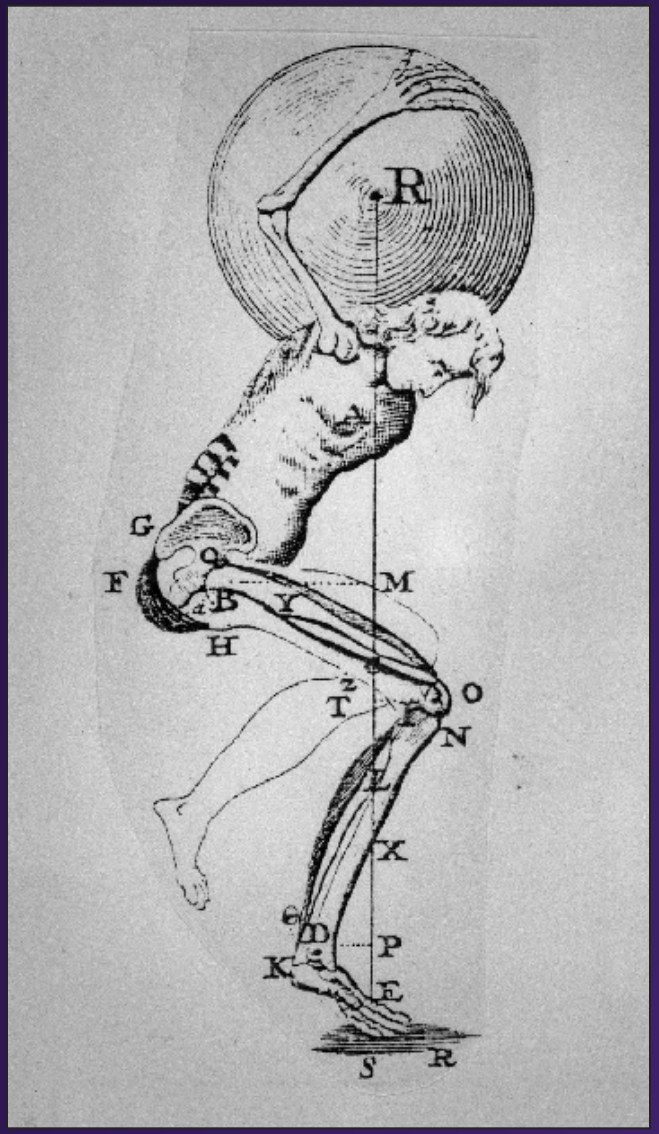


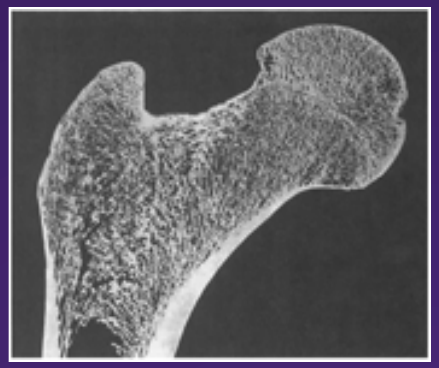
Musculoskeletal Biomechanics

BIOEN 520 | ME 527

Session 17A

Test Considerations and Limitations

Review: Sessions 8-16...



- Intro to cell biomechanics...
- Structure-Function-Properties of Musculoskeletal Structures...

  Bone, ligaments, tendons, cartilage, & muscle

- Anatomy and Biomechanics of Joints and Joint Systems...

  Spine, hip, knee, shoulder, elbow/wrist, and foot/ankle

- Intro to biostats...

Session 17A Discussion Question…

[Q]: During Session 2B, we discussed a number of important test considerations when planning biomechanical experiments… What additional factors should we consider and why?

Hints:
1) *Follow this LINK*
2) *The figure below…*
3) *See S17 handout…*

Considerations discussed in Session 2B

[Q]: What were some of the test considerations we discussed during Session 2B?

S2B

- Research question (hypothesis) / study design
- Biomechanical parameters of interest
- Experimental model (live, cadaver, animal, etc.)
- Environment (temp, humidity, etc.)
- Controls (age, gender, etc.)
- **Additional Factors???**

"Other" Testing Considerations…

[Q]: Based on the "hints" given, what other factors should be considered?

- Model selection & inclusion/exclusion criteria

  Affects the validity and applicability ("generalizability") of our tests results…

- Safety of the subjects and researchers

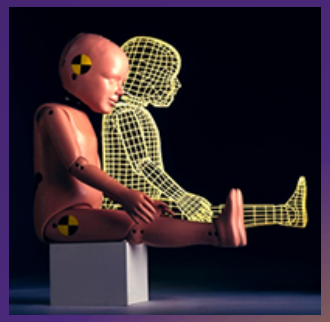
- Cost of tissues and running experiments (time and $)

Model Considerations…

We've discussed numerous model choices…

- Live human volunteers
- Post-mortem humans (PMHS)
- Live animals
- Post-mortem animals
- Non-biologic models

Physical



- Analytical/mathematical models
- Inverse dynamics models
- M-S/Forward dynamics models
- Finite element models

Computational

Model Considerations…

[Q]: Can you think of examples of when model selection and inclusion/exclusion criteria might affect the validity/applicability of our test results?

