Shocking Standard: People in High Speed Craft

Cameron R. ‘Dale’ Bass
Duke University
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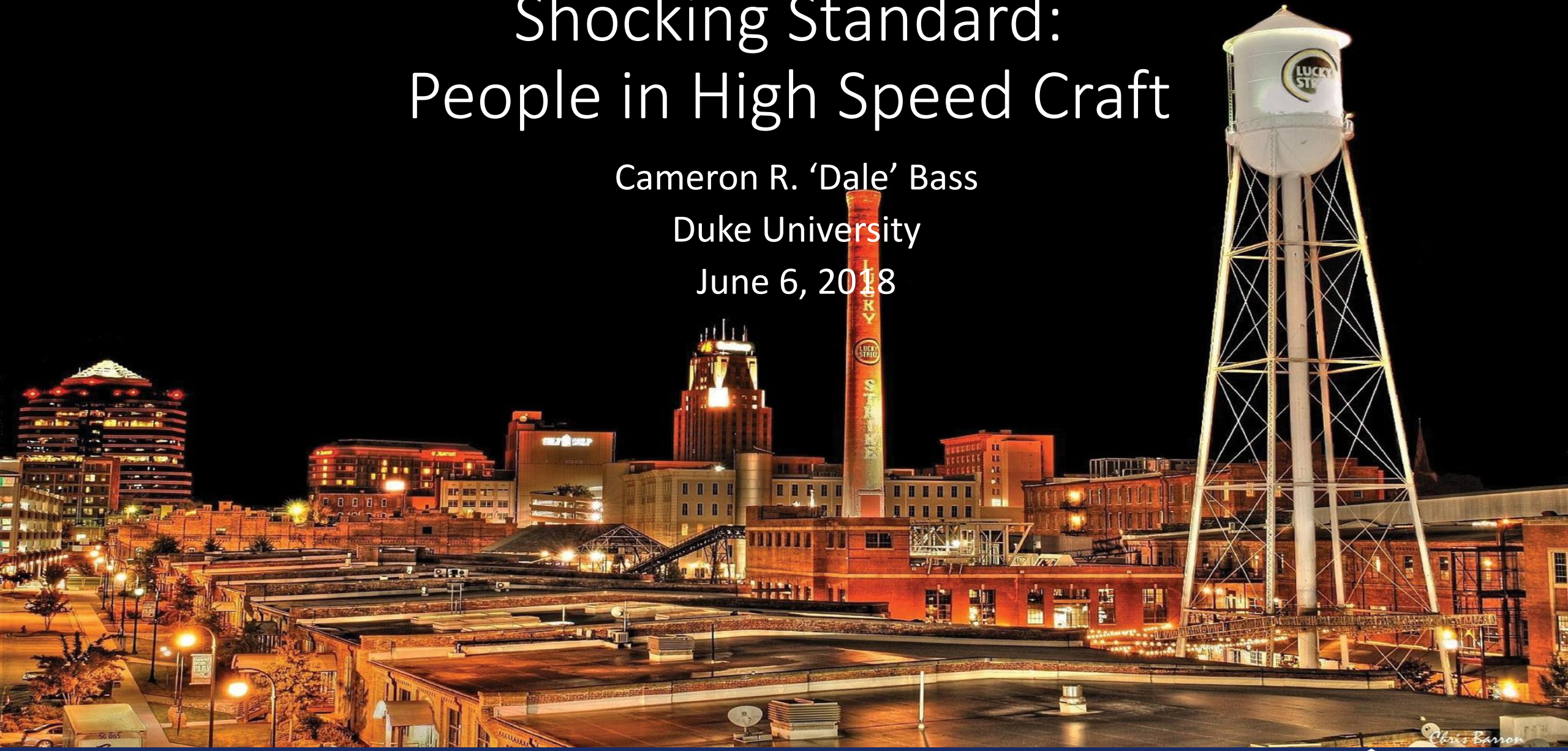

The Problem

- Repeated impact/shocks (i.e., vibration, mechanical shock) are suspected to contribute to lumbar spinal injuries and chronic pain
  - Epidemiologically, known problem, especially with high speed craft
- Guidelines intend to limit exposures (eg, EU Directive 2002/44/EC – vibration) are often *nonsense* for high speed craft

