Biomechanics

- Agenda
  - Review
  - Musculoskeletal disorders
  - Biomechanical modeling

Review: Musculoskeletal Disorders

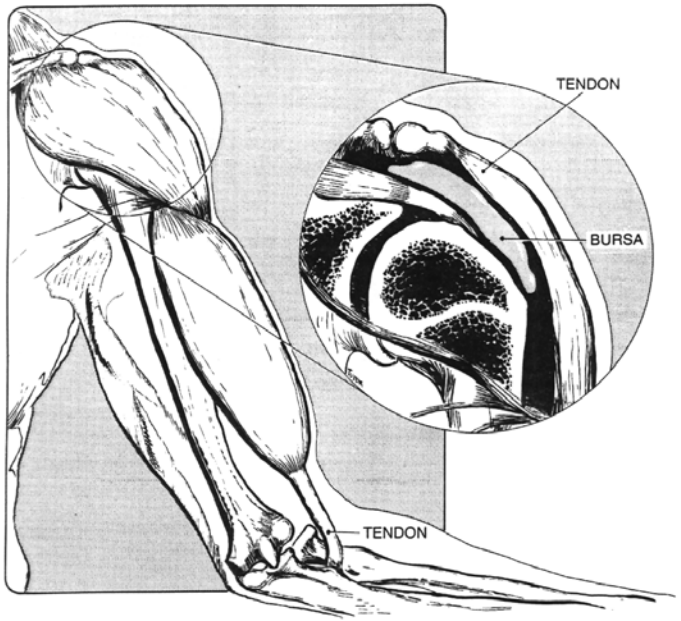
- Definition
  - Intermediate-term (months/years) effects of body activity upon the nerves, muscles, joints, and ligaments.
- Approach to Reducing Musculoskeletal Disorders
  - Written program
  - Employee involvement and training
  - Medical management
  - Program evaluation

Review: Musculoskeletal Disorders

- Main Occupational Risk Factors
  - Repetition/duration
  - Joint deviation
  - Force

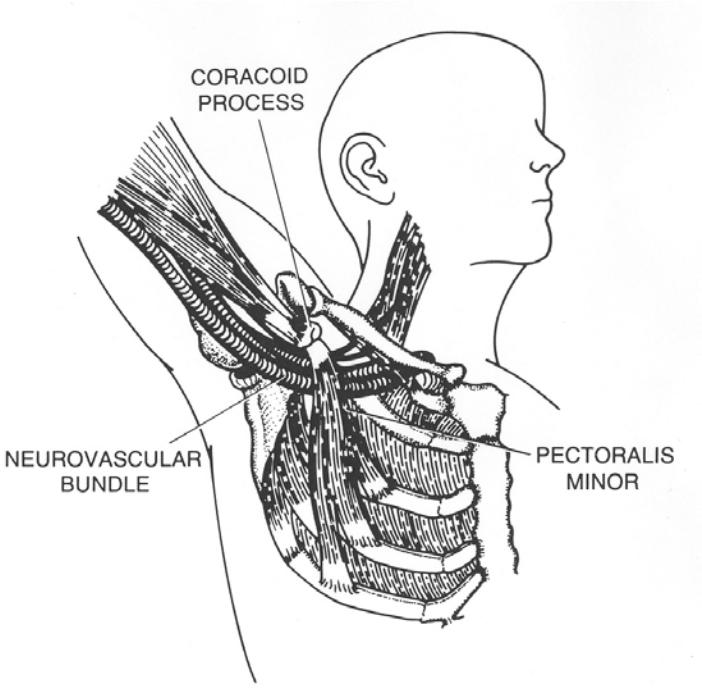
Musculoskeletal Disorders

- Shoulder/Neck Problem
  - Tendonitis: Inflammation of a tendon
    - Most common around shoulders, elbows, knees, and wrists
  - Tendon tears