- Age
- Gender
- Height/Weight
- Pre-existing pathologies

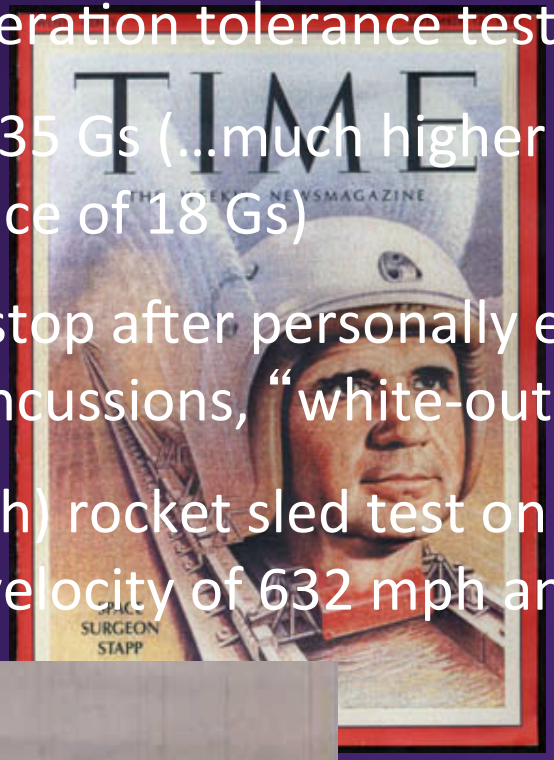
Model Considerations (Human Volunteers)…

- Advantages
  - Physiologic human response
  - Subject feedback (questionnaire)
- Disadvantages (limitations)
  - Can’t test to injurious (or high risk) levels
  - Can be difficult to instrument
  - Can’t directly measure internal forces/strains
  - IRB approval required (privacy/confidentiality)

Model Considerations (Human Volunteers)…

Historical Example: Colonel John Paul Stapp (1910-1999)

- Conducted acceleration tolerance testing on himself.
- Exposed to over 35 Gs (…much higher than the generally accepted tolerance of 18 Gs)
- Commanded to stop after personally experiencing broken ribs, broken wrist, concussions, "white-outs," "red-outs," etc.
- Ran his final (29th) rocket sled test on Dec 10, 1954. Sled reached a peak velocity of 632 mph and peak accel of 46.2 Gs.



Model Considerations (Human Volunteers)...

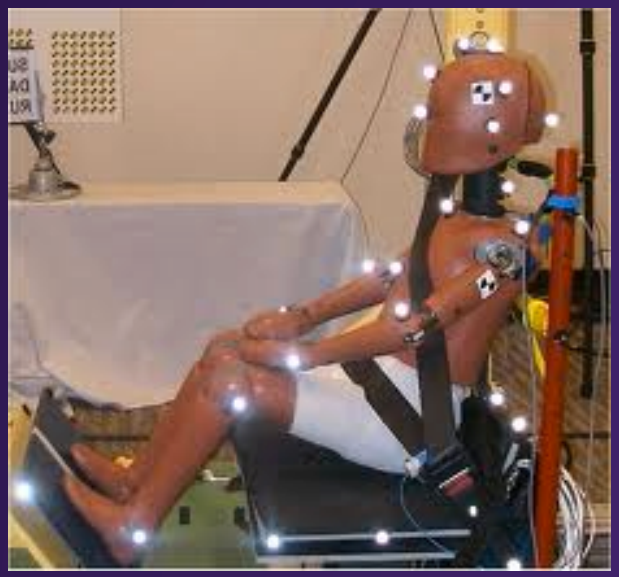
632 mph sled test...

http://www.youtube.com/watch?v=s4tuvOer_GI

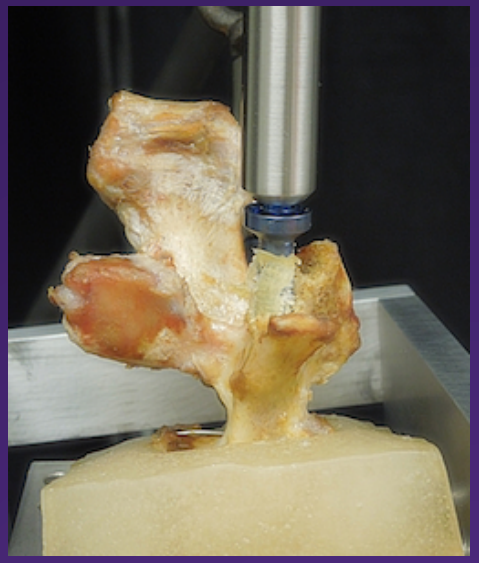
Model Considerations (Human Volunteers)…