Example: Nonsense

- US Navy Seat Assessment Off of Coronado, California
  - Testing isolated (1) seat
  - Nonisolated seats = 14
  - This guy is in a nonisolated seat
- Sea State: 1.
- Two ‘Rogue Waves’ (Wakes)

EU RMS Calculation

- EU Directive - RMS (Root Mean Squared) Acceleration < 1.15 m/s^2
- For an eight hour day…

EU RMS Calculation

- Weighted for an 8 hour day, based on the exposure measured via RMS

- RMS ~ 0.20 m/s^2 < 1.25 m/s^2 (EU)

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- So we're good?

Nonsense: EU RMS Calculation

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Nonsense: EU RMS Calculation

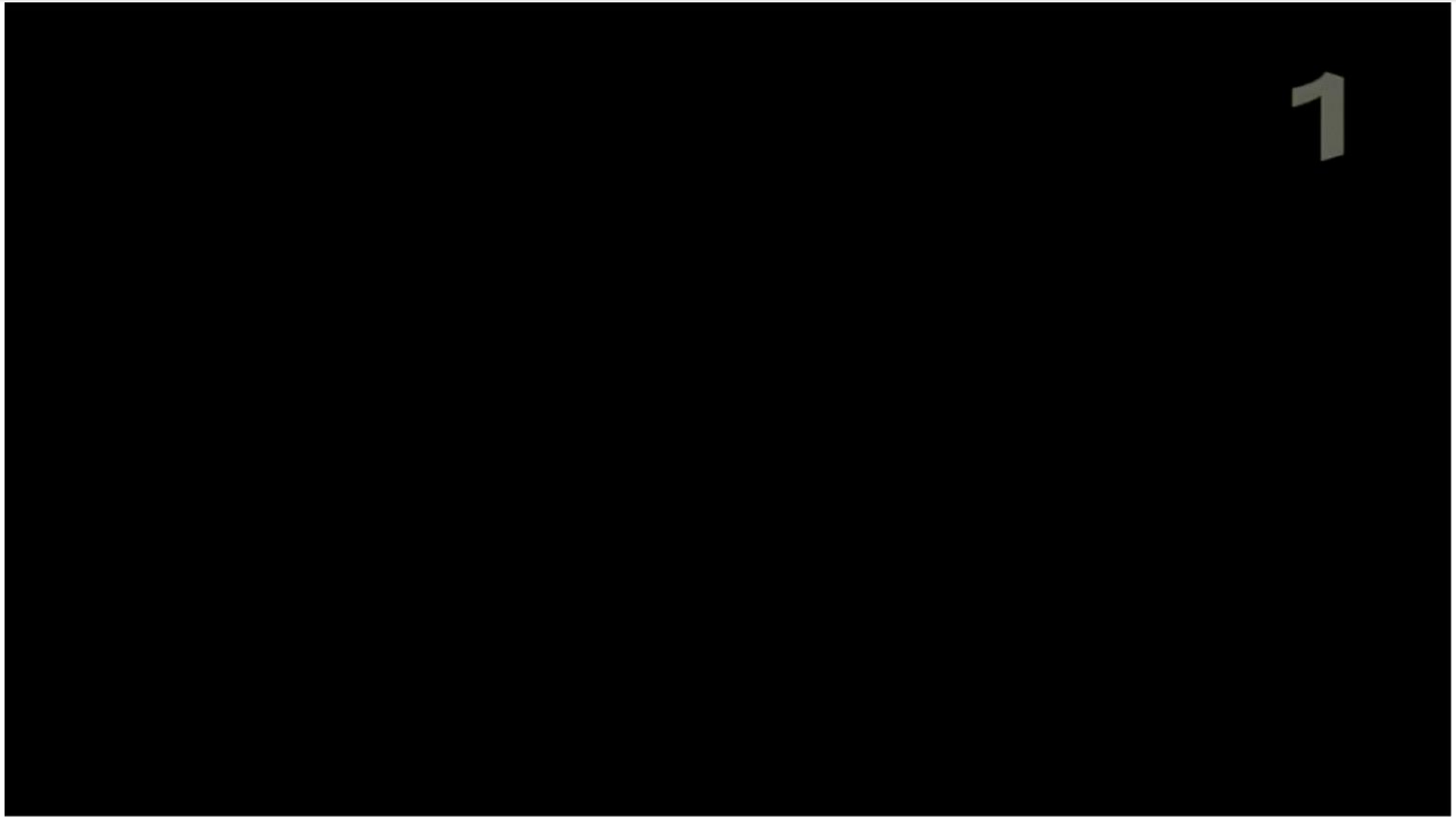
- No, we're not good!
- RMS hides the impact, but cannot hide…
- His 'fucking back' hurt…
- … as did everyone's in the front row but the guy in the isolated seat
- An acute disk herniation in an engineer in the 3rd row.

