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High Speed Craft Operations:

The Biomechanics of Women

Cameron ‘Dale’ Bass

Duke University

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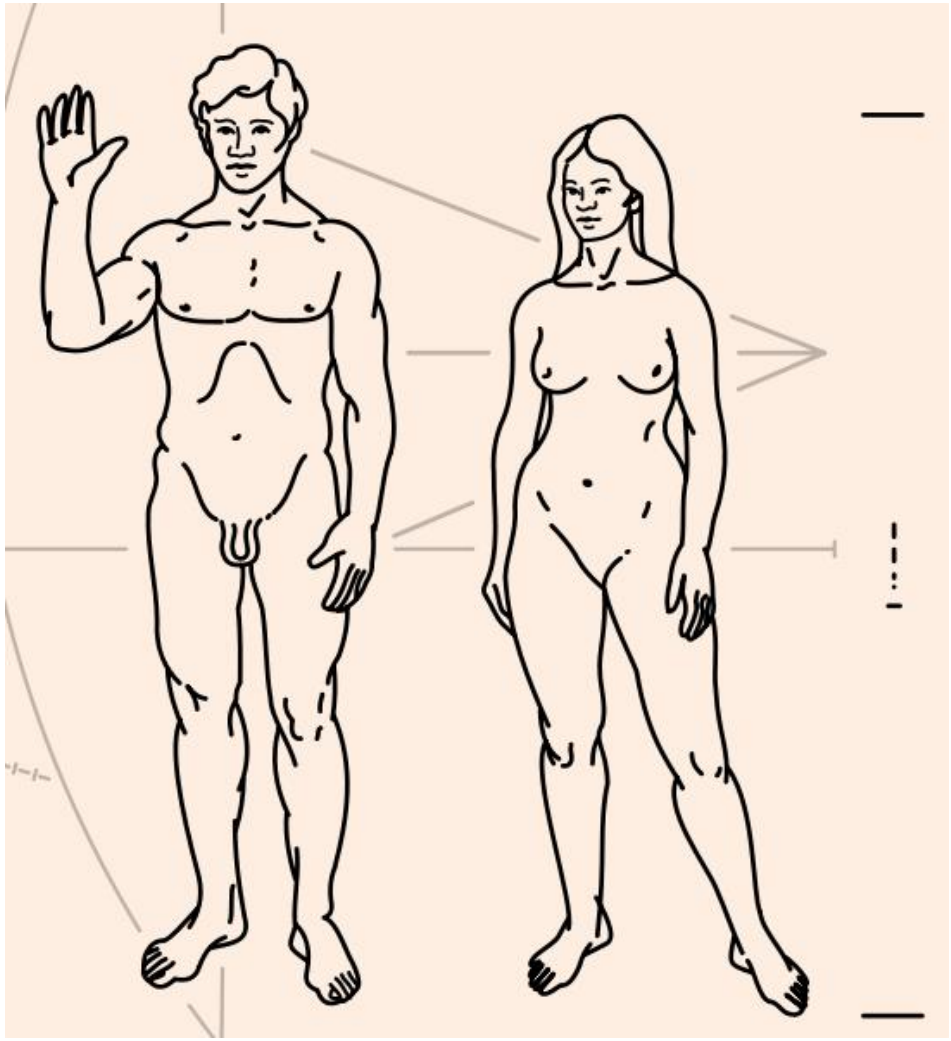
High Speed Craft Operations:
The Biomechanics of Women
and Men

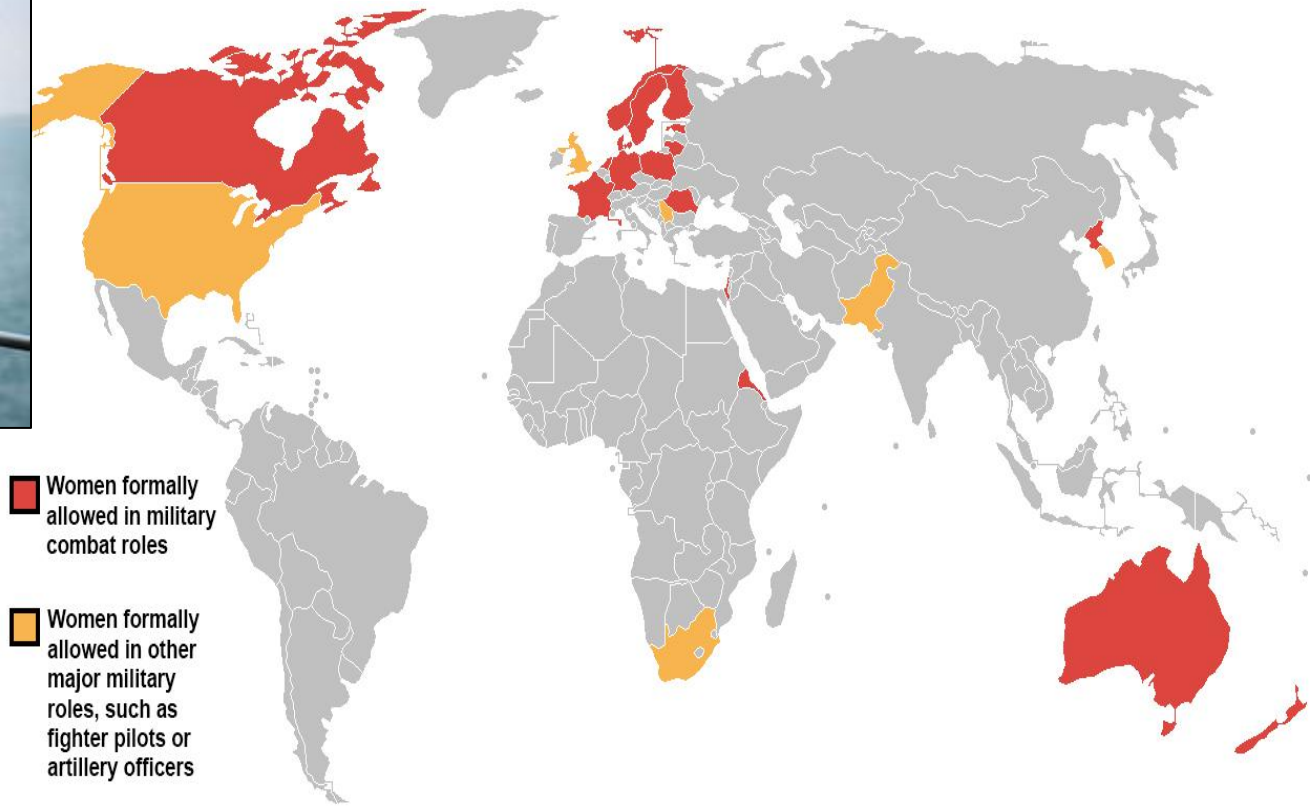
Cameron ‘Dale’ Bass
Duke University

Men, Women - Different?



Pioneer Plaque

Women in Combat



- US: Women make up 14 percent of active military.
- US DOD – All roles open to women (Dec. 2015)

Injury Biomechanics

US Mk V SOC
Off San Diego
Sea State ~1-2

Fundamental Differences - Men/Women?

Two types of differences:

1. Differences in size/mass distribution

2. Intrinsic differences on a stress basis (accounting for size/mass)

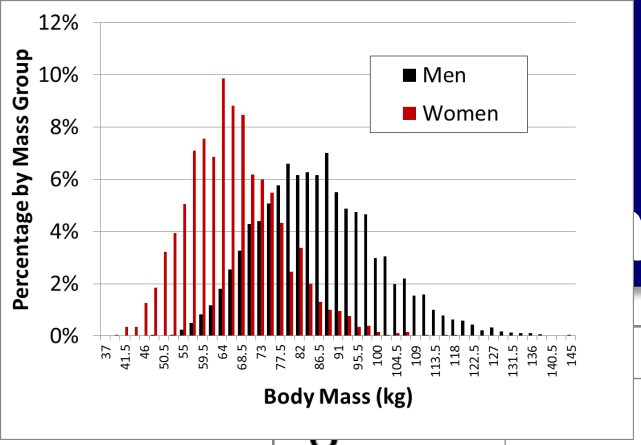
Fundamental Differences - Men/Women?