Restraint System Example: US Air Force Research Labs

Restraint system tests usually performed using dummies (left), but AFRL able to perform human volunteer testing (right)



Model Considerations (Human Cadavers)…

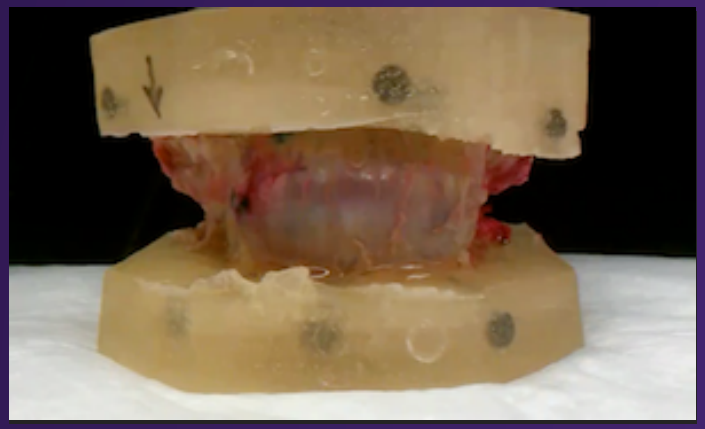


- Advantages
  - Can test to injurious/high risk levels
  - Can dissect to level of inquiry
  - Better fixation of instrumentation
- Disadvantages (limitations)
  - No neurologic or physiologic response
  - Cell death and tissue property changes
  - Can be expensive
  - Biosafety risks to researcher

Model Considerations (Human Cadavers)…

Examples:

- Obtain tissue properties for devices
- Quantify injury tolerance levels
- Examine device performance
- Evaluate surgical procedures



Model Considerations (Live Animals)…

- Advantages
  - Testing of new devices while maintaining physiologic function (e.g., biocompatibility)
  - No privacy/confidentiality issues
- Disadvantages (limitations)
  - Difficult to relate findings to humans
  - Cost of animal husbandry
  - Infectious diseases
  - Need IACUC approval
  - Protest groups

Model Considerations (Live Animals)…

Examples:

- Evaluate implanted medical devices (Bryan disc before human trials)
- Determine threshold for neurologic injury (MEP/SEP)

Model Considerations (Animal Cadavers)…

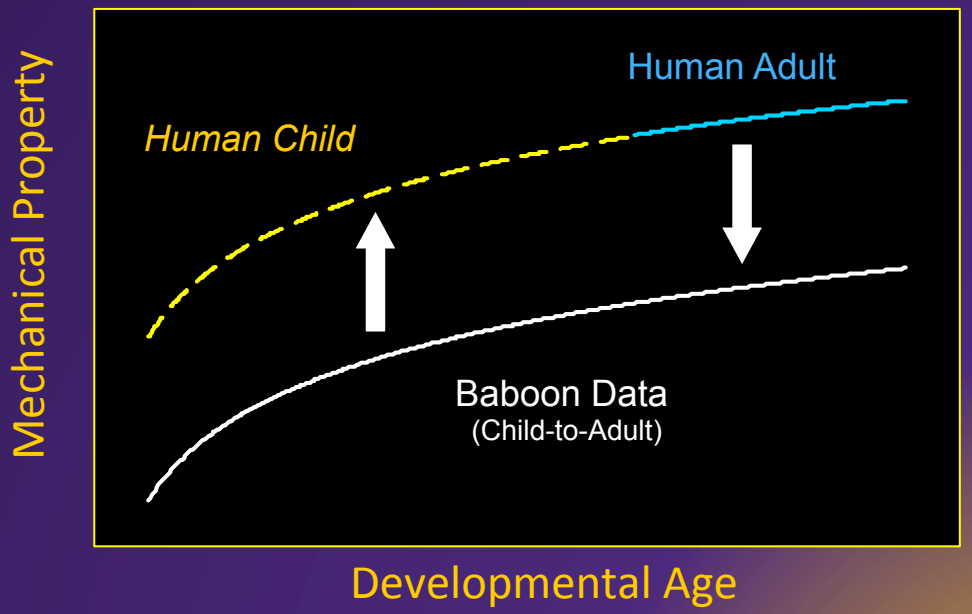
- Advantages
  - Testing of high risk/injurious levels possible
  - Less expensive (…than live/humans)
  - No privacy/confidentiality issues
  - Can dissect to level of inquiry necessary
  - Younger tissues more readily available
- Disadvantages (limitations)
  - Not human
  - No physiologic response
  - Infectious diseases
  - Protest groups

Model Considerations (Animal Cadavers)…

Examples:

- Using immature primates to predict pediatric human tissue properties.