So, Circa 2007

- Idea (We didn't think it was a particularly novel idea)

How Many Little Impacts …

… Equal One Big Impact …



DUKE BME

… For the Spine

The ‘Dose’ Matters

- Start simply – with spinal compression only
- Assumed a ramp profile similar to what we measured in high speed craft
- Difficult to solve the whole problem without solving a smaller part first
- Ignoring what Johann said yesterday, we started in the laboratory

Did a Bunch of Tests on Spines

- Repeated loading tests from 6 studies

  (Brinckmann 1988, Hardy 1958, Liu 1983, Hansson 1987, Gallagher 2005, Huber 2010)
- 107 (78 male and 29 female) cadaveric lumbar specimens
- Single FSU in load control repeated axial compression
  - Posterior elements intact
- Survival analyses
  - Number of cycles, effective stress, sex, and age
  - ISO 2631-5 R-value

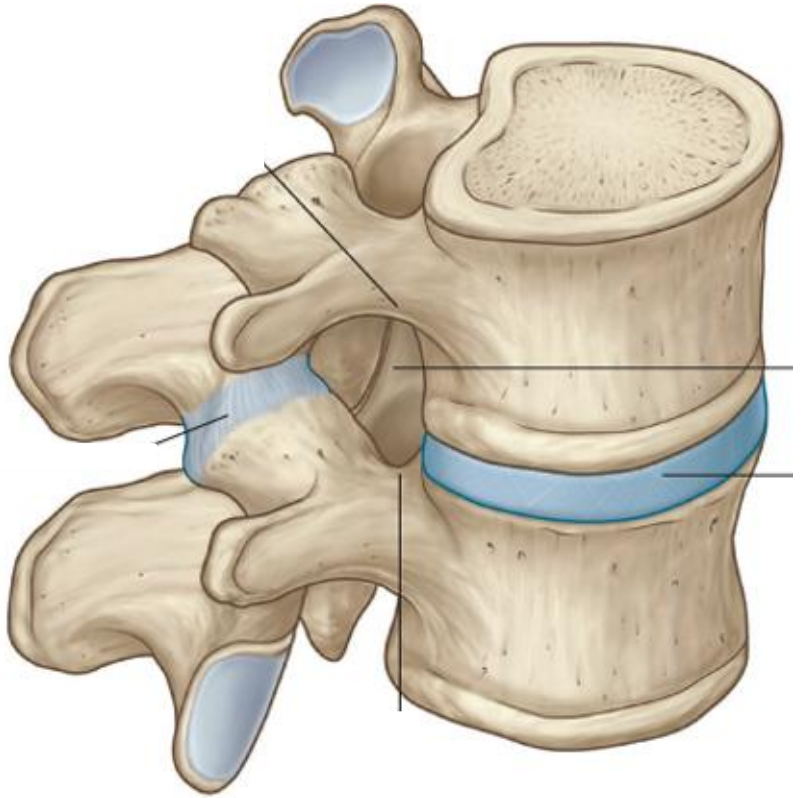


Image: Drake, Gray's Anatomy for Students, 2nd Edition.