Musculoskeletal Disorders

- Shoulder/Neck Problem
  - Thoracic Outlet Syndrome
    - Compression of nerves and muscles between neck and shoulder.
  - Shoulder strain/sprain
    - Causes
      - ✓ Muscle overuse from repetition or static exertions
      - ✓ Excessive exertion
      - ✓ Tissue degeneration

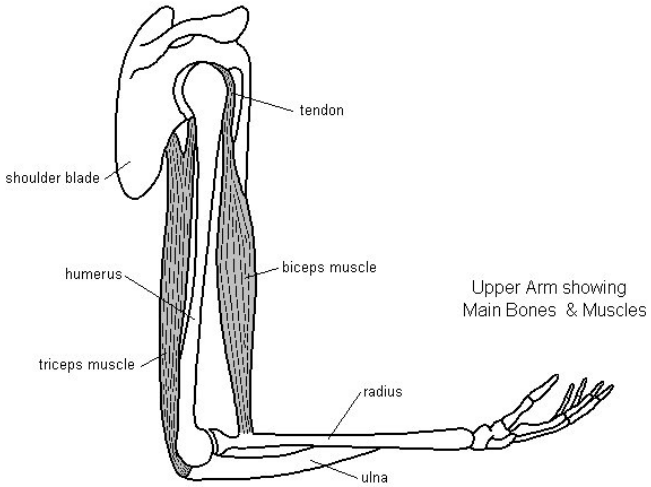


Musculoskeletal Disorders

- Shoulder/Neck Problem
  - Occupational risk factors for shoulder disorders
    - High force
      - ✓ Heavy loads
      - ✓ Loads held away from the body
    - Awkward postures
      - ✓ Overhead reaches
      - ✓ Reaching behind the body
    - Static loading
    - Repetition
    - Dynamics/motion

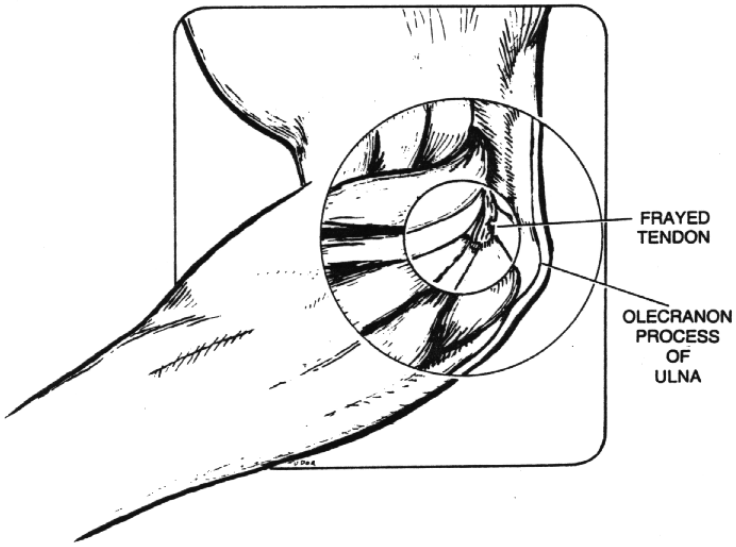
Musculoskeletal Disorders

- Elbow Problem
  - Occupational risk factors
    - Heavy lifting
    - Awkward postures
      - ✓ Extreme pronation/supination
      - ✓ Prolonged flexion/extension of wrist
    - Mechanical stress / Trauma
    - Repetition
      - ✓ Repetitive extension
      - ✓ Repetitive pronation/supination



Musculoskeletal Disorders

- Elbow Problem
  - Tennis elbow:
    - Tendinitis (lateral side of the elbow)
    - Causes
      - ✓ Prolonged or repetitive **extension** of hand
      - ✓ Repetitive pronation/supination
      - ✓ Supination of **gripping** hand