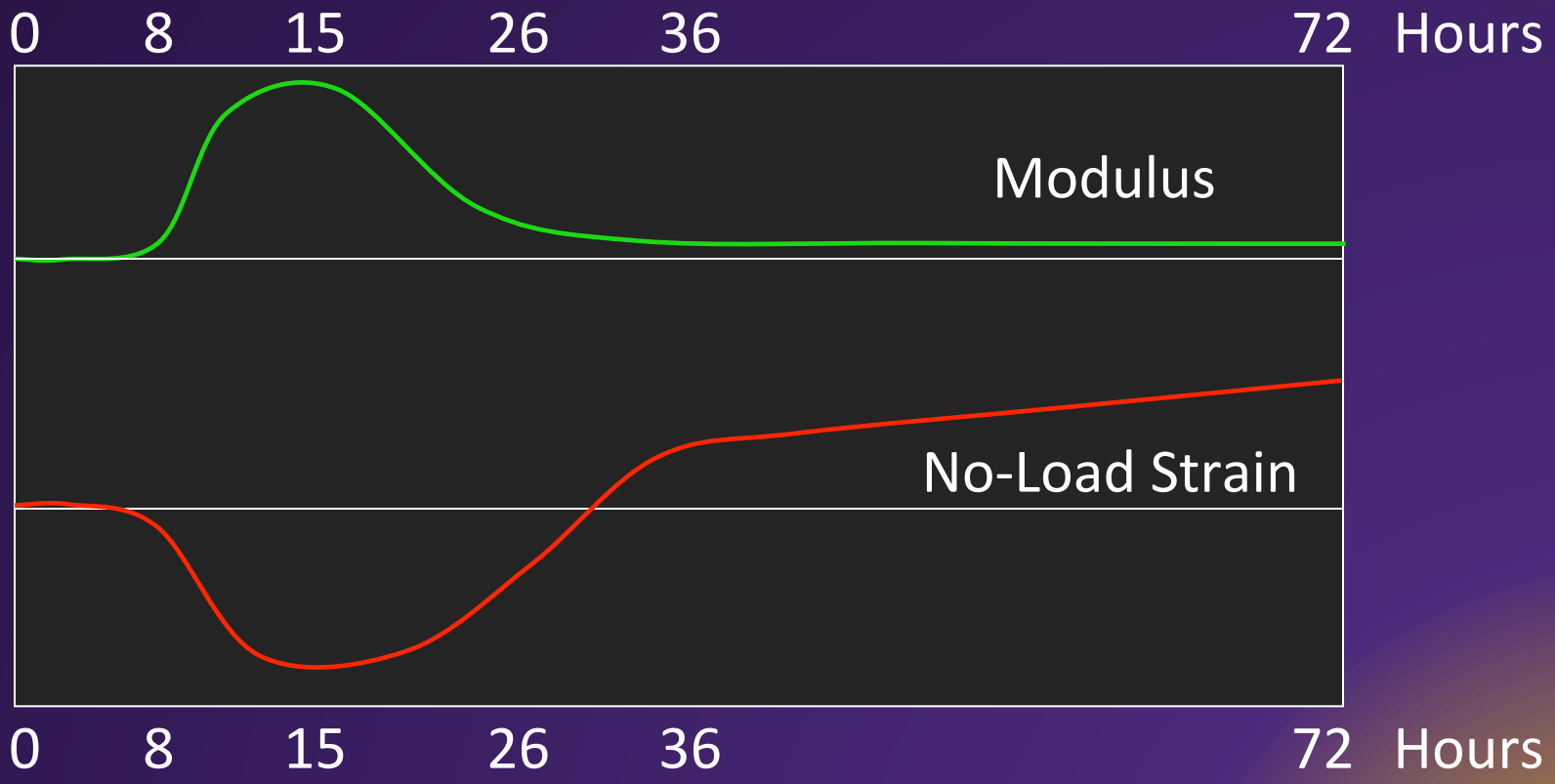
Mechanics of human pediatric C-spine



Model Considerations (Cadavers in general)

- Issues working with cadaver tissues?
  - Biosafety (blood-borne pathogens)
  - Tissue availability (esp. humans)
  - Effects of death on tissue of interest
  - Storage Issues (embalmed/fresh-frozen)
  - Cost (esp. humans)

