Abdominal Twin Pressure Sensors for the Assessment of Abdominal Injuries in Q Dummies: Status

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Outline

- Context
- Development status
  - Sensor and dummy availability
  - Summary of previous tests and behavior
  - Candidate Injury criteria and risk curves
- Perspectives
  - Remaining needs, shortcomings & integration
  - Importance and need for test procedure
- References

Context

- Abdominal injuries commonly injured in (older) children
  - At higher risk than adults (CASPER, Javouhey et al. 2006, and others)
- Configuration: mainly belt loading in frontal impact
  - Submarining, pre-submarining (misuse, relaxed posture, etc), submarining and jackknifing (e.g. Arbogast et al. 2007)
  - Phenomenon can be on/off = loading/no loading
  - Includes no CRS or CRS with or without evident misuse (CASPER, Beillas et al. 2012)
- Aims of protection strategy: move at least some injured children to the non/less injured category
  - Different tools could address the problem incl. ergonomics, education and of course better CRS and cars
- Here: Evaluation of CRS performance by impact testing. Requires:

  1) Instrumented dummy to evaluate risk/loading to the abdomen

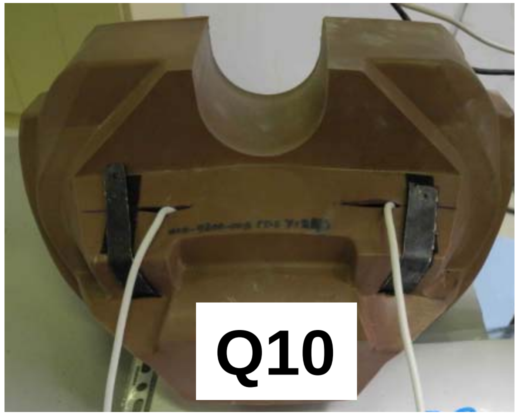
  2) Test procedure, representing a situation where children are injured (abdomen loading high on dummy). Better CRS reduce the load…

1) Abdominal instrumentation: Abdominal Pressure Twin Sensors (APTS) V2

- Child: V1; <u>CASPER: V2</u>
- Soft cylindrical bladder filled with oil, subminiature pressure sensor in cap
- Implanted in dummy abdominal block
  - Q3 and Q6, Q10: D=50mm, L=135mm
  - Q1.5 (design ongoing: D=35mm, L=100mm)

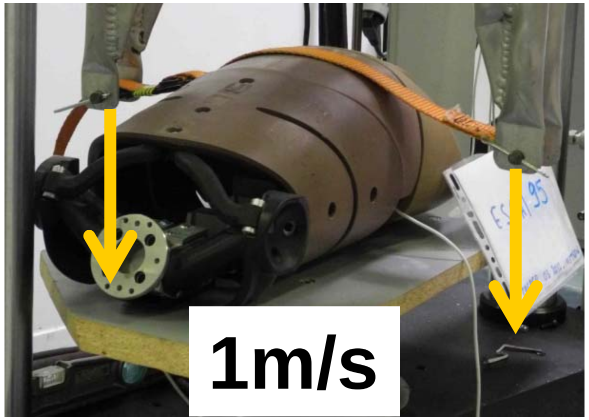
1) APTS V2: abdomen integration

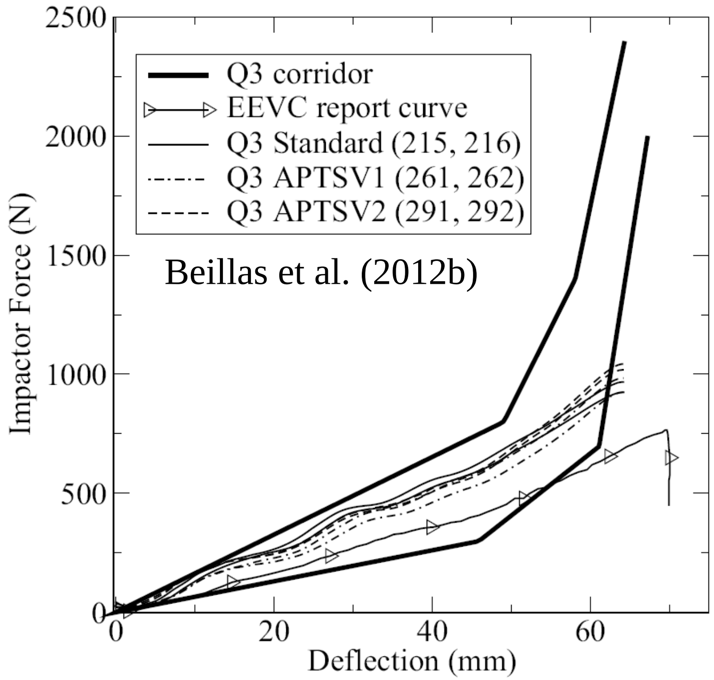
- holes drilled in full abdomen (abdomen held in plaster)
  - Limitations: friction? Tolerance? → discussions with Humanetics for integration in mold

