A Statistical Analysis of Driver Knee Locations Relative to Vehicle, Occupant and Belt Fit Variables

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I. INTRODUCTION

Recent analyses of driver belt fit have shown a strong influence of body mass index (BMI), defined by body mass in kilograms divided by stature in meters squared [1]. In a laboratory study, the average location of the lap belt relative to the anterior-superior iliac spine (ASIS) landmarks of the pelvis was 51 mm further forward for individuals with BMI of 35 kg/m^2 than for those with BMI of 25 kg/m^2. Individuals with BMI of 25 kg/m^2 experienced belt locations about twice as far from the pelvic bone as was observed with the Hybrid-III midsize-male ATD. These findings suggest that load sharing between the lap belt and knee bolster in a frontal impact may be different for drivers and ATDs. A key consideration is the initial position of the driver's knees relative to the bolster. Although several studies of knee location have been published (summarized in [2]), no statistical model describing the distribution of driver knee locations across vehicle package layouts is available. Moreover, the relationship between lap belt fit and driver knee location relative to the vehicle is unknown.

II. METHODS

Knee locations and belt fit were quantified using laboratory data from 97 men and women with a wide range of stature, BMI and age measured in 9 vehicle package configurations as part of a larger study [1]. The location of the right infrapatella ("knee") landmark was quantified relative to the accelerator pedal reference point (PRP, fore-aft coordinate, X), driver centerline (Y coordinate) and accelerator heel point (AHP, vertical coordinate, Z). A measure of the fore-aft lap belt fit relative to the left ASIS was calculated using the methods in Reed et al. [1]. A linear regression analysis was conducted to quantify the location of the knee as a function of vehicle package layout and driver attributes. Potential predictors were fore-aft steering wheel location relative to the accelerator pedal (SAE L6), vertical steering wheel location relative to the pedals (SAE H17) and driver stature (mm), BMI and age. The association between knee location and lap belt fit was also examined.

III. INITIAL FINDINGS

Equations 1-3 present regression models. All reported effects are significant with $p<0.001$. Higher steering wheel locations were associated with more-forward and higher knee locations. More-rearward steering wheel positions were associated with lower and more-rearward knee locations. Taller drivers' knees were more rearward, higher and farther from driver centerline, on average. BMI, age and lap belt fit were not significantly associated with knee location.

$$\text{KneeX re PRP (mm)} = 172 - 0.377\,\text{H17} + 0.378\,\text{L6} + 0.156\,\text{Stature},\ R^2_{adj} = 0.76,\ \text{RMSE} = 26.2\text{ mm} \quad (1)$$

$$\text{KneeY re Driver Centerline (mm)} = -201 + 0.217\,\text{Stature},\ R^2_{adj} = 0.27,\ \text{RMSE} = 38.7\text{ mm} \quad (2)$$

$$\text{KneeZ re AHP (mm)} = -372 + 0.671\,\text{H17} - 0.217\,\text{L6} + 0.272\,\text{Stature},\ R^2_{adj} = 0.82,\ \text{RMSE} = 27.2\text{ mm} \quad (3)$$

IV. DISCUSSION

The results indicate that taller drivers experience a greater initial gap between the knee and knee bolster, on average. Across 350 mm of driver stature (roughly 5th-percentile female to 95th-percentile male), the difference in mean fore-aft knee location relative to the bolster is 55 mm. The lack of association between knee location and BMI or lap belt fit means that, in frontal impacts, the pelvis-lap belt relationship is likely to affect knee excursion across the knee location range.

References

[1] Reed MP, Stapp Journal, 2013 [2] Atkinson P, SAE, 200 2009-01-0390.

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