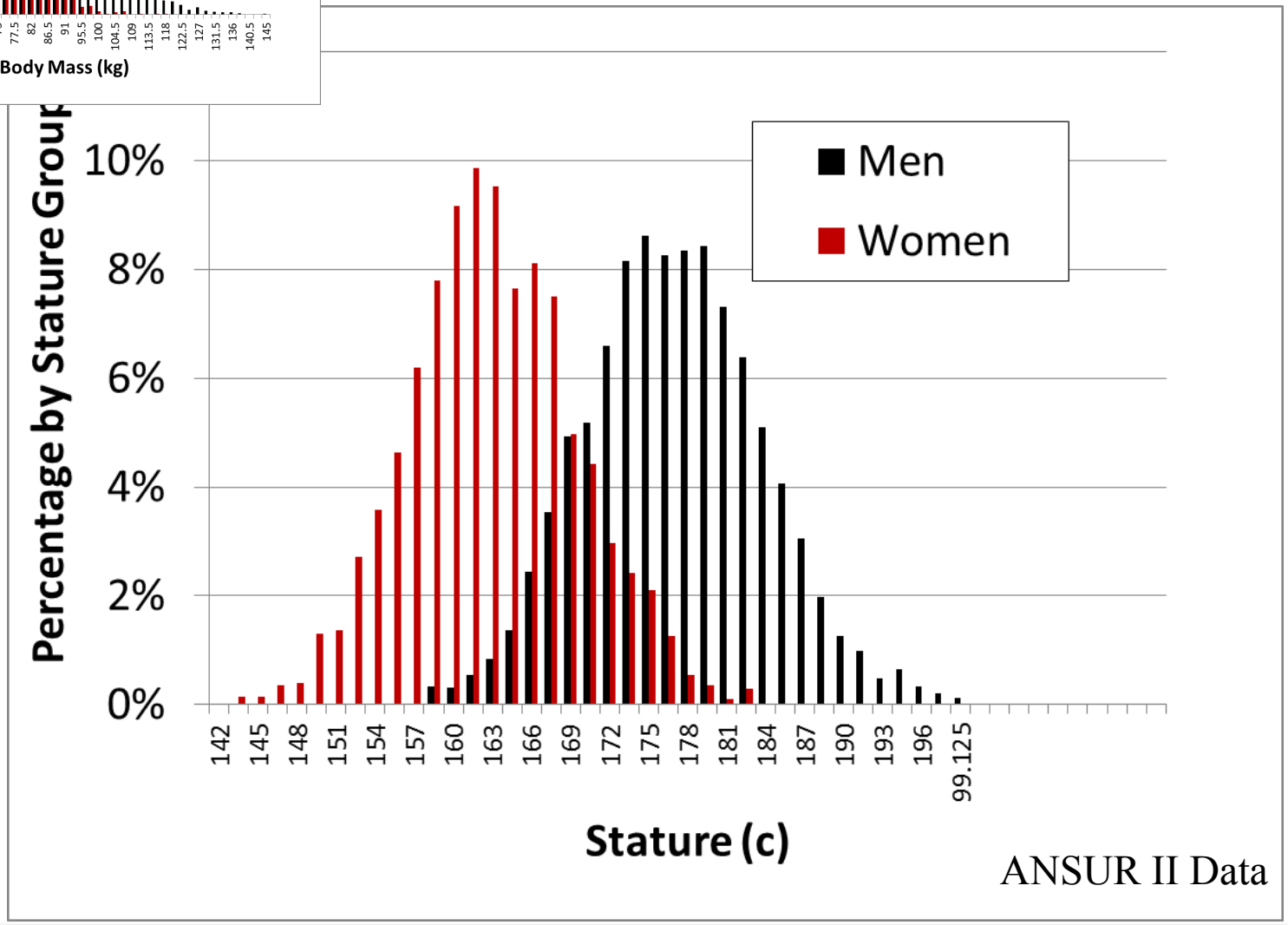
Are any differences important in operations?

- Changing fitness or other personnel standards? Undesirable!
- Changing equipment? Yes!
- Helpful modifications of training (for both men and women). Yes!