Musculoskeletal Disorders

- Back Problems
  - Are extremely prevalent and costly (only colds cause more doctor visits than back pain).
  - Include:
    - Low-back pain
    - Low-back impairment
    - Low-back disability
    - Low-back compensation

Musculoskeletal Disorders

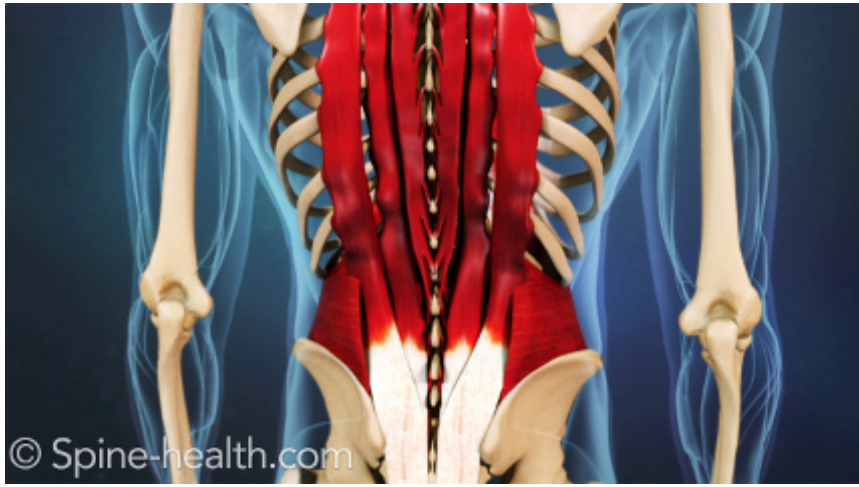
- Back Problems
  - Occupational risk factors for low back disorders (LBDs)
    - Heavy work
    - Static work postures
    - Frequent bending and twisting
    - Lifting and forceful movements
    - Vibration
    - Pushing / pulling
    - Unexpected loading

Musculoskeletal Disorders

- Back Problems
  - Origins of LBDs
    - Degenerative
    - Traumatic: Acute fracture
    - Inflammatory: Infectious swelling
    - Tumors
    - Congenital

Musculoskeletal Disorders

- Back Problems
  - Low back strain/sprain
    - Most common low back disorder
    - Muscle strain or tendon strain due to abnormal stretch of the tissues
    - Ligament sprain or tendon strain due to excessive tension load
    - http://www.spine-health.com/video/lower-back-strain-video
    - Causes
      - ✓ Repetitive lifting, over flexion, sudden movements, etc.
      - ✓ Tissue degeneration