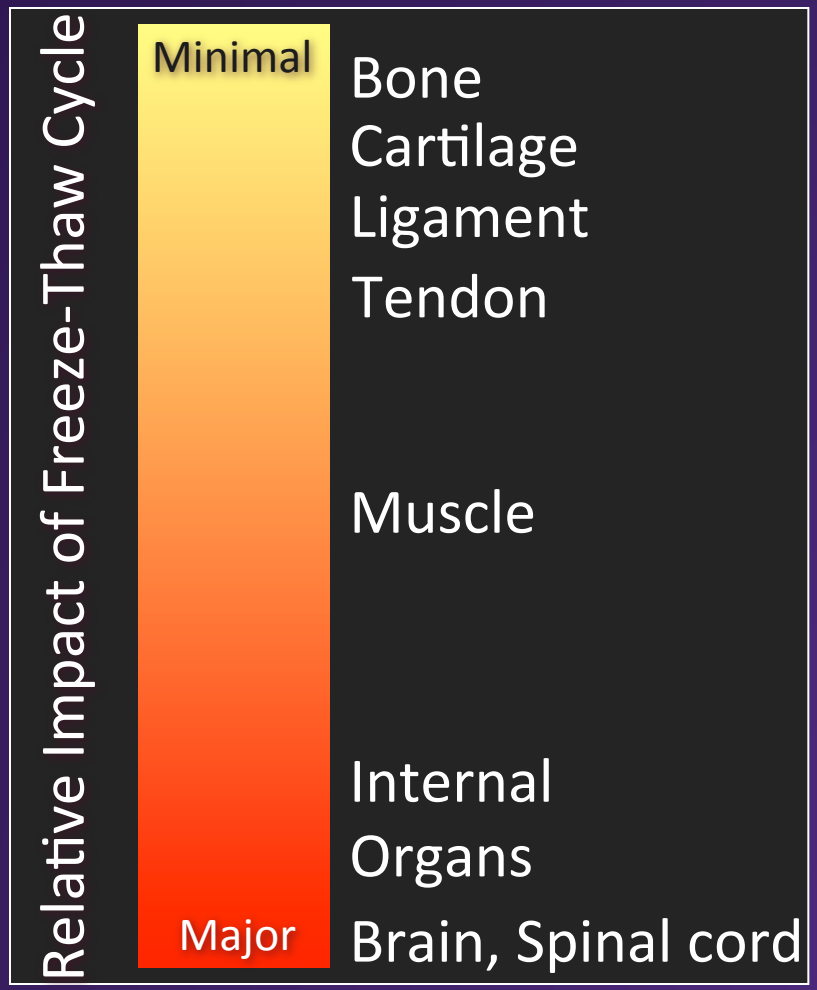
Model Considerations (Cadavers in general)



Van Ee et al., J Biomech Eng 2000

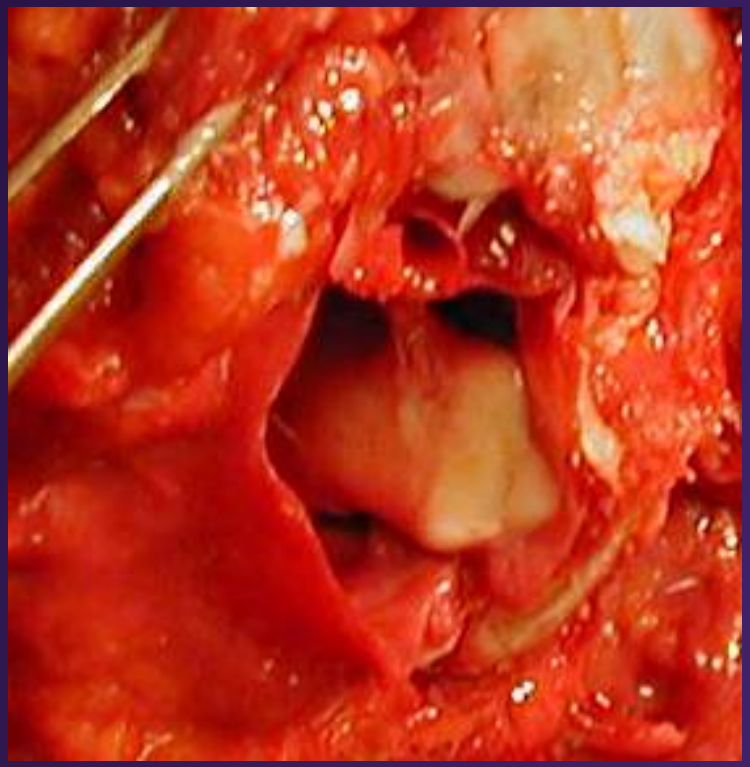
Model Considerations (Cadavers in general)