Intrinsic Size Differences: Averages and Distributions

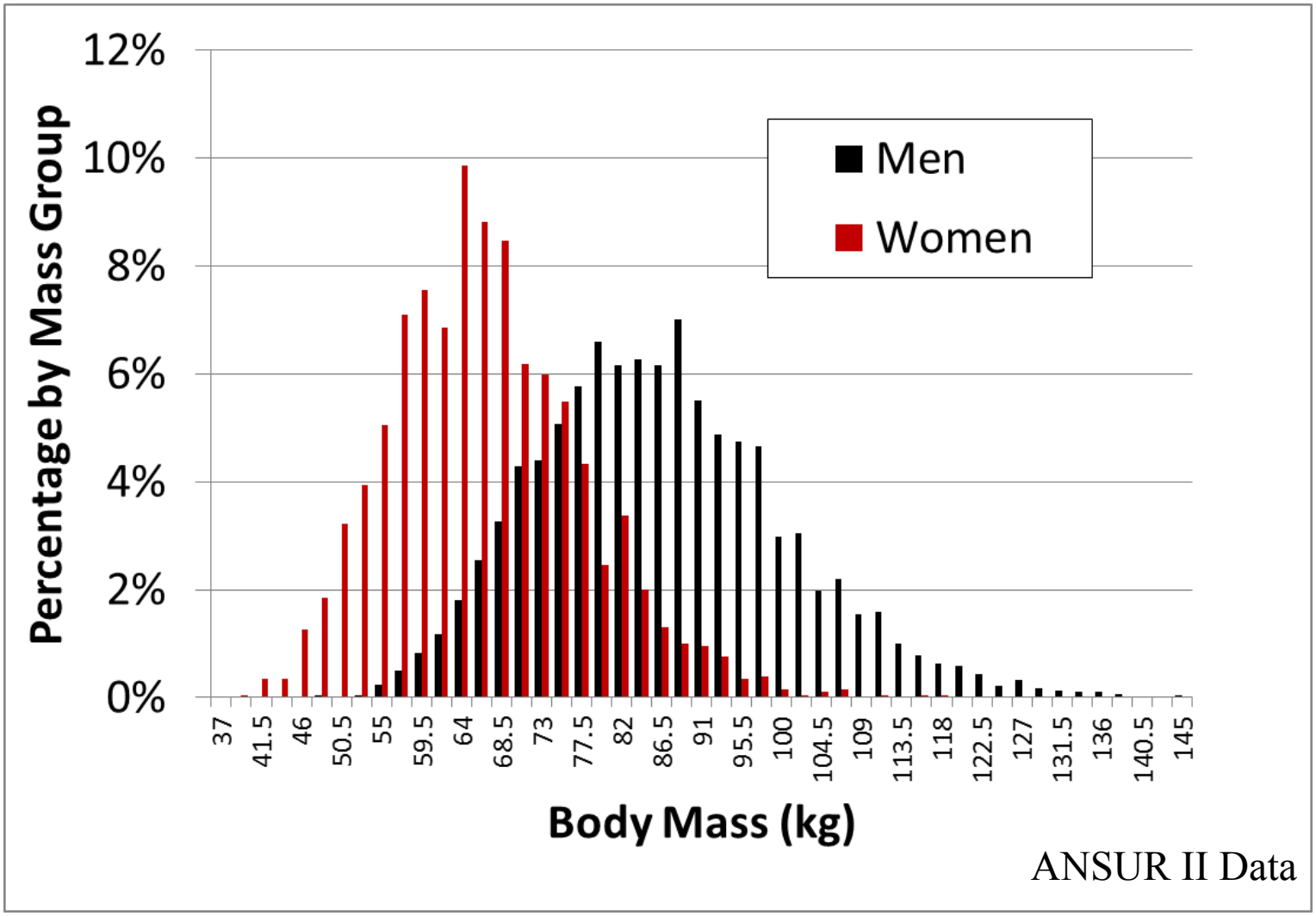
Stature – ng Military Population





ANSUR II Data

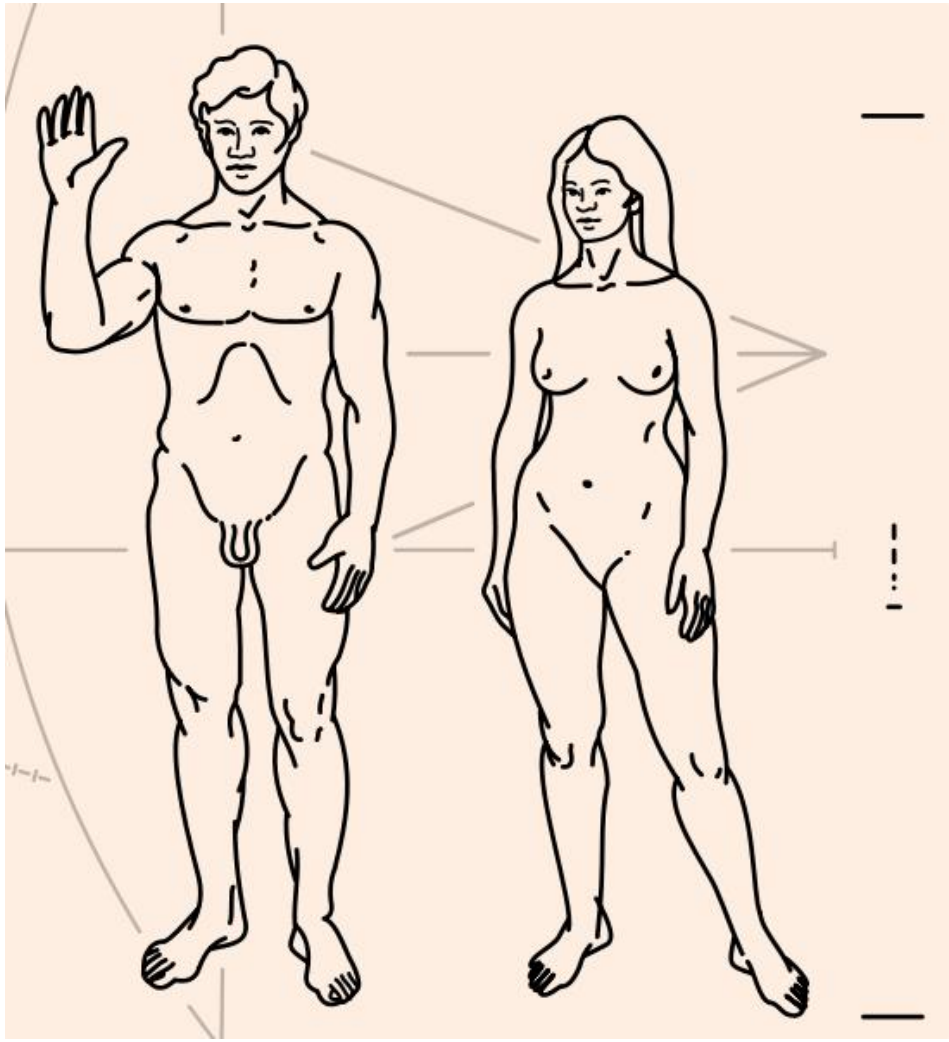
Body Mass – Young Military Population



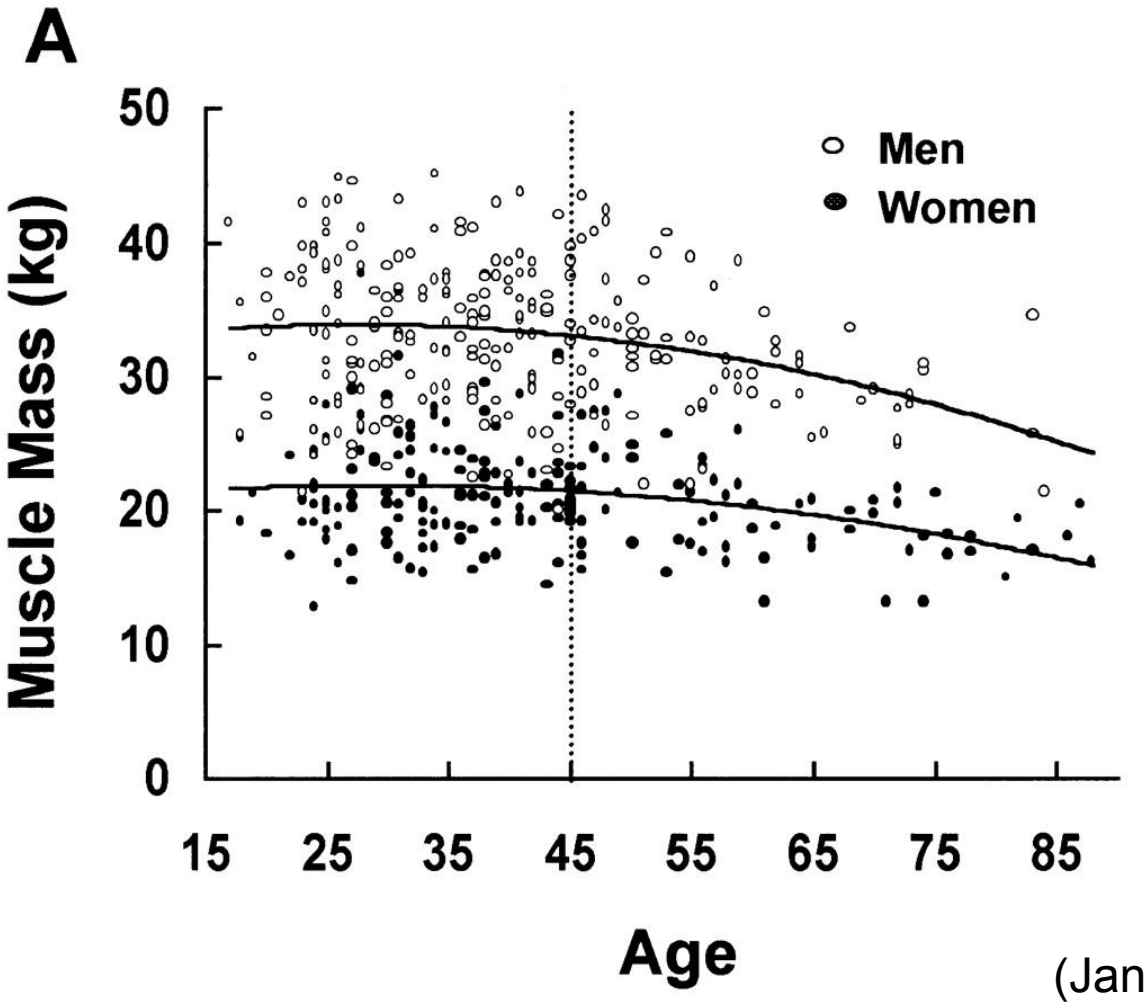
ANSUR II Data

Mass Distribution

- Example differences
  - Upper body lean mass (Miller, 1993)
  - Muscle distribution (Janssen, 2000)
- However, for example…
  - Male and female muscles are not fundamentally different
  - Bone tolerances not significantly different for gender (eg. Salzar, 2007)