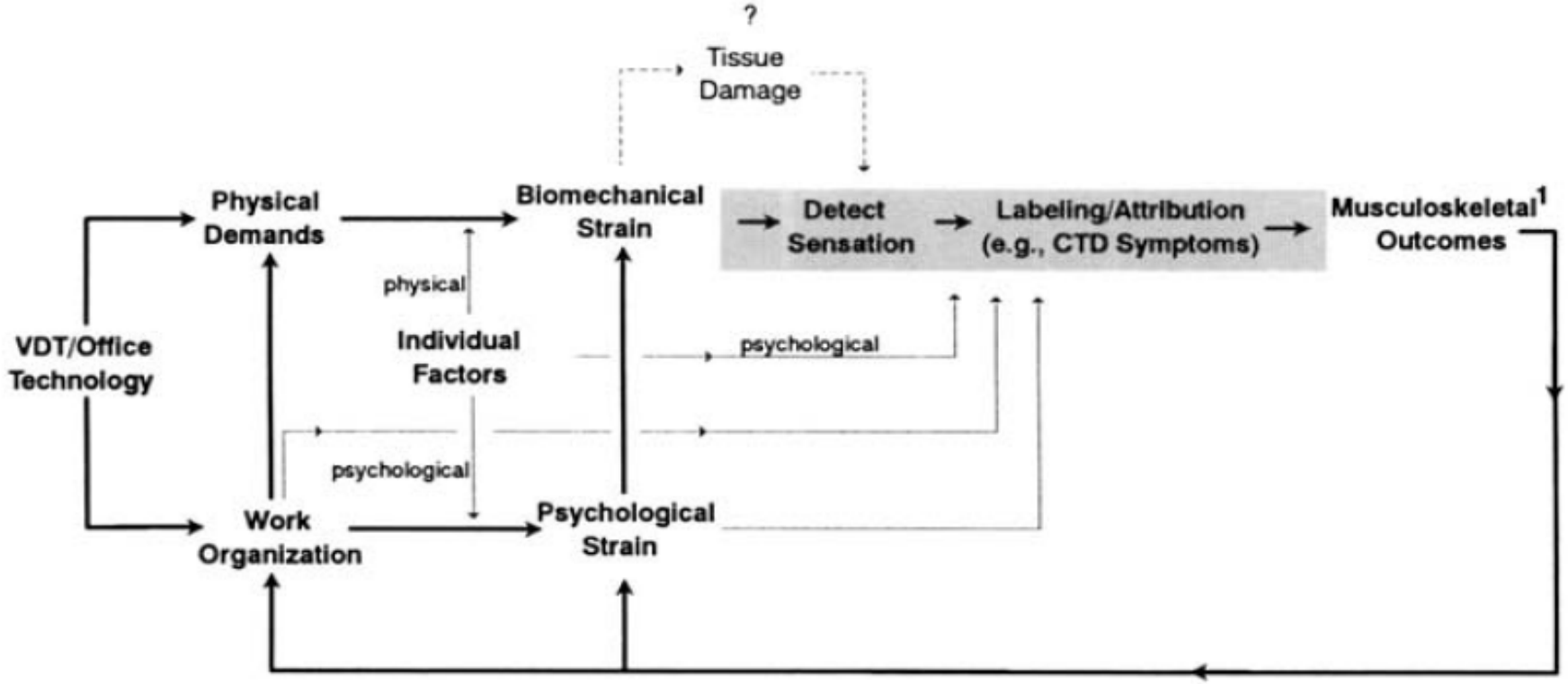


Musculoskeletal Disorders

- Leg Problems
  - Bursitis of the knee from kneeling

Musculoskeletal Disorders

- Ecological model of musculoskeletal disorder in Visual Display Terminal (VDT) work (Sauter, 1996)



1: symptom reporting/complaints; health care utilization; disability; performance problems

Musculoskeletal Disorders

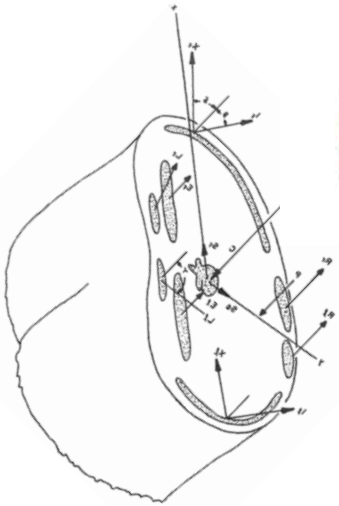
- Engineering Solutions
  - Analyze the job.
  - Work to improve high-risk jobs first.
  - Consider automation or mechanization.
  - Consider job enlargement.
  - Minimize joint deviation.
  - Minimize force duration and amount.

Musculoskeletal Disorders

- Administrative Solutions
  - Job rotation
  - Part-time workers
  - Exercise
  - Stress reduction
  - Supports

Biomechanical Modeling

- Why Biomechanical Model?
  - To simulate various loading conditions.
  - To quantitatively predict responses.
  - To test extreme conditions without concerning subject safety and health.
  - To understand the interaction between various components of the body and environments.