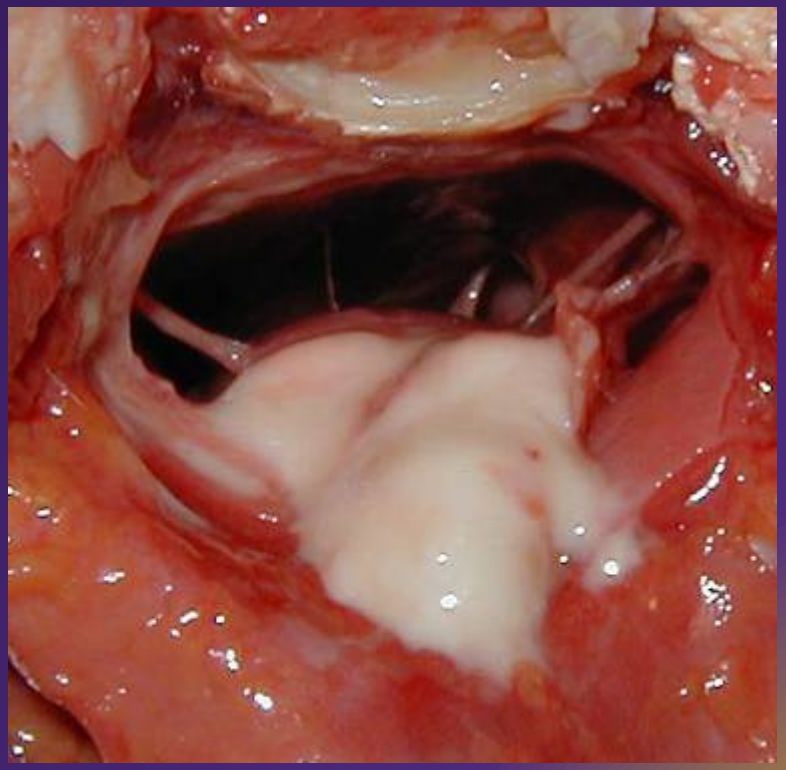
Freeze-Thaw Effects



Model Considerations (Cadavers in general)

Freeze-Thaw Effects





Spinal Cord

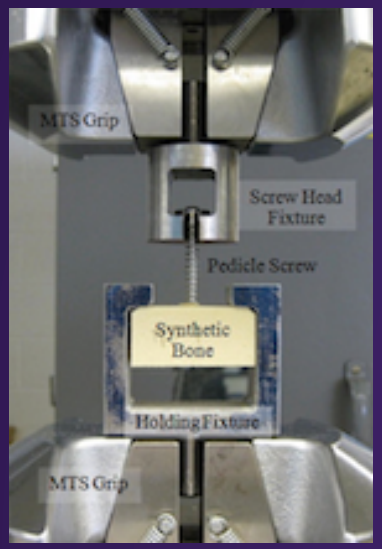
Model Considerations (Non-biologic physical models)

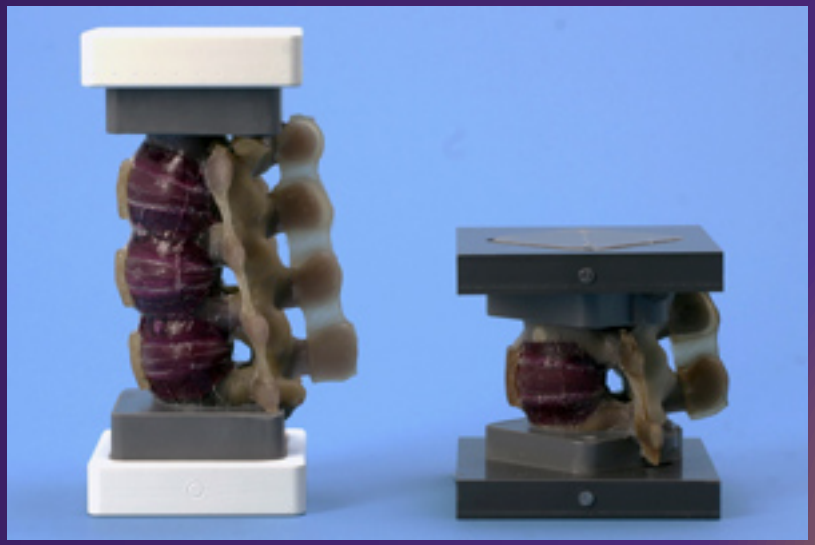
- Advantages
  - Repeatability
  - Instrumentation
  - No biohazard risk
- Disadvantages (limitations)
  - May lack biofidelity
  - Initial cost

Model Considerations (Non-biologic models)