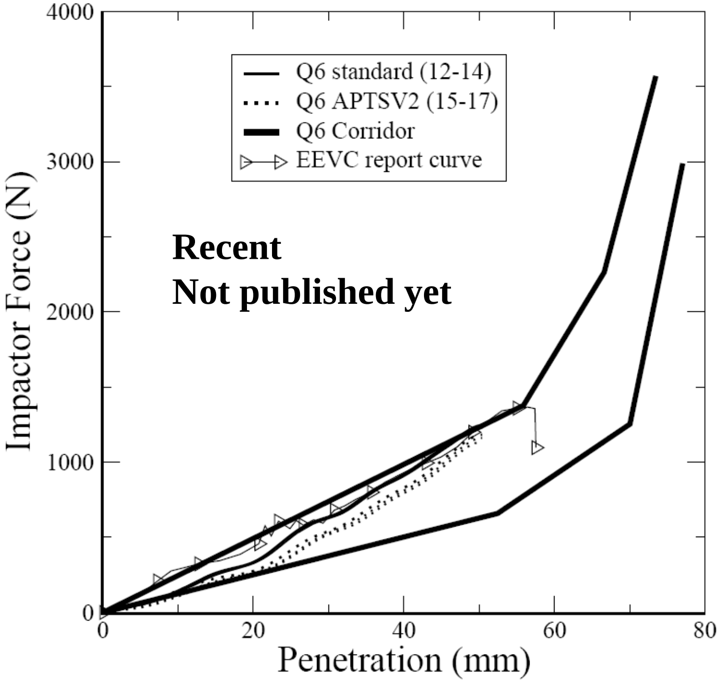


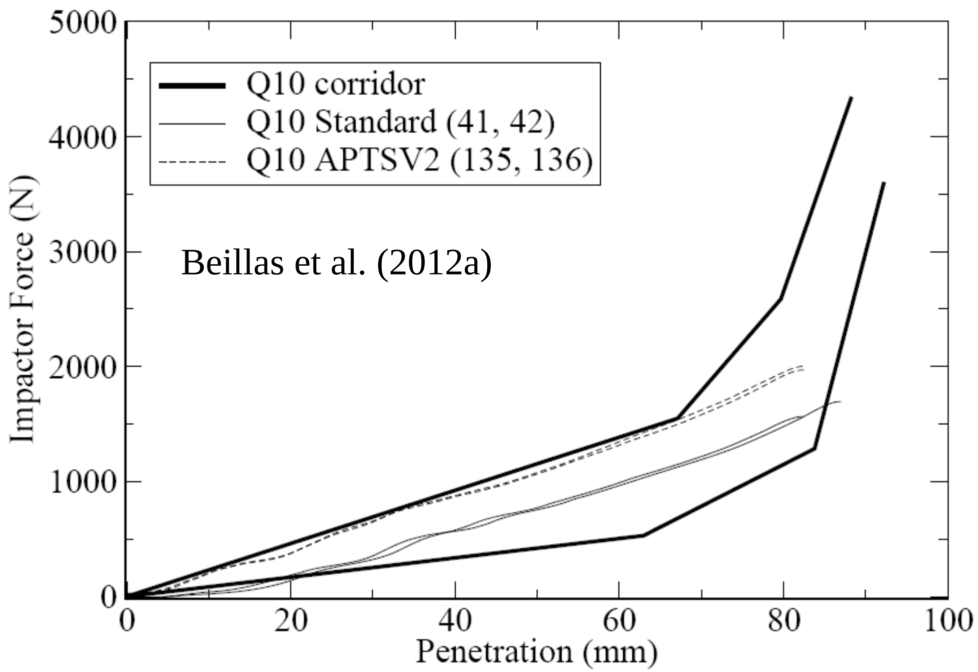
- Attachment: Velcros used at the bottom to prevent the upward migration of the sensors
- Friction: use of baby powder → better control (not requiring to maintenance) would be better. Sock?

Abdominal compression with belt: Mid abdomen, 1m/s, (biofidelity Corridor conditions)



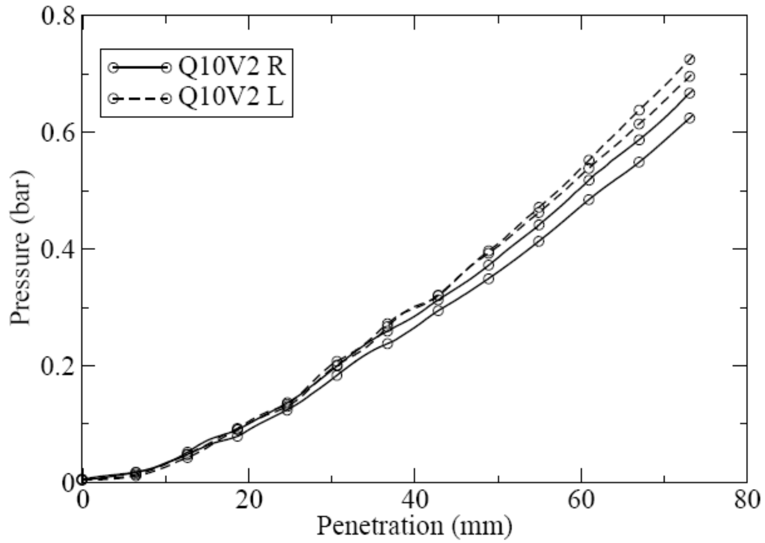




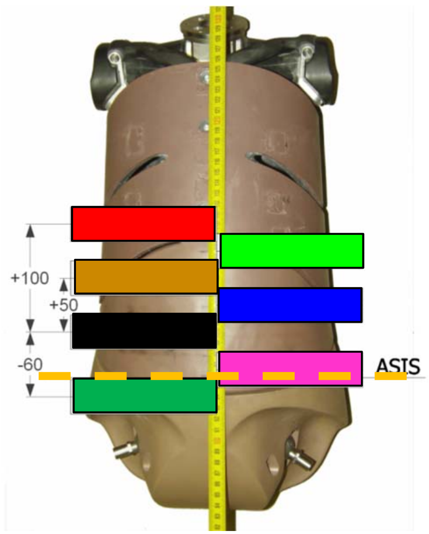


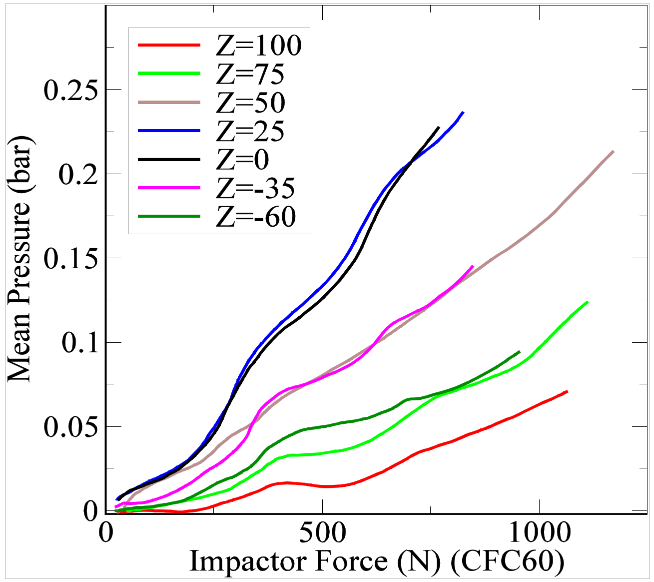
Q10 (Beillas et al., 2012a)

Pressure response: mostly linear against penetration or force (midabdo, 1m/s, belt loading)



Pressure response (1m/s, belt loading): sensitivity is reduced towards pelvis and thorax