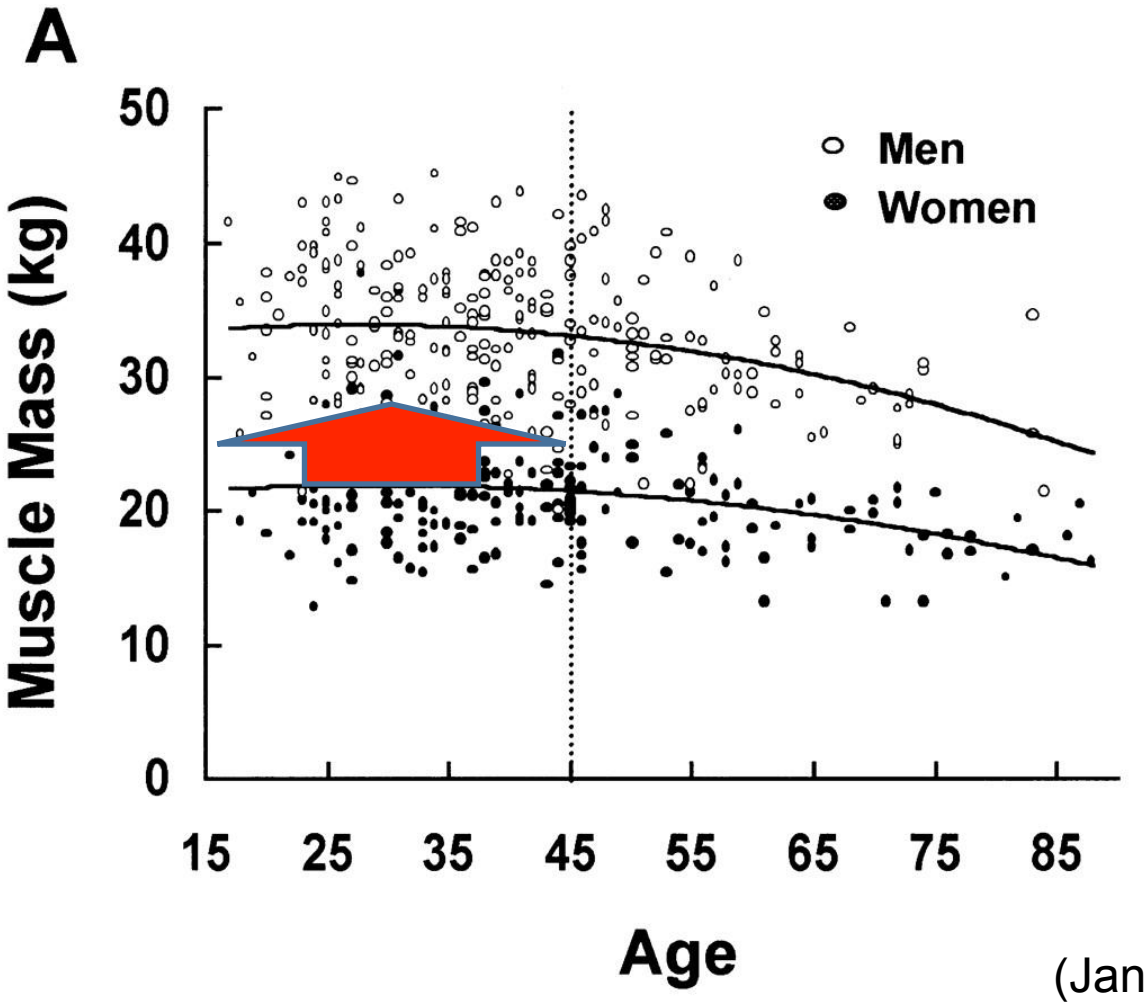


And There's a Lot of Variability



(Janssen, 2000)

And There's a Lot of Variability



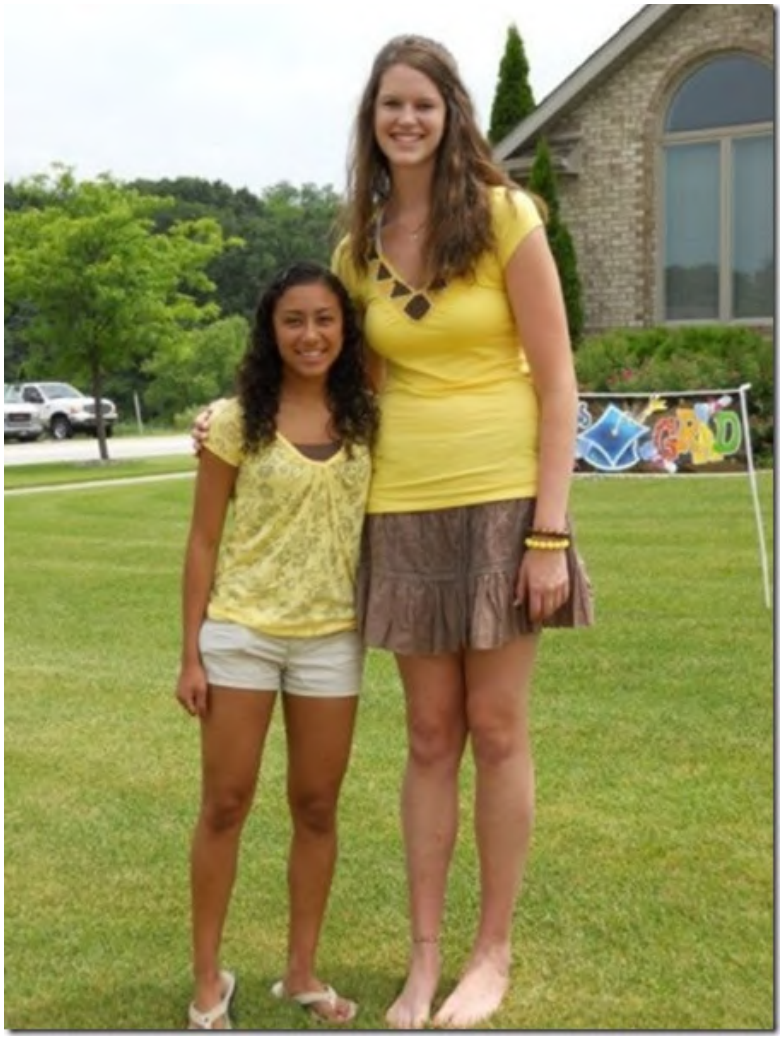
Accounting for Total Mass Differences

(Janssen, 2000)

