Effects of Driver Characteristics on Seat Belt Fit

Matthew P. Reed
Sheila M. Ebert
UMTRI

Jason J. Hallman
Toyota Technical Center USA
Crash Injury Data

Older occupants are at greater risk in crashes
**Crash Injury Data**

**Obese** occupants are at greater risk in crashes

*M*Body Mass Index (BMI) = \( \frac{\text{Body Mass (kg)}}{[\text{Stature (m)}]^2} \)

Ridella et al. 2013 IRCOBI
Body Shape Data

Human body shape varies widely

Hybrid-III ATD

Laser Scan Data
Research Question

How is driver belt fit affected by age, gender, stature, and BMI?
### Methods

Men and women with a wide range of age and body size

<table>
<thead>
<tr>
<th>Measure</th>
<th>Men (N=46)</th>
<th>Women (N=51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stature (mm)</td>
<td>1759 (85)</td>
<td>1601 (67)</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>87.9 (17)</td>
<td>69.9 (16)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>28.4 (4.9)</td>
<td>27.3 (5.7)</td>
</tr>
<tr>
<td>Erect Sitting Height (mm)</td>
<td>913 (40)</td>
<td>845 (42)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>58 (19)</td>
<td>59 (20)</td>
</tr>
</tbody>
</table>

![Graph showing relationship between stature and weight]  
![Graph showing relationship between stature and age]
Methods

Driver mockup with 5 sets of belt anchorage locations

**Midsize Sedan Package**

L6 = 550 mm
H30 = 270 mm

**Lap Belt Angle:**

- 30°
- 52°
- 75°

**5 Belt Conditions:**

3 lap belt angles with midrange D-ring
2 D-ring angles at midrange lap angle

**FMVSS 210 Definition**
Methods

Landmarks measured with FARO Arm coordinate digitizer
Methods

Additional body measurements in hardseat and laser scanner
Methods

Belt fit measures

Shoulder Belt:
Inboard edge of belt at height of top of sternum relative to midline

Lap Belt:
Top of belt at lateral position of ASIS wrt ASIS
Methods

Pelvis flesh margin estimates

An adjustment was made to correct for the effects of adiposity on the distance between the surface landmark and the bone.
Results

Lap Belt Fit

\[ X = -64 \]

\[ Z = 61 \]

Large symbols = obese
Male +   Female o

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Results

Lap Belt Fit

T060
80 years
35 BMI
1663 mm
-99, 117

T044
24 years
29 BMI
1621 mm
-53, 83

T053
72 years
24 BMI
1697 mm
-64, 51

T029
28 years
20 BMI
1779 mm
-5, -1

Large symbols = obese
Male +    Female o

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Results

Lap Belt Fit

\[
\text{LapBelt X (mm)} = 156 + 0.297 \text{ ELBA}
\]

\[-0.30 \text{ Age}
\]

\[-5.12 \text{ BMI}
\]

\[-0.04 \text{ Stature},
\]

\[R^2_{\text{adj}} = 0.57, \text{ RMSE} = 25.8\]

Effective Lap Belt Angle (ELBA, deg): LBA taking into account driver-selected seat position

\[
\text{LapBeltZ (mm)} = -70.1 + 4.7 \text{ BMI}, R^2 = 0.52, \text{ RMSE} = 22.9
\]

All effects and full model $p<0.01$
Results

Lap Belt Fit

BMI dominates effects of age and gender

belt further forward wrt pelvis
Results

Shoulder Belt Fit

Shoulder Belt Score (mm) = 338 – 22.3 YZAngle – 0.284 Stature + 0.0189 YZAngle*Stature, $R^2_{adj} = 0.60$, RMSE = 24.4

No significant effects of gender, BMI, or age
Results

Comparison of Factor Effects

Over relevant population ranges:
Stature (1500-1850 mm), Age (20-80 years), BMI (20 to 40 kg/m²),
Results

Lap Belt Fit

Mean belt locations with respect to ASIS at lateral location of ASIS (not occupant centerline)

Midsize male pelvis in mean posture
Results

Lap Belt Fit

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Results

Pelvis Locations and Abdomen Contours

Laser scans obtained in slightly different posture
Alignment based on measured human pelvis position and orientation
Results

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Discussion

Many people *could* place the lap belt in a lower location, closer to the pelvis

Could they be educated to position the belt better?
Conclusions

**Obesity** has a strong effect on lap belt routing: On average, an obese individual places the belt fully above the pelvis and an average of 61 mm forward of the ASIS.

**Age** has a smaller effect on belt routing than BMI across the population range

**Gender** did not have a significant effect after accounting for stature

**Lap belt anchorage locations** have much smaller effects than driver factors.

The effects of BMI on lap belt fit were not significantly different for **short/tall, men/women, old/young**

Shoulder belt fit is strongly affected by **D-ring location** and body size
Implications and Future Work

Current ATDs with standard usage procedures are not capable of representing the **large belt-skeleton offset and sub-optimal belt routing** observed in this study, so current testing does not evaluate the load-sharing situations encountered by most occupants, particularly those who are obese.
Better Protection for All
Acknowledgments

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http://www.toyota.com/csric/