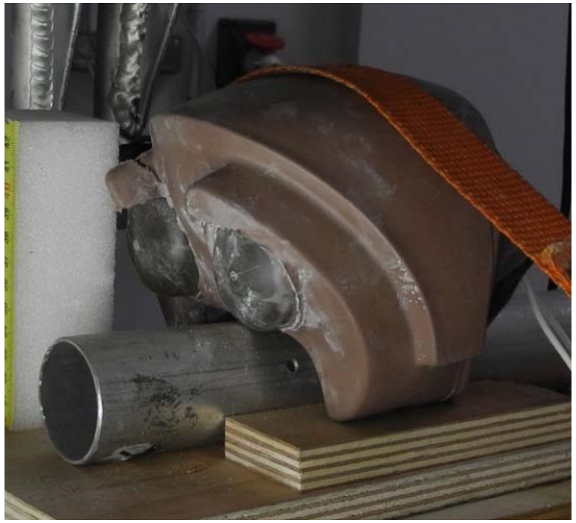
Similar results for Q3 (Beillas et al., 2012b) and Q6 (not published yet)

Limitations: Only one abdomen/sensor pair for each dummy

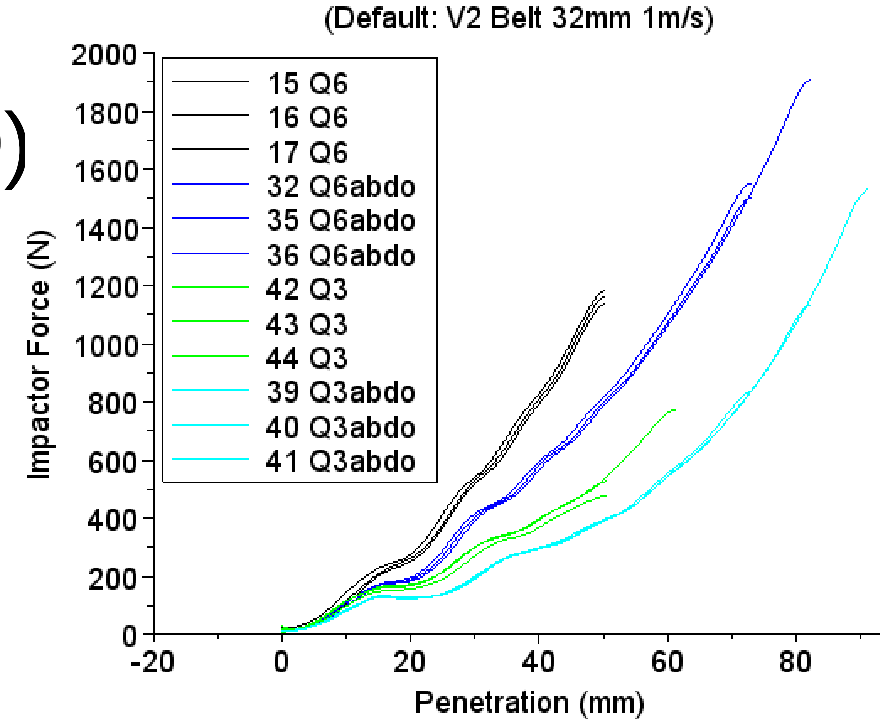
Pressure levels are relatively low

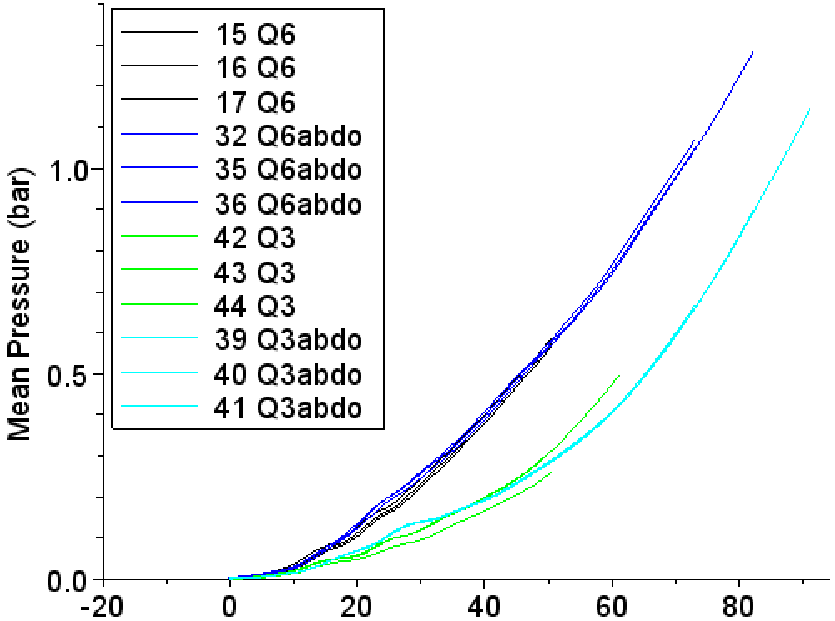
Isolated abdomen in compression (Q3, Q6, Q10)

- Objective: simplified test that could be used for calibration/certification…
- Belt, bars, etc
- E.g. Q3/Q6: Less force out than in dummy but pressure vs. penetration not affected