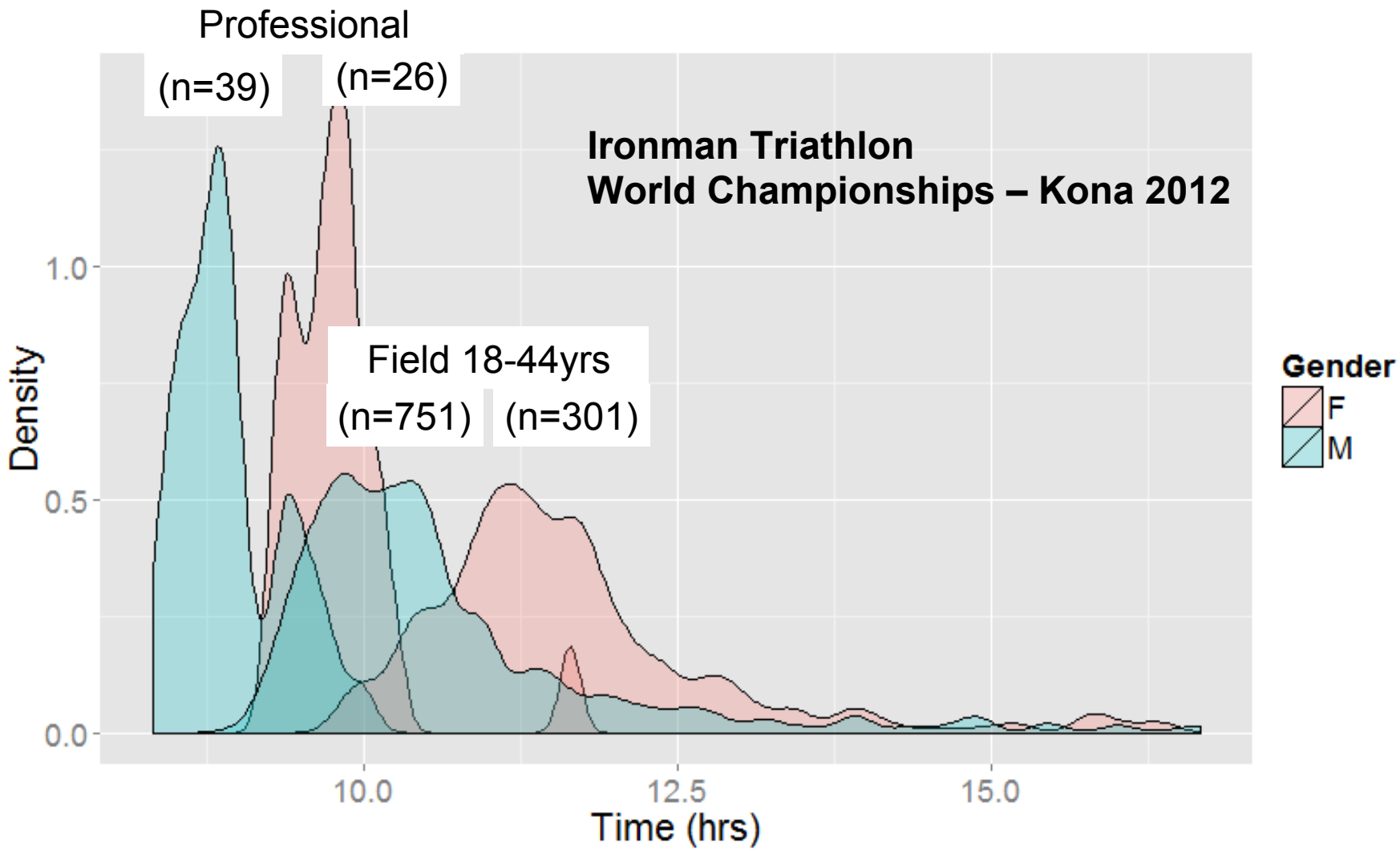
Observation:

There are some 1.85 m, 100 kg women

Important to think in terms of distributions of people, not just averages!



And a Lot of Overlap



Size Effect: Bone Fracture in Military Age Populations

Long Bone Fracture

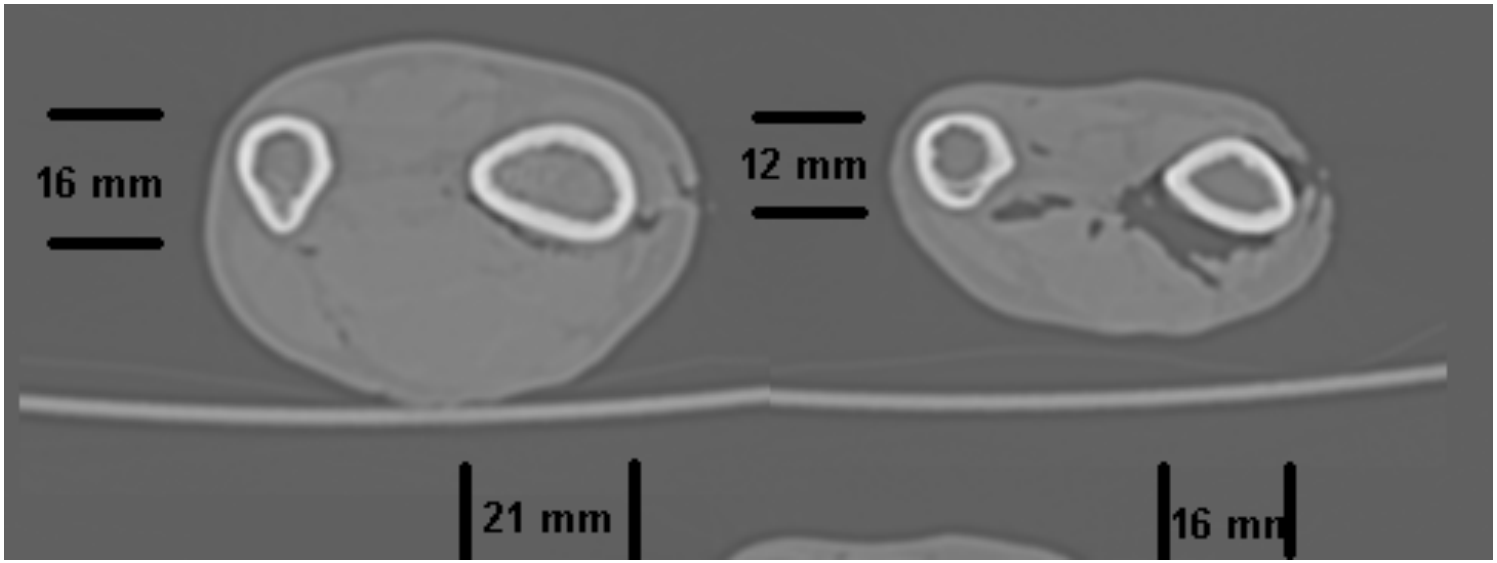
Singh, 2009

- Observation (Late 90's, US Department of Transportation:
  Catastrophic forearm fractures in female car drivers

Long Bone Fracture

Large Male Forearm

Small Female Forearm



Bunch of tests on cadavers, risk associated *with size only*

- Above, male radius of inertia = ~2.3 x female
- Outside size, no gender difference (Bass, 1997)

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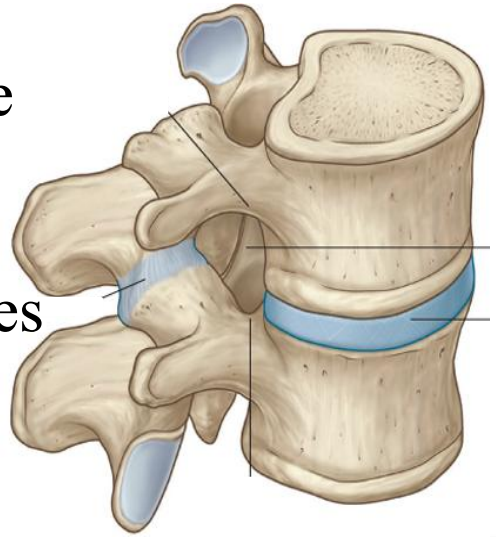
Intrinsic Difference: Lumbar Spine Fracture Military Age Populations