Interesting Fact

- Spine failure theory based on Palmgren-Miner fatigue theory
- Developed for Use in Boats!
- Liberty Ships in WW2

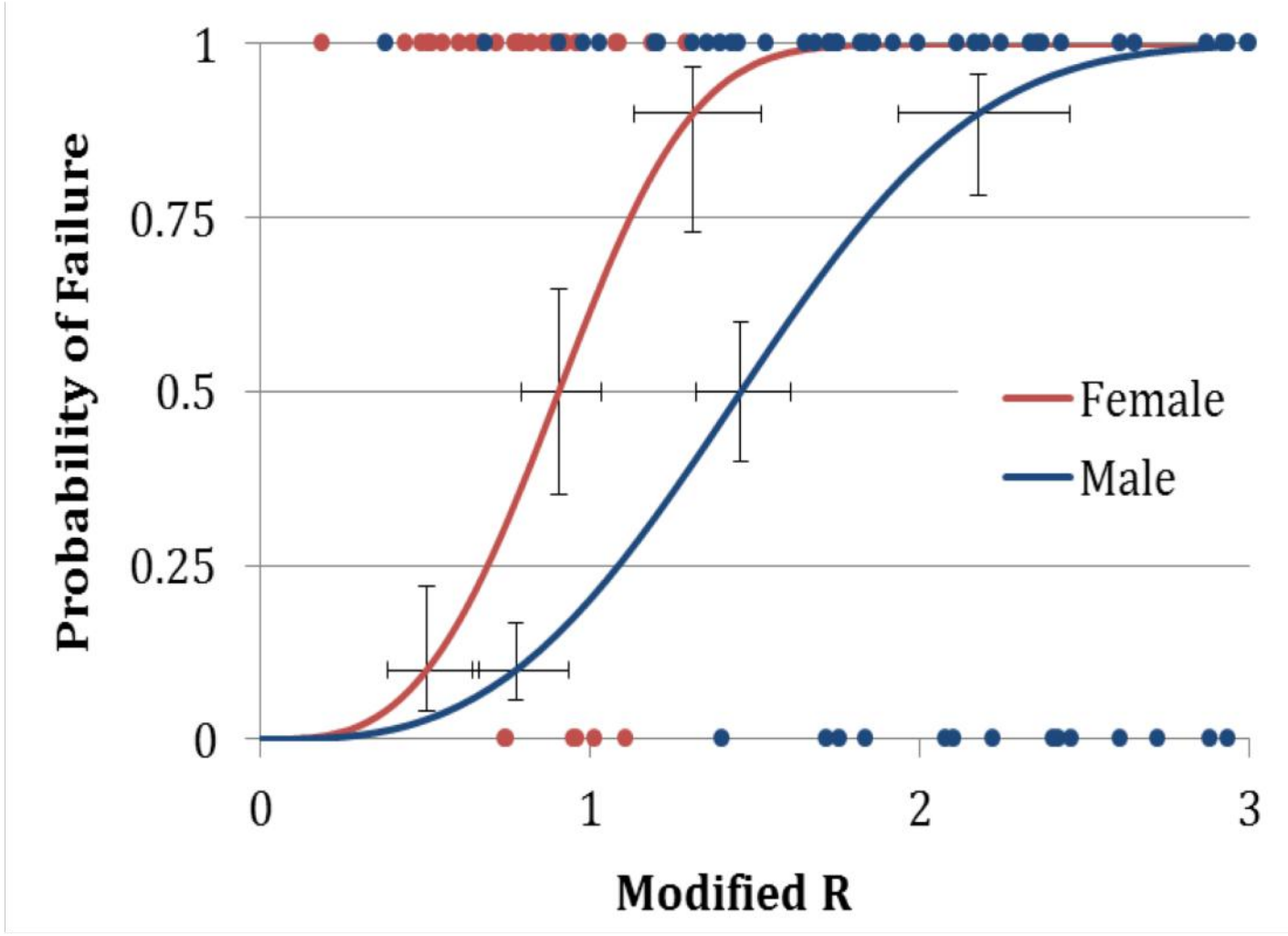
Details – We Will Mostly Ignore

$$R = \frac{\sigma_{max} \cdot C^{(1/6)}}{6.75 - G_{age} \cdot Age}$$

Modifications

- **Effective stress** :

  Peak applied load – facet contribution, divided by endplate area
- **Sex:** Males and females modeled separately
- **:** Tuned separately for males and females