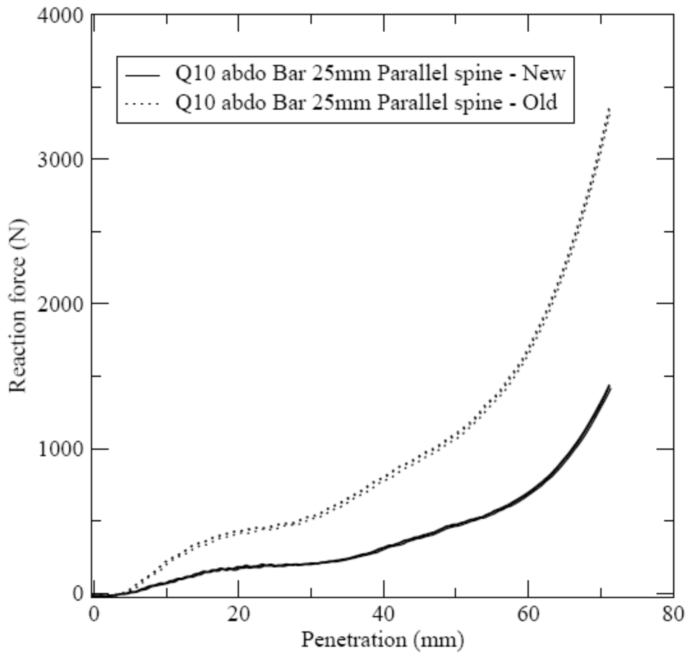


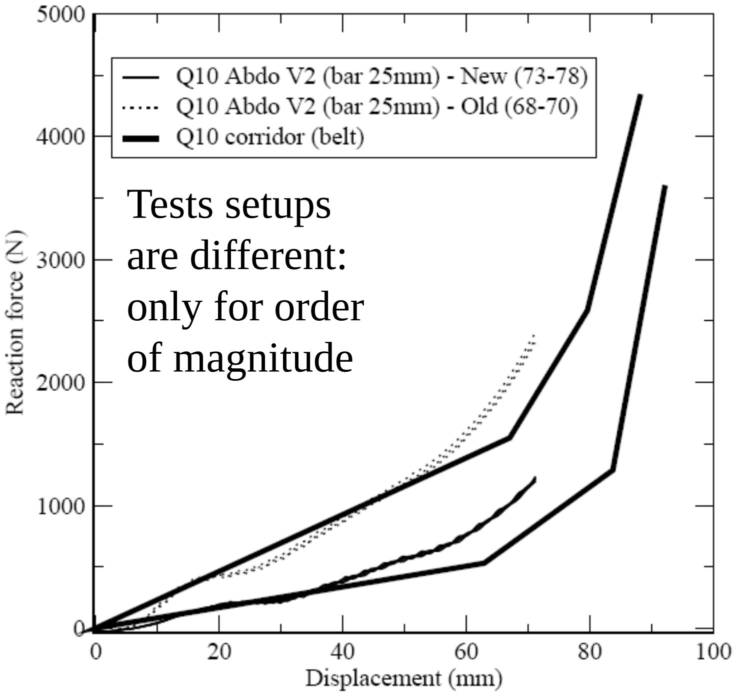
Q3

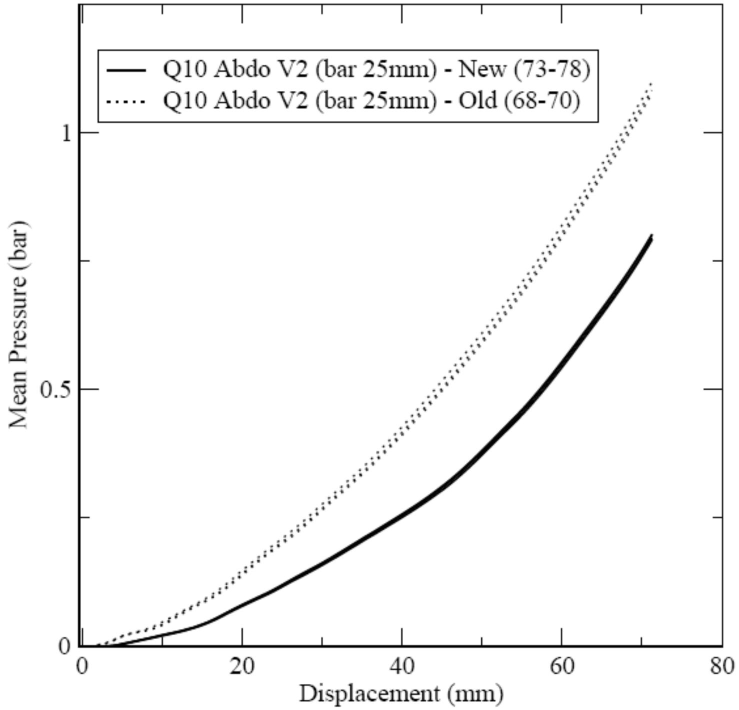




e.g. Q10 tests: two abdomens
- Old (1410g drilled)
- New (1050g drilled)