Sex Differences in Injury from Lumbar Repeated Loading

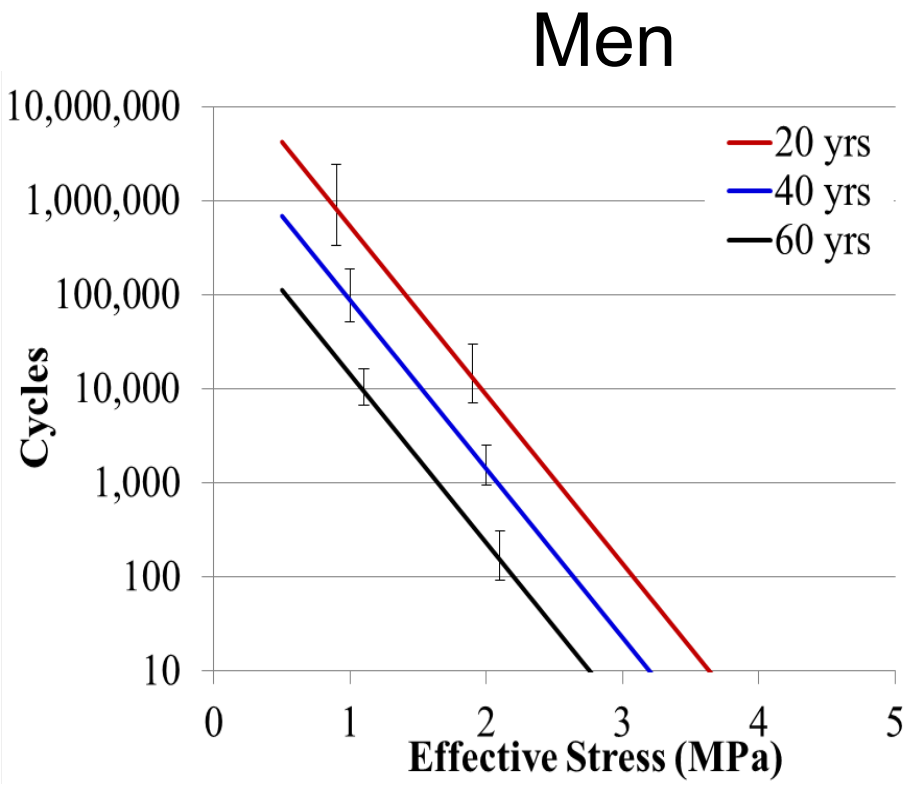
- Compressive cyclic loading (i.e., vibration, mechanical shock) contributes to lumbar spinal injuries, chronic pain…

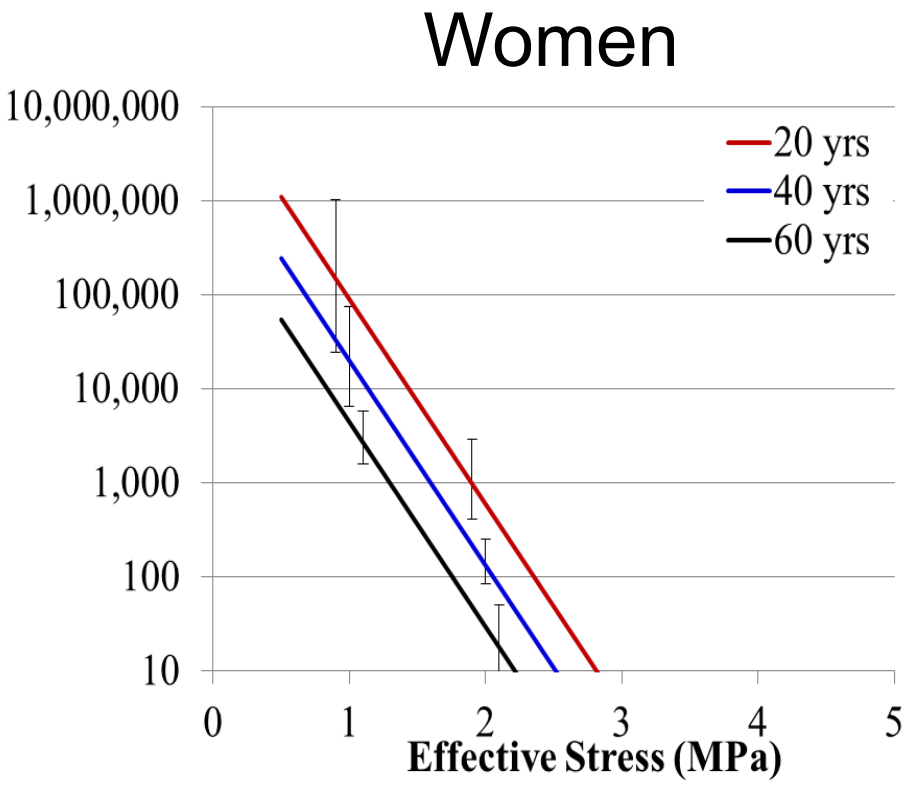
  …especially with high speed craft

- Objectives of this study:
  - Find human lumbar spine tolerance to repetitive compression using stress, cycles, age, sex
  - Evaluate and improve career exposure guidelines
- Take a bunch of cadaver spines
- Analysis using Palmgren-Miner fatigue theory