Steps in Developing a Model

- Problem identification
  - Define objectives and purpose
  - Determine type of model
    - e.g. static, dynamic, 2-dimensional, 3-dimensional, numerical, computational
  - Define constants and variables
    - e.g. anthropometric data, moment arm, external load, kinematics

Steps in Developing a Model

- Model formulation
  - Define simple system with objectives and bounds
  - Define input and output
- Obtain mathematical solution
  - Requires of algebraic and numerical methods
- Model validation

Common Goals

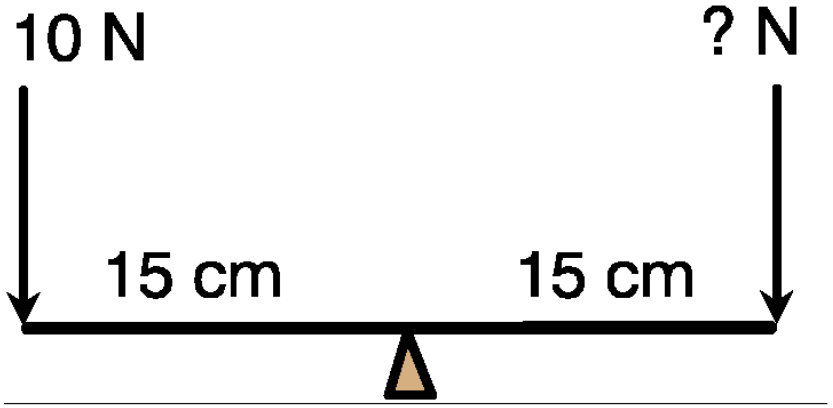
- Estimate muscle force level
- Estimate tissue loading
  - Joint compression, shear, torsion
  - Ligaments tension force
  - Bone impact force
- Estimate tissue deformation
- Estimate posture

Types of Models

- Types
  - Static vs. Dynamic
  - Part of body vs. Whole body

Static Modeling

- Study of bodies at rest
- Free Body Diagram (FBD)
  - Schematic representations of a system identifying all forces and moments acting on the components of the system
    - Rigid body
    - Force vectors
    - Fulcrum

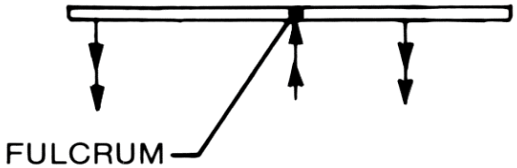


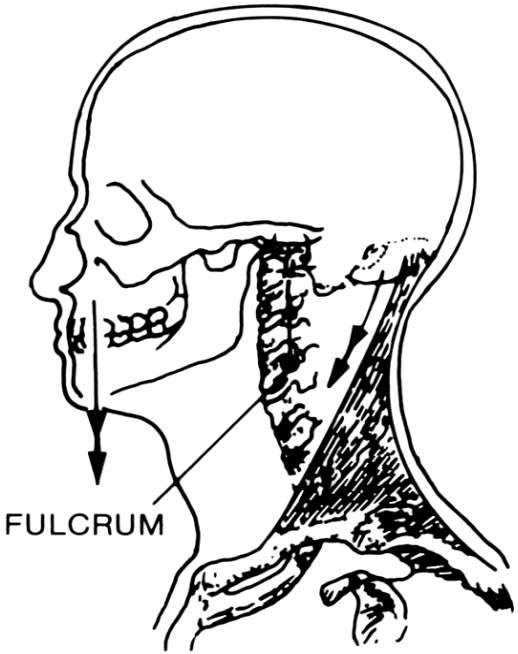
Static Modeling

- Static equilibrium (2-dimensional)
  - Sum of forces equal zero
    - No translation of rigid body
    - $\sum F_V = 0$: to prevent translation vertically
    - $\sum F_H = 0$: to prevent translation horizontally
  - Sum of moments equal zero
    - No rotation of rigid body
    - $\sum M_A = 0$