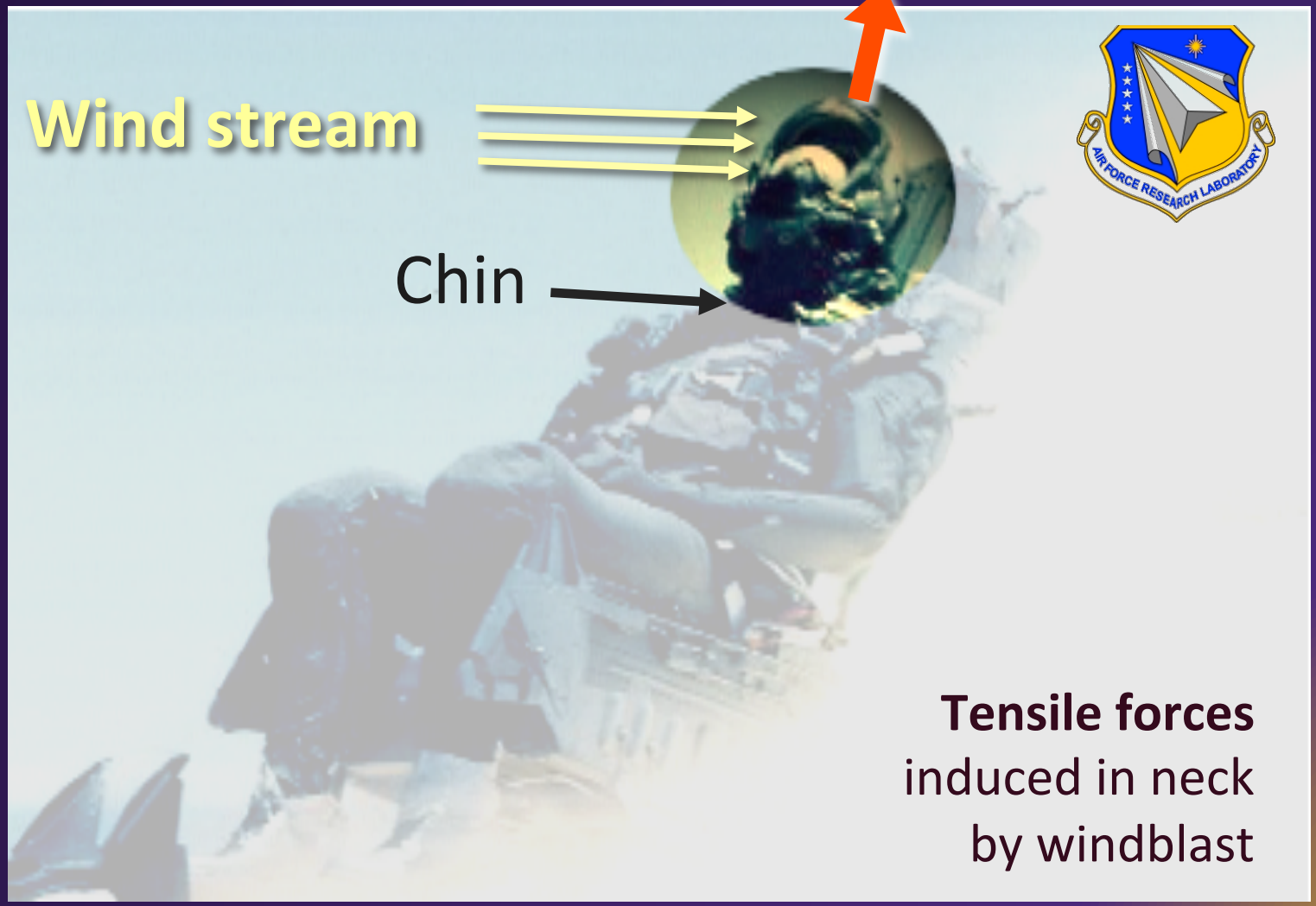
Examples:

- Crash test dummies, helmet headforms, etc.)
- Anatomical models (e.g. Sawbones)
- Representative materials (plastic, foam, rubber, etc.) to answer the biomechanical question



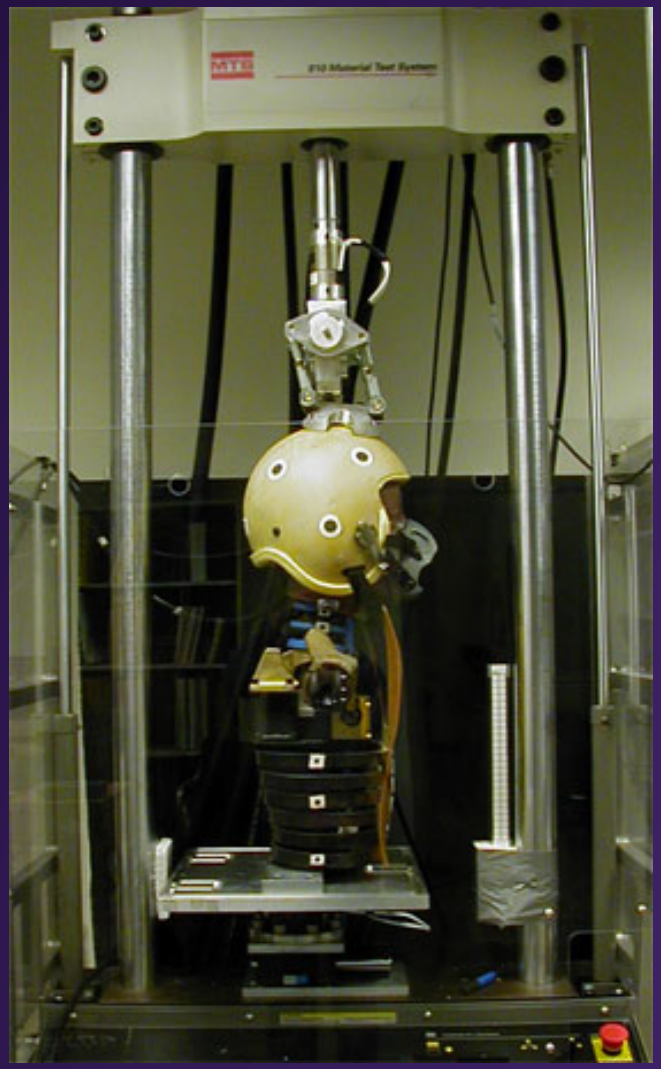


Case Study: Using two models...