50% Injury Risk Cycles vs Stress





Differences in age, sex

Putting it Together: Injury Risk

- **Lumbar Spine Repeated Motion:**

  Men and Women are Different

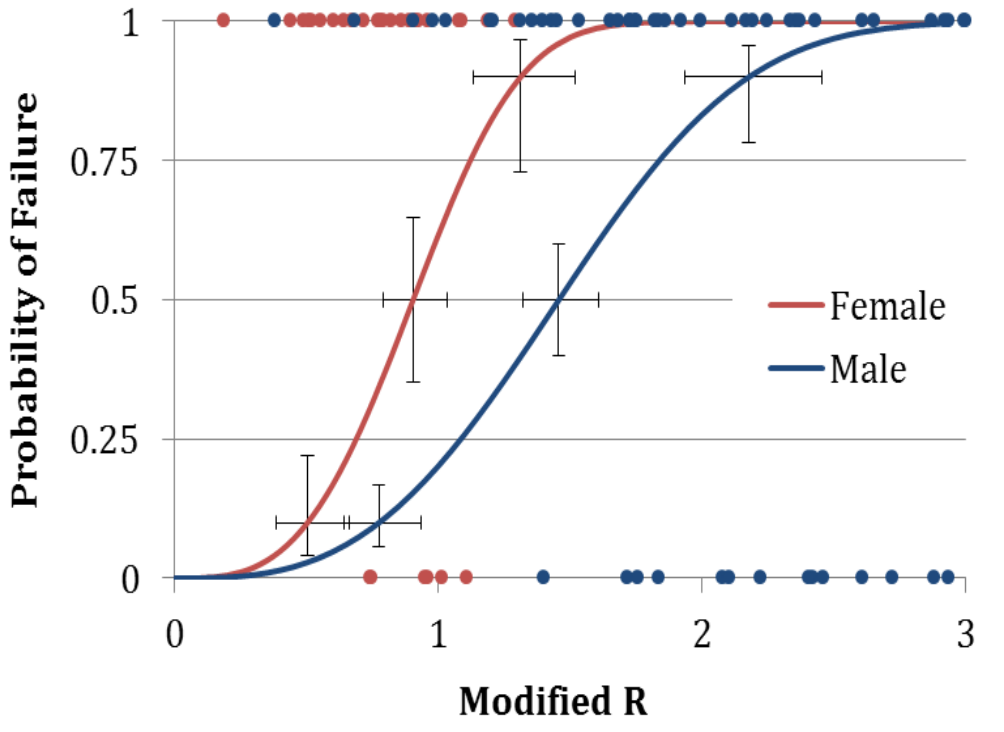
- **Effective stress -**

  $\sigma\downarrow max$

  Sex: Males and females modeled separately

  Number of Impacts

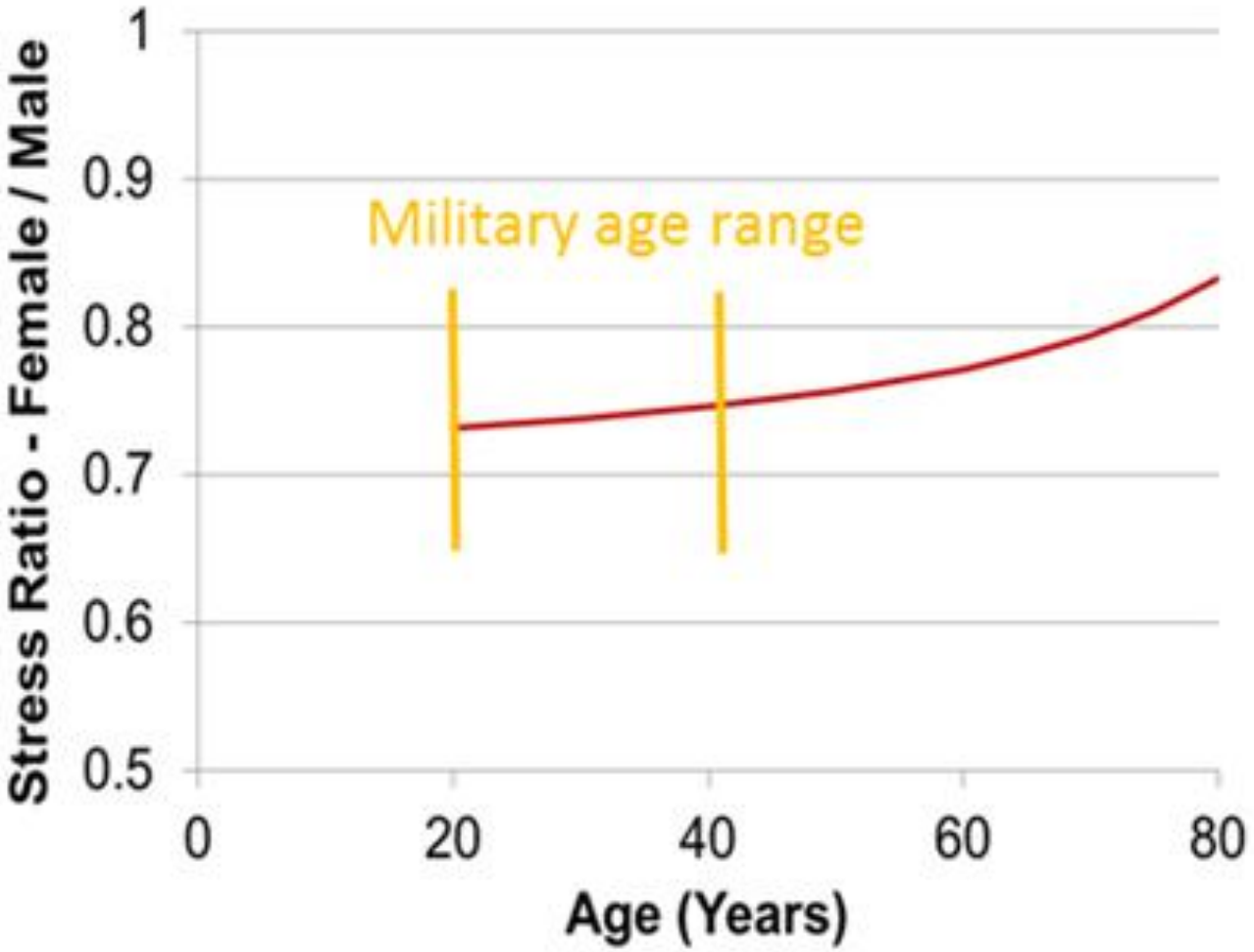
$$R=\sigma\downarrow max \cdot C\uparrow(1/6\ ) /6.75 - G\downarrow age \cdot Age$$



Male to Female Stress/Strength Ratio

Women are consistently weaker, but the disparity lessens with age

Basis for ISO standard on repeated impact



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Preface:

The EU Directive on 'Vibration' Applied to High Speed Craft Injury is *Biomechanically Absurd*

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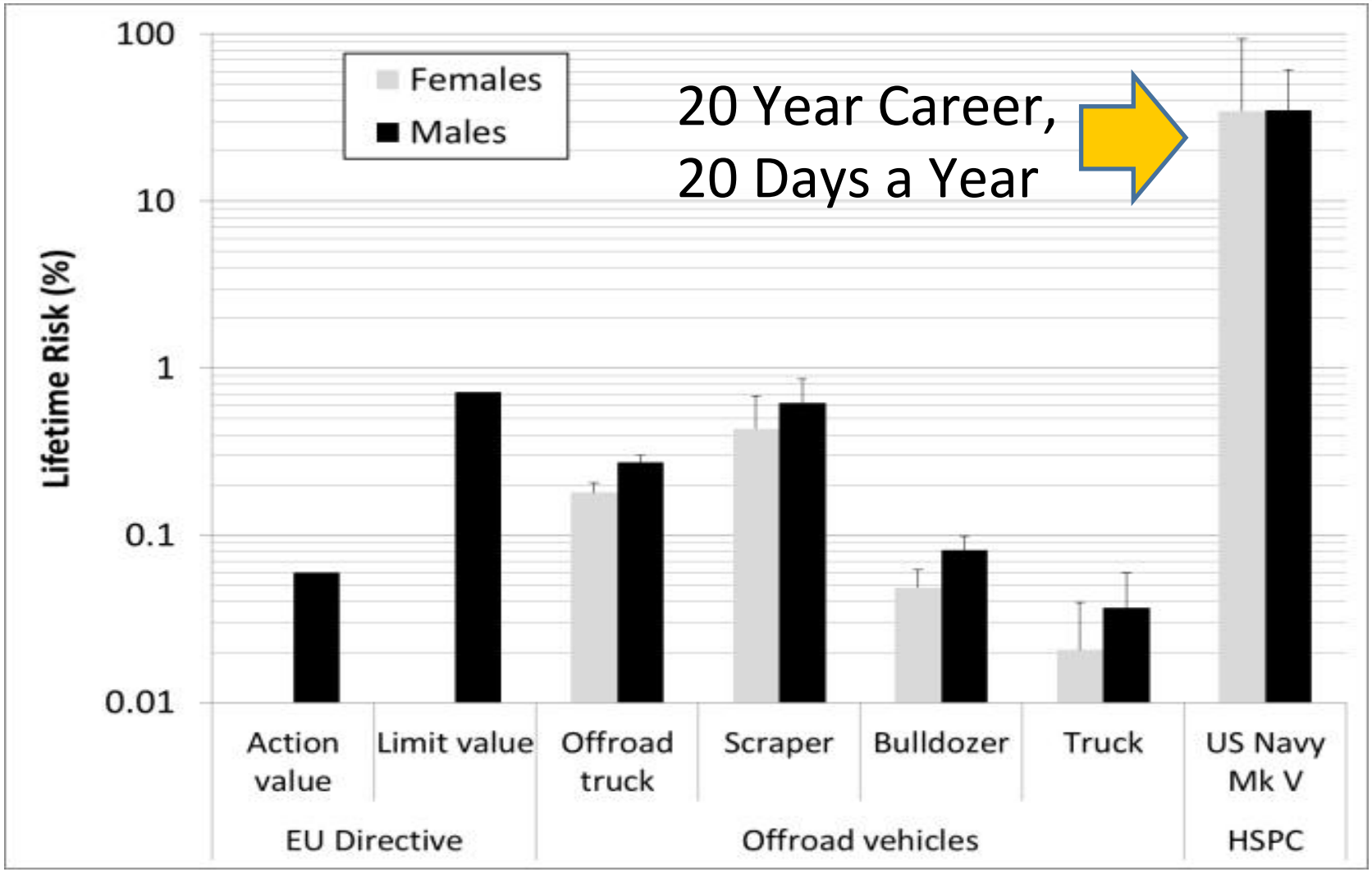
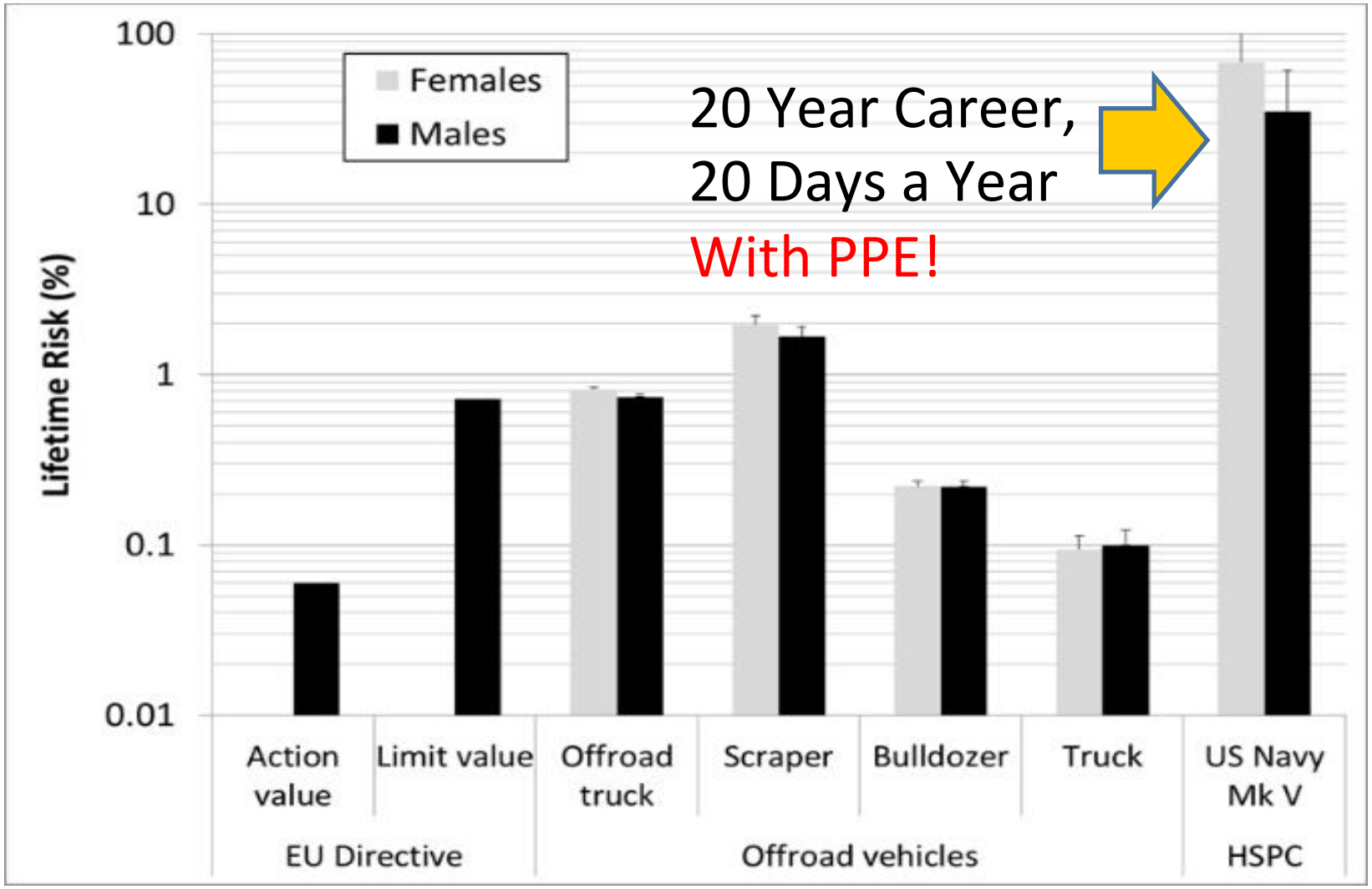
The EU Directive on 'Vibration' Applied to High Speed Craft Injury is *Biomechanically Absurd*