This R Thing

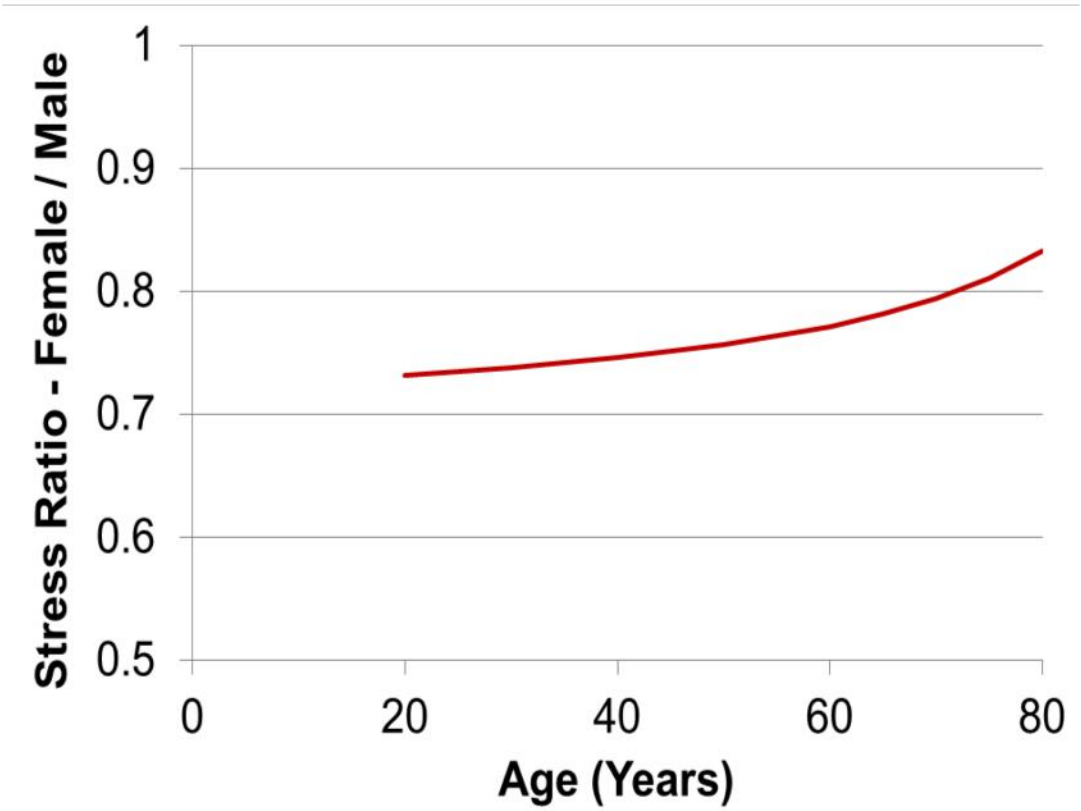
$$R = \frac{\sigma_{max} \cdot C^{(1/6)}}{6.75 - G_{age} \cdot Age}$$

- Depends on:
  - Severity of each impact (σ_{max})
  - Number at each impat level ($C^{(1/6)}$)
  - Age (Age)