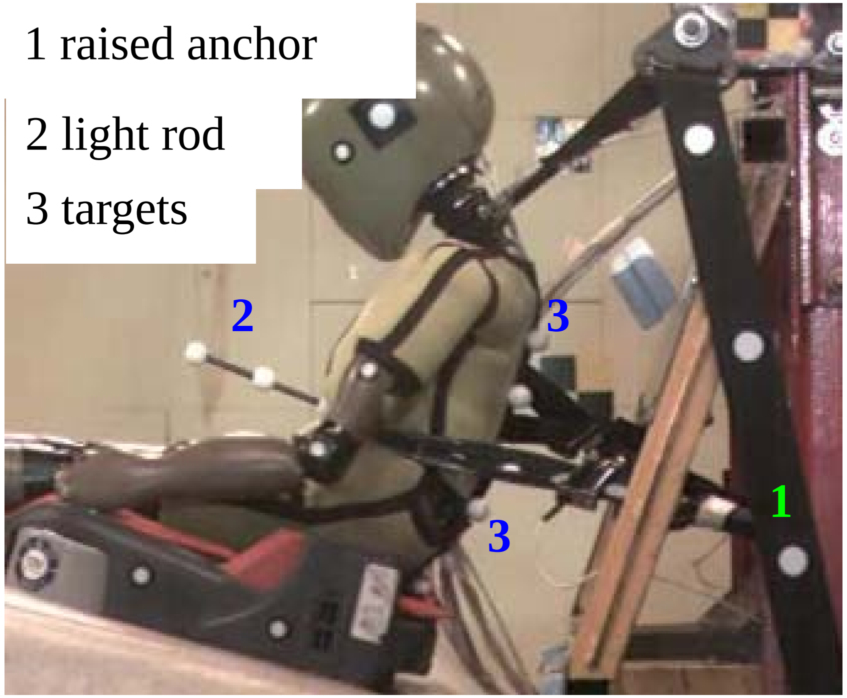


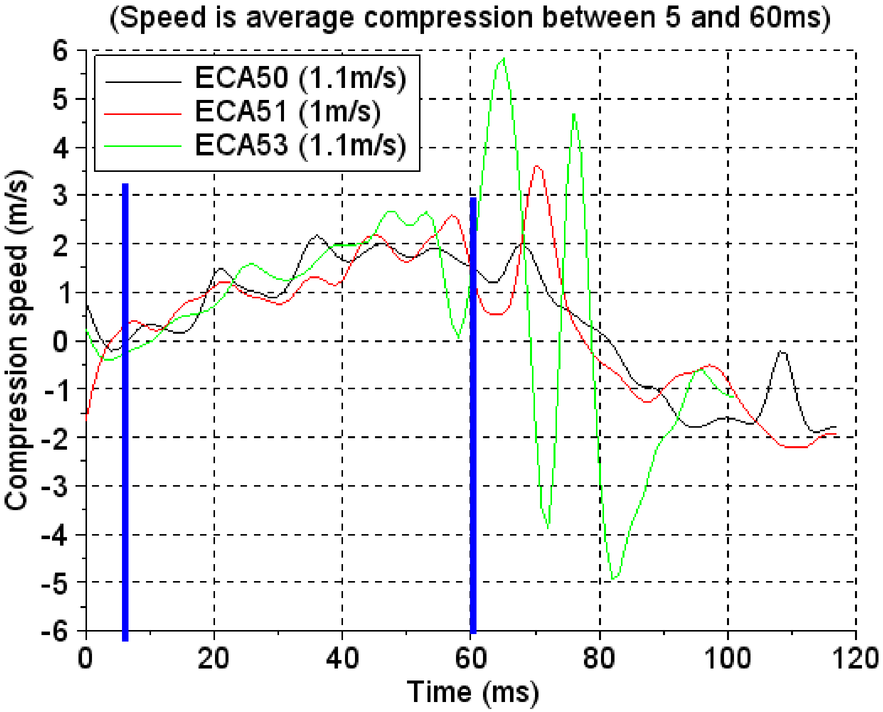




Comparison with sled test conditions

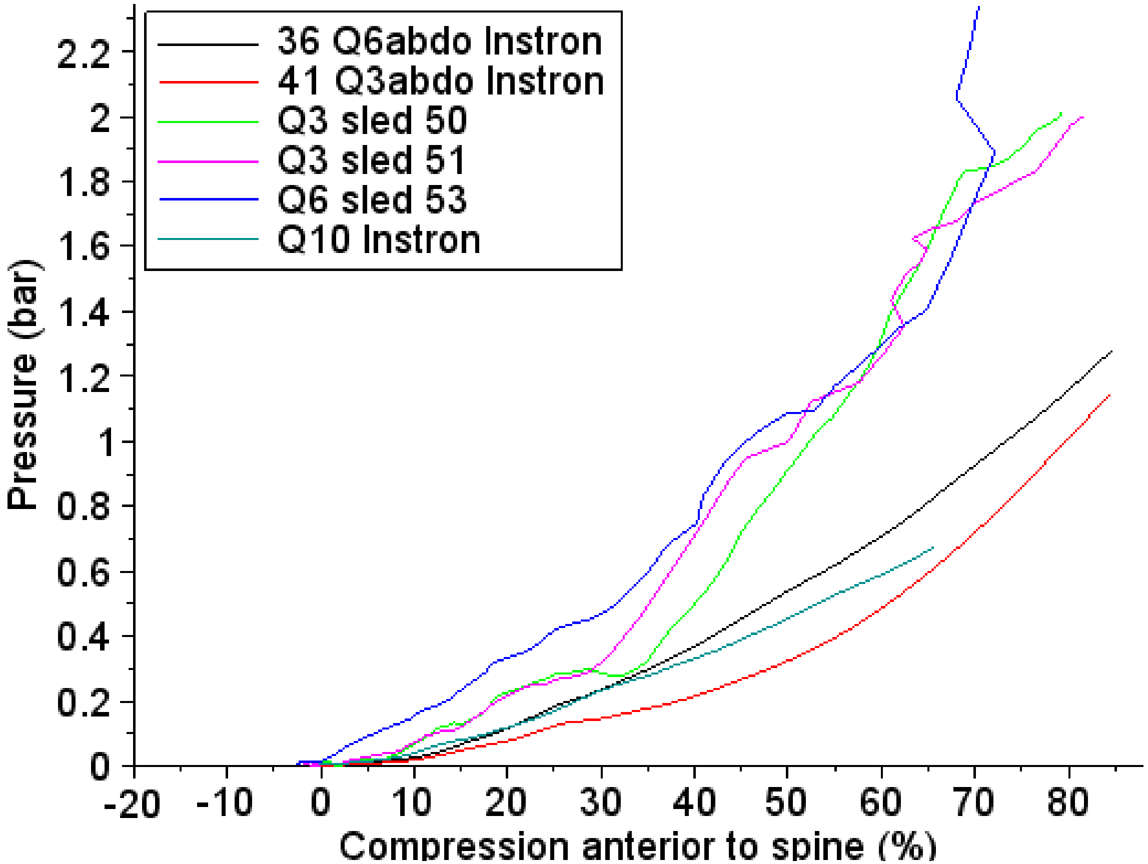
- Q3 and Q6 abdo compression obtained by tracking (n=3)
  - Hard stop reached on one test…
- Belt load projected based on angle to compute force
- Velocity: around 1m/s (average).

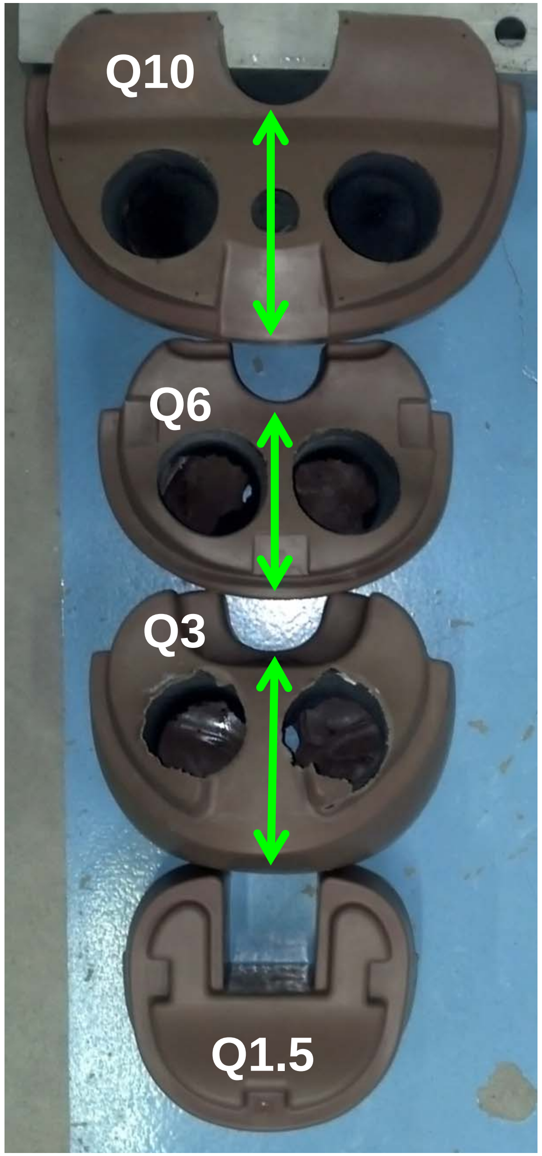




Compressive response: Comparison between dummies and configurations

- Normalization? → compression in front of spine
  - Used for human models (Beillas & Berthet, 2011)





