODS
We extracted crash test data for 6- and 10-year-old dummies exposed to frontal collisions in either vehicle or sled tests from the National Highway Traffic Safety Administration (NHTSA) test database [1] (n=98) and 9 previously published studies [2-10] (n=68). These data are a preliminary sample. After culling offset frontal tests and other special tests, we were left with 94 tests of the 6-year-old dummy, comprised of 62 tests with high-back booster seats (HBB), 20 tests with low-back booster seats (LBB), and 12 tests with no booster (None). All tests used a lap and torso seat belt and varied in speed change from 24 to 64 km/h. There were 21 tests of the 10-year-old dummy, comprised of 17 HBB tests and only 4 tests with no booster. There were no LBB tests of the 10-year-old dummy. The speed change for the 10-year-old dummy tests varied from 43 to 62 km/h. The speed change of vehicle-to-barrier tests was calculated assuming a coefficient of restitution of 0.10.

Separate comparisons of the 6- and 10-year-old dummy data were performed using an analysis of covariance (ANCOVA) wherein the categorical variable was booster seat type (HBB, LBB, None) and the co-variant was speed change. Significance was set to a level of p<0.05.

RESULTS
Analysis of the 6-year-old dummy data showed that peak neck tension varied with speed change (p<0.0001), but not with booster seat type (p=0.092) (Figure 1). Peak neck tension remained below the injury assessment reference value (IARV) of 1890N [11], which is associated with a 3% chance of injury, for speed changes less than about 40 km/h.

Analysis of the 10-year-old dummy data was based on limited no-booster data, but nonetheless showed a significant decrease in peak neck tension for the HBB compared to no booster seat (p=0.0002). Peak neck tension did not vary with speed change in the 10-year-old data—possibly because of the small range of speed changes—and again appeared to exceed the IARV of 2290N [11] at about 40 km/h.

DISCUSSION & CONCLUSIONS
Booster seats appear to benefit 10-year-old children more than 6-year-old children; however, a possible lack of biofidelity with the 6-year-old dummy at high speeds may explain this finding [4,5,9]. Without the HBB data above 4900N (circled in Figure 1), neck tension was about 700N lower in a HBB and LBB than in no booster (p=0.0004). More work is needed to resolve this biofidelity issue and better understand how much booster seats benefit 6-year-old children.

REFERENCES