ISO Standard 2631 pt. 5

Implications?



Implications?

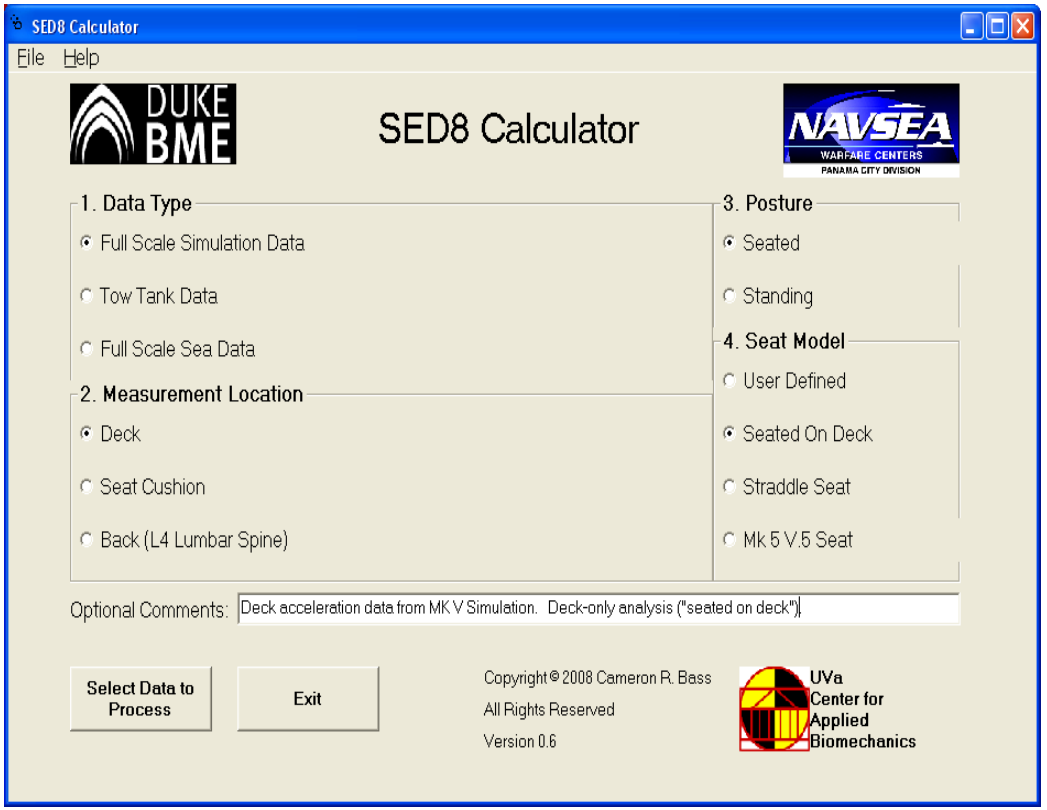


Plug

- Developed by US Navy, Duke
- Basis for ASTM-F1166, Mil Std 1472G, Current work towards ANSI S2, ISO2631 pt. 5

- Injury Assessment for US Naval Craft
  - Used by US HSC Boat-Building Industry starting in Fall 2008
  - Used for US Combatant Craft Medium
  - Soon to be updated
  - Free!

Mail:eric.pierce@us.navy.mil



Bottom Line

- *On average*, men and women are biomechanically different
  - Differences by size (e.g. long bone strength)
  - Intrinsic differences on a stress basis (e.g. lumbar fatigue injury)

- ***Important:*** But may not be true for particular men and women
  - For example, US Smoke Jumper Crews (~5% women)
  - Tend to be taller than average women, much stronger and more fit. *Similar biomechanical profile to the men*.

- Always need to consider distribution beyond the average!

Bottom Line

- Which differences are important, *which are not*
- For example, lumbar spinal injury not especially different…

  …until adding equipment of ‘constant mass’ across sexes
- Size differences often matter
  - Design for 1.4 m – 2.1 m military personnel, may be difficult, depending on craft
  - But if they matter, women are not necessarily small men
- ***Always include the human early in any design***

Source

This presentation has been produced by staff of

Injury Biomechanics Laboratory

Biomedical Engineering – Duke University