Compressive response: conclusions

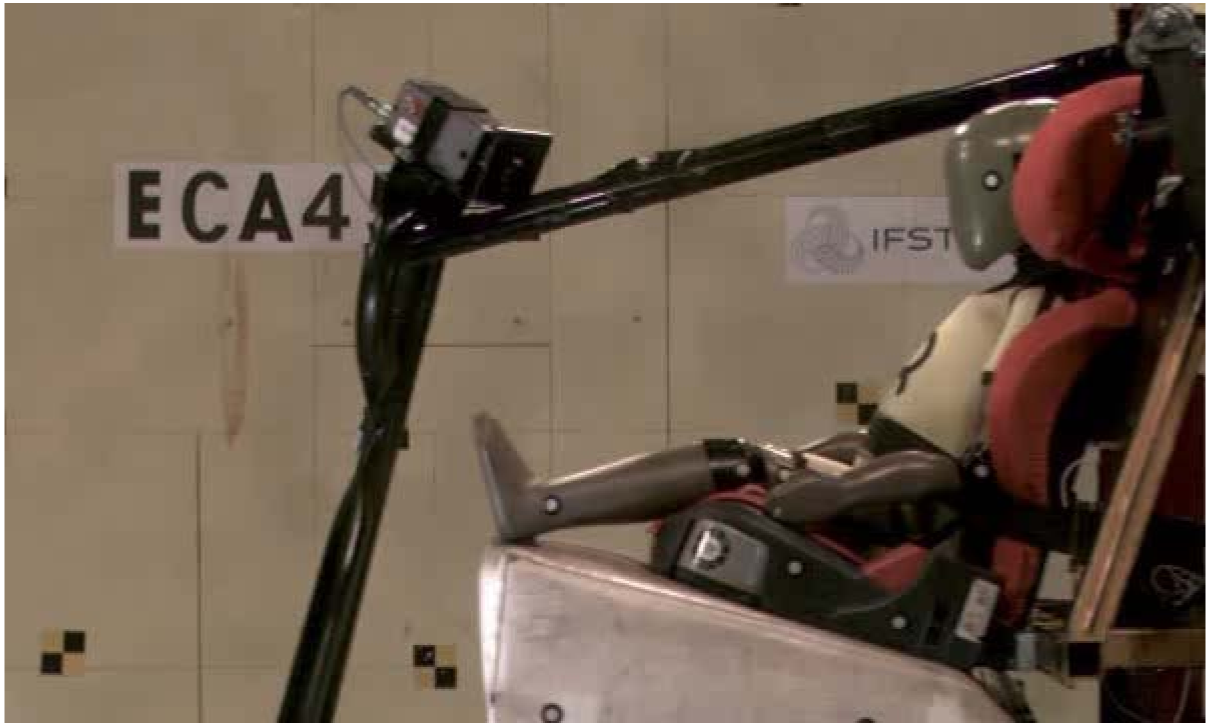
- APTS V2 effects:
  - Q3, Q6: response unaffected; Q10: stiffens
  - Corridors: Q3, Q6: ok. Q10: which abdomen?
- Pressure seems more related to compression/penetration than force (which is dependent on load path…)
  - Could be used to transfer criteria between dummies
- Seems possible to use isolated abdomen with sensors to characterize response + calibration
  - Pressure reached over 1bar
  - Exact setup to select: (probably 3 levels: pressure cell in pressure tank, isolated bladder, bladders in abdomen)

Sled testing

- Numerous sled tests conducted with APTS V2:
  - Q3: Ifsttar, TUB, Dorel, TRL, …, various positions and CRS
  - Q6: Ifsttar
  - Q10: Dorel (Beillas et al., 2012a), JAMA members, TRL
  - Planned: TUB (Q3), TME (Q6), Others (Q10), TRL, …
  - Reconstructions (Q3 or Q6): Ifsttar, TUB, Fiat, Idiada, LAB…
  - Many more tests with APTS V1

Examples of sleds

- Q3 repeatability
  (Beillas et al. 2012b)
- Limitation: the only test found for repeatability in sled and no reproducibility



Test number	APTS version	Peak Pressure (bar)			Average of max (bar)	CV
		Right	Left	Max.		
Q3_37	V2	2.13	2.20	2.20	2.32	4.4%
Q3_38		2.39	2.12	2.39		
Q3_40		2.22	1.77	2.22		
Q3_45		2.26	2.13	2.26		
Q3_46		2.42	2.17	2.42		
Q3_47		2.41	2.26	2.41		

Examples of sleds

- Resistance-durability
  - Q10 JAMA: sensor line disconnection (needed re-soldering)
  - Extreme loading: Q6 sled issue (63 km/h instead of 50km/h → hard stop): 7 bars, 8kN lap belt, no damage
- Otherwise: no failure, no damage since V2 manufactured

→ need to further reinforce wiring (new attachment design ongoing for APTS Q1.5)

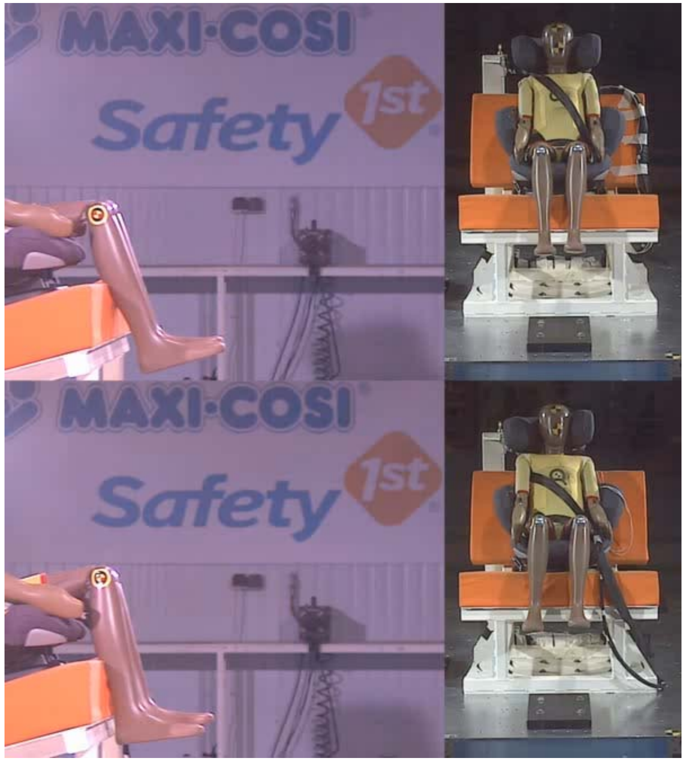
Examples of sleds

- Abdominal load detection: Objective of most tests and reconstructions…e.g.
  - Q3: Casper reports
  - Q6: LAB tests (V1) (Beillas et al. 2012b)
  - Q10: mainly belt under the arm (Beillas et al. 2012a, JAMA tests)

