Developed to address an inconsistency between

- Accident investigation: a restraining system with a belt load limitation at 4kN and an AB is much more efficient than a belt with a load limitation at 6kN.
- Crash tests: the deflections measured on an HIII were higher with the 4kN+AB system compared to the 6kN.

- The increase of deflection due to the airbag loading was higher than the decrease of deflection associated to the decrease of belt load.
- This would not have been an issue if the risks associated to the deflection were the same for the belt and the airbag.
Equivalent Deflection (Deq)

Kent et al. (2003)
Equivalent Deflection (Deq)

\[ \sigma_{\text{max}} = M_f \frac{\max(1/v)}{s} + F_c / s \]
\[ M_f \max = F_z \frac{l}{2} \]
\[ \sigma_{\text{max}} = F_z \frac{l}{2} \cdot \frac{(1/v) + F_x}{s} \]
\[ \sigma_{\text{max}} = \alpha(F_z / F_{z\text{critical}} + F_x / F_{x\text{critical}}) \]

If \( F_{z\text{critical}} \neq F_{x\text{critical}} \) then
\[ \sigma_{\text{max}} \neq \beta F_{\text{tot}} \]
Equivalent Deflection (Deq)

% risk

Hybrid III deflection

\[ \text{d localized} \]

\[ \text{d distributed} \]

evaluated separately

subtracting the localized deflection from the total deflection

combination (d localized, d distributed)
Equivalent Deflection (Deq)

combination (d localized, d distributed)?

Iso-risk curves

- Cumulative risks
- Separated risks
- Linked risks

quadratic combination form of localized and distributed deflections
Equivalent Deflection ($Deq$)

\[ F_{\text{shoulder}}(t) = k \cdot d_1(t) + c \cdot v_1(t) \]

\[ d_{\text{localized}}(t) = d_{\text{total}}(t) - d_{\text{distributed}}(t) \]
Equivalent Deflection (Deq)

\[
d_{\text{equivalent}}(t)^2 = d_{\text{localized}}(t)^2 + (f_n * d_{\text{distributed}}(t))^2
\]
Equivalent Deflection (Deq)

- Equivalent deflection criterion was evaluated against 48 paired HIII and PMHS tests.
- An injury risk curve was proposed based on accident investigations.
### Equivalent Deflection (Deq)

- Probability of AIS3+ risk for 45 years

<table>
<thead>
<tr>
<th></th>
<th>Current laboratory study</th>
<th>Accidentological study</th>
</tr>
</thead>
</table>
| **Equivalent deflection criterion predicts risk consistent with accidentological study results** | ![Image](image)

<table>
<thead>
<tr>
<th>Belt Configuration</th>
<th>Sternal deflection criterion</th>
<th>Equivalent deflection criterion</th>
<th>Shoulder belt criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 kN belt + airbag</td>
<td>27 %</td>
<td>1 %</td>
<td>1 %</td>
</tr>
<tr>
<td>6 kN belt</td>
<td>13 %</td>
<td>11 %</td>
<td>18 %</td>
</tr>
</tbody>
</table>

- Foret-Bruno et al. (2001)
Equivalent Deflection Criterion improves the injury prediction for combined loadings

- better than the sternal deflection criterion for the data sample used

- using Hybrid III available measurements
  - application in short term
  - potential improvement of its reliability with several thoracic deflection measurements

- predicting risk consistent with accidentological study results
  - better protection with 4 kN load-limiting belt plus airbag than with 6 kN load-limiting belt
Equivalent Deflection (Deq)

![Graph showing the relationship between Equivalent Deflection (Deq) and Risk rodpot (%). The graph includes data points for Drivers and Passengers, with an iso-risk line.](Image)
Equivalent Deflection (Deq)

Risk (%)

Risk Deq
Risk rodpot
Equivalent Deflection (Deq)
Equivalent Deflection (Deq)

Further analysis

- Check hypothesis with updated Human Body Model
- Check coefficients with updated data/methods
  - Risque curves from PMHS Airbag loading
  - Relative risk using HBM
- Use of THMPHR to better evaluate the real deflection and therefore the accuracy of the Equivalent deflection.
  - The maximum deflection itself does not discriminate belt/Airbag loading
  - The THMPHR is complementary to the Equivalent deflection
Equivalent Deflection (Deq)

Variation of deflection versus SRP - THMPHR

IR-TRACC Position

Deflection

- SRP 400daN
- SRP 600daN

LR, LL, UR, UL

Variation of deflection versus SRP - THMPHR

Deflection

- SRP 400daN
- SRP 600daN

LR, LL, UR, UL
Equivalent Deflection (Deq)

Thorax AIS3+

Risk

Deflection (mm)

Belt 45 y/o
Belt 65 y/o
Distributed 45 y/o
Distributed 65 y/o
Equivalent Deflection (Deq)

Thorax AIS3+

- Belt 45 y/o
- Belt 65 y/o
- Distributed 45 y/o
- Distributed 65 y/o

Deflection (mm) vs. Risk