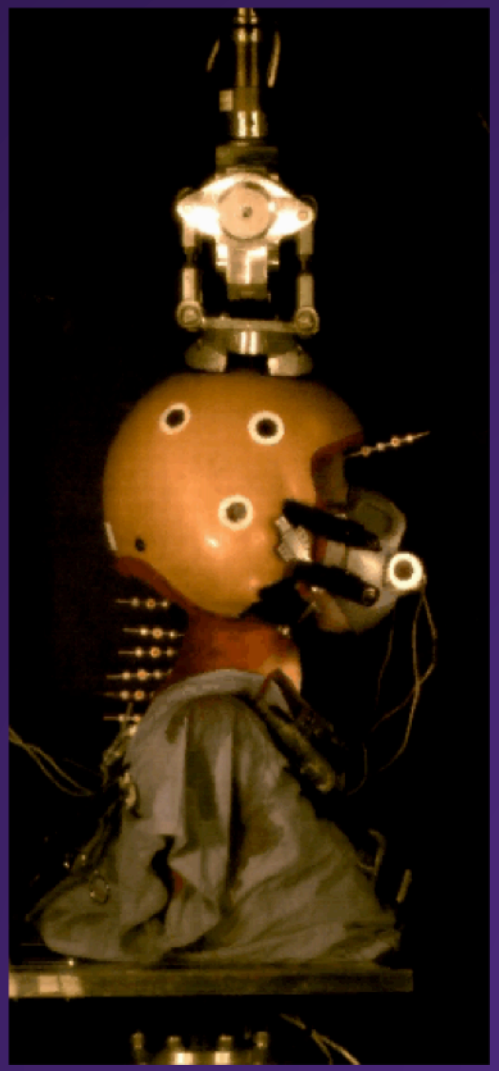


Tensile forces
induced in neck
by windblast

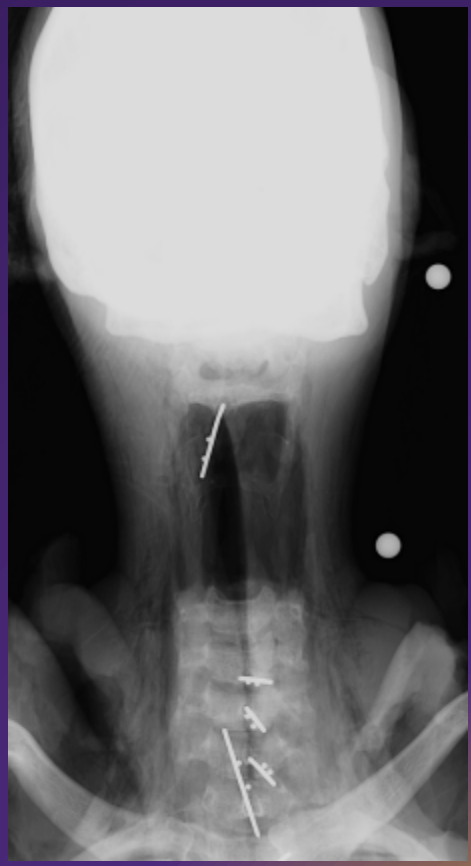
Case Study: Using two models...



ATD



PMHS



C2-C3 Dislocation

Biosafety…

- Lab Certification / Personnel Training

  Biosafey Level-2 (BSL-2) for bloodborne pathogens

- Universal Precautions

  Always assume tissue is a potential hazard

- Wear PPE appropriate for protocol

  scrubs
  gloves
  head covering
  respirator
  face shield
  lab coat
  eye protection
  footwear
  lead shielding
  etc.

Biosafety…

- Tips…
  - Don’t be in a hurry
  - If you get frustrated, take a break
  - Don’t work alone

Costs of Biomechanical Research…

- Examples…
  - Post-mortem animal — free-$50 + storage and disposal fees
  - Live human testing — compensation for participation ($25-100) + IRB
  - Post-mortem human — $100-$5000 + storage and disposal fees
  - Live animal testing — husbandry costs up to $32/day (approx. $11,800/yr) + fees
  - Anthropomorphic Test Devices — >$100,000 for fully instrumented dummy

Costs of Biomechanical Research…

UW Animal Husbandry Costs

Animal	Approx cost per year
Mouse	$380
Rat	$1,000
Rabbit	$1,300
Cat	$9,000
Dog	$9,300
Pig	$11,800

* Doesn't include veterinary fees, initial cost of animal, or processing fees