Which is Something Like What We Expect

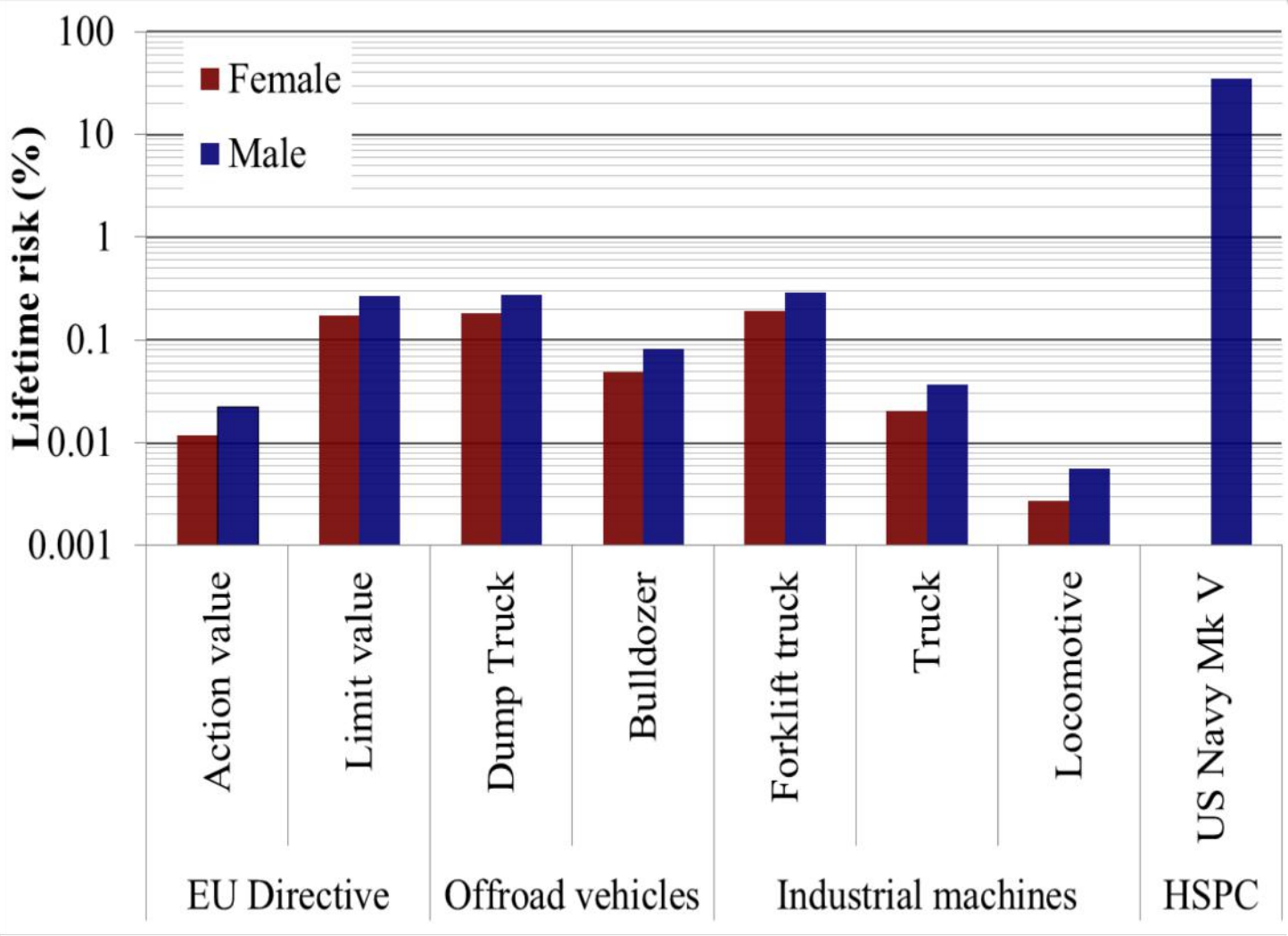
- The exponent (1/6) matters
- 1/6 means that the big ones are much more important than the small ones
- At 1 g, even a lifetime is not enough to injury the spine (generally conforms with experience of people walking for a lifetime)

Another Interesting Fact



Women's spines are generally weaker than men's on a stress basis (*accounting for differences in lumbar spine size*)

Predicted Risks with New Standard



From mean estimate of RMS exposure:

Note: Women have lower risk because their torsos are lighter per body mass…

Implications

- Can be used in design and assessment tools to mitigate risk.
- Being a high speed craft operator for 20 years may be risky for your lumbar spine…
- Care must be taken when burdening women with equipment not scaled for their torsos (e.g. body armor)

New Standard

- New ISO2631.5 (2018) has been accepted by ISO after 10 years of discussion (arguments)
  - The arguments were irrelevant to high speed craft
  - Applicable to high speed craft for large impacts (to 14 g or more)
- Methodology Accepted for US Mil Std 1472.
- Strong need for HSC health surveillance (epidemiology)
- Additional research on off-vertical loading needed
  - In the laboratory and in the field

Source

This presentation has
been produced by
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