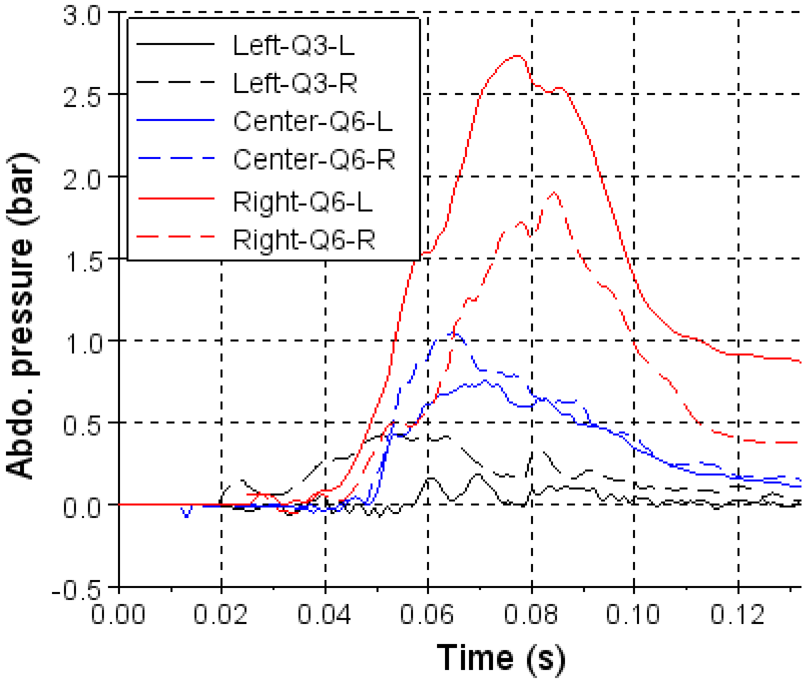
Q6 test: Short description	Max. (bar)
Standard, ISOFIX CRS	0.31
Relaxed posture, no CRS	1.23
Standard posture, seat reclined, no CRS	1.23
Relaxed posture, feet on front seat, ISOFIX	1.33
Leg folded, belt under arm, no CRS	1.85
Standard posture, belt above armrests, ISOFIX	2.33

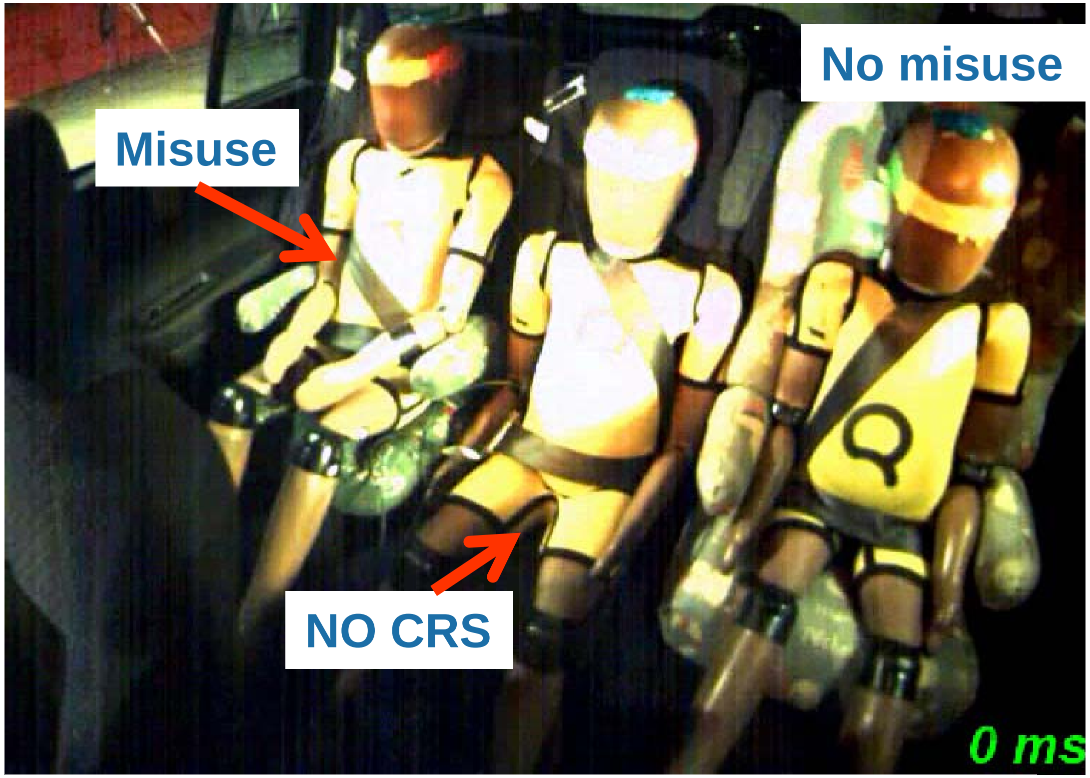
Normal: Max: 0.83 bar

Misuse (belt under arm) Max: 1.82 bar



Accident reconstruction example: Case 2032 (LAB-FIAT)





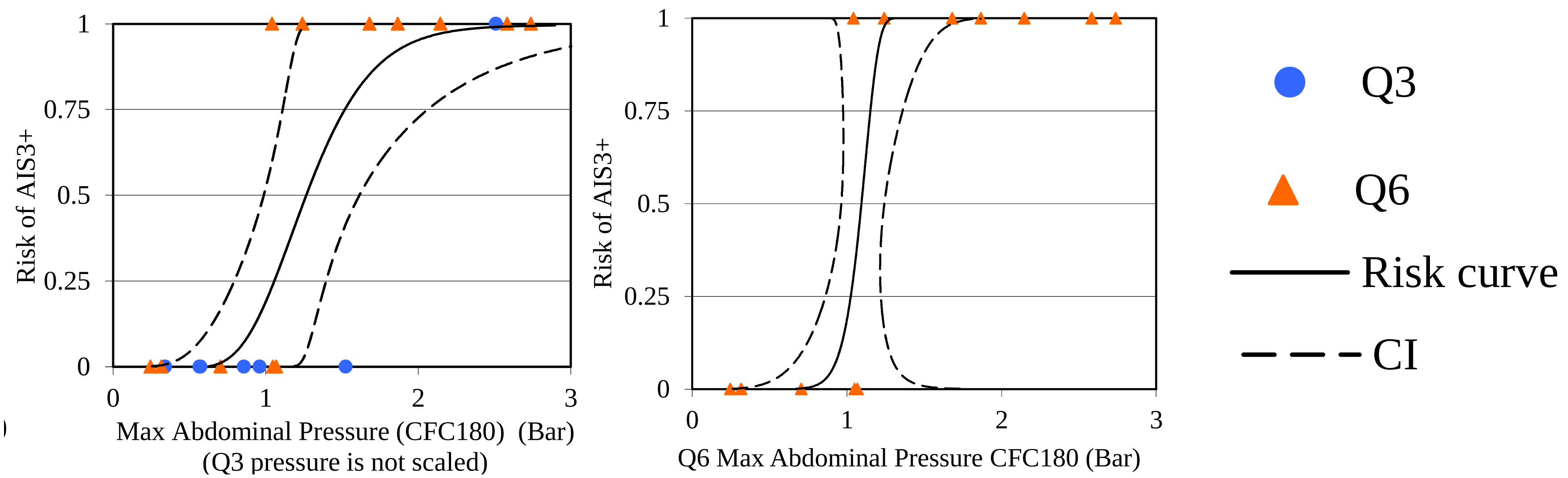
6YO (MAIS4)	8YO (MAIS3)	4YO (MAIS4)
Ruptured liver (4) & Pancreas (4)	Intestinal wound (3)	liver rupture (4) rib fx (3)

- 2 declared as valid, 1 invalid (injury mechanism not reproduced: no abdominal loading=normal restraint kinematics)

All Reconstructions summarized in Beillas et al. 2012b

Reconstructions & risk curves

- Full reanalysis (Beillas et al., 2012b): 8 cases removed (loading mechanisms, sensor malfunctions, invalid at car level) → 19 cases (12 Q6, 7 Q3) kept



- Max Pressure and Pressure rate based Pmax*(dP/dt)max, (dP/dt)max: all predictors of injury (pressure rate correlated with pressure); even narrower confidence interval for rate based
- Max pressure: same trends for Q3 scaled and Q6, Q3 and Q6, and Q6.
  - CFC180 seems good choice for filter
- Q3 (scaled) points have higher pressures than Q6 points at the same AIS
  - But only 1 AIS3+ for Q3…

Reconstructions & risk curves: Discussion and conclusions

- Important limitations:
  - Lack/limited overlap surprising (Sampling? Ncases? Limited submarining?...), Inherent limitations of reco.
  - Confidence interval very sensitive to individual points but limit (50% risk) relatively stable
  - Scaling between dummies ? (Q3/Q6, and now Q10)

→ Confidence intervals and risk curves to be considered cautiously. Observation of dummy and instrumentation performance in a set of realistic test conditions that are believed to correspond to real accidents

→<u>New</u>: Based on recent results: dummy scaling could be attempted based on penetration. No particular reason to scale Q3/Q6 based on response.

Summary and perspectives: Remaining issues and open questions for sensors

- Durability: reinforcement of cable needed → design ongoing
- Integration: discussions with Humanetics for Q10
  - Reservations in mold, mounting procedure/friction control needed…
- Compressive response: Q3, Q6 ok. Q10: need some clarification
- Calibration: out of dummy procedure tested → needs to be finalized
- R&R: limited testing performed for sled… (ok otherwise)
- Detection of abdominal loading: ok (Reco and sleds):
  - Typically <1 bar when pelvis loaded, >1 when abdomen loaded
  - Limited experience for Q10 (only 2 misuse tested)…
- Criteria and Risk curves: candidate available based on accident reconstructions for Q3 and Q6 (with limitations).
  - Pmax CFC180 (around 1.1-1.3 bar depending on hyp.)
  - No curve for Q10: scaling based on compression?
- Other: ongoing work on Q1.5, Thor + Simulation of sensors to help scaling

2) Test procedure

- Improved CRS (here: booster), evaluated by impact testing require:
  1) Instrumented dummy to evaluate abdominal risk
  2) Test procedure, representing a situation where children are injured (and the abdomen loading is high on the dummy)
- Note: 2) is really important.
- E.g. Sled testing on Q10 (Dorel)
  (Beillas et al. 2012a)

Q10	R44	NPACS	5xboosters	normal
			no CRS	no CRS
			booster	belt under arm
	ADAC	Golf body	5xboosters	normal

E.g. Sled testing on Q10: normal vs. no CRS

Seat	Cfg	Peak press. (bar)
Booster1 (Isofix)	1	0.83
Booster2 (Isofix)	1	0.73
Booster3 (inflatable)	1	0.78
Booster4 (Backless)	1	1.02
No CRS	1	0.44
Booster1 (Isofix, Misuse)	1	1.82
Booster5 (Isofix)	1	0.65
Booster1 (Isofix)	2	0.54
Booster2 (Isofix)	2	0.96
Booster5 (Isofix)	2	0.51
Booster4 (Backless)	2	0.57

Config 1=Bench, Config 2=Body in white

Note:
dummy
Q10 vs P10

2) Test procedure

- Improved CRS evaluated by impact testing require:
  1) Instrumented dummy to evaluate abdominal risk
  2) Test procedure, representing a situation where children are injured (and the abdomen loading is high on the dummy)
- E.g. Sled testing on Q10 (Dorel) (Beillas et al. 2012a)
  - abdo not loaded w/o CRS on NPACS → not injurious. But no CRS leads to higher risk in real world. No Protection.
    - Cause: Dummy behavior? Bench? Anchor position? Other?
  - Any CRS is ok, no differentiation → Are there good and bad CRS for the abdomen?
    - Injury with CRS and no detected misuse (CASPER, Beillas et al. 2012)
    - Differentiation is the objective of a test procedure for CRS. Otherwise enforcing usage is enough.

→ Test procedure seems inappropriate for the goal…

References and acknowledgements

- P. Beillas, F. Alonzo., M-C. Chevalier , H. Johannsen, F. Renaudin, P. Lesire. (2012) Abdominal Pressure Twin Sensors for Q dummies: From Q3 to Q10. Icrash Conference 2012 Proceedings, Milan, Italy
- P. Beillas, F. Alonzo, M-C. Chevalier, P.Lesire, F. Leopold, X. Trosseille, H. Johannsen. (2012) Abdominal Twin Pressure Sensors for the Assessment of Abdominal Injuries in Q Dummies: In-Dummy Evaluation and Performance in Accident Reconstructions Stapp Car Crash Journal & Conference 2012
- CASPER project reports (WP1), under review...

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