Skeletomuscular Levers

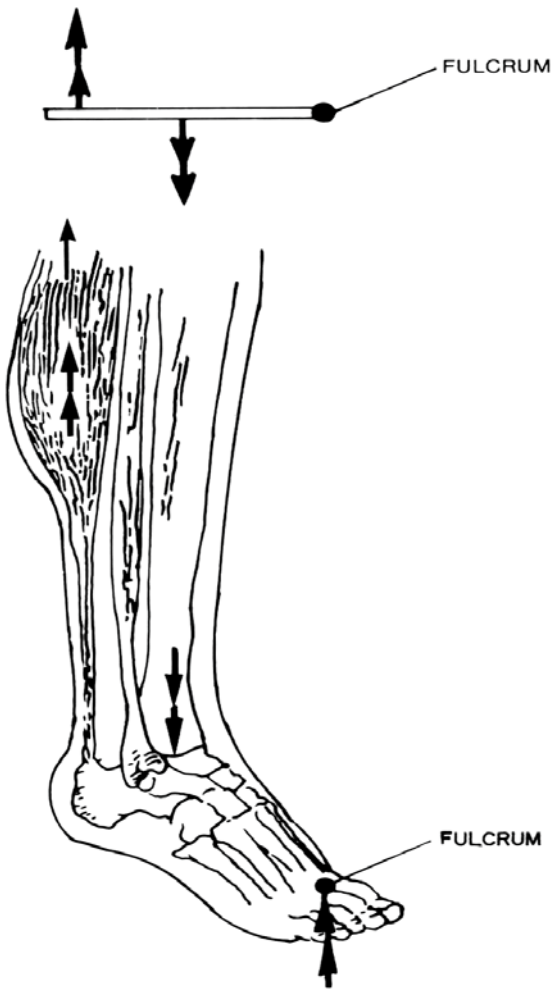
- First-class
  - Fulcrum is **between** the two loads, which is good for **fine positional control**.





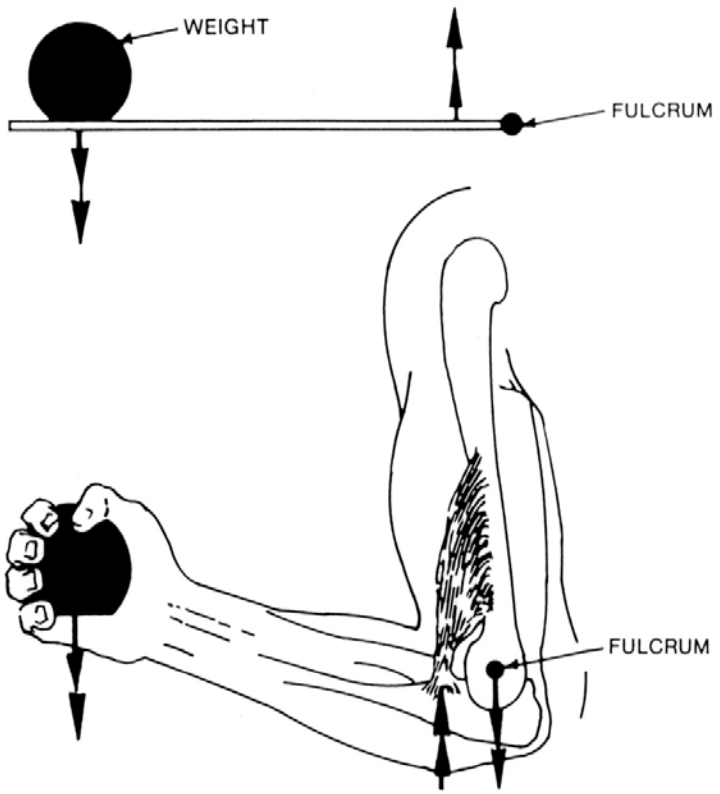
Skeletomuscular Levers

- Second-class
  - Fulcrum is at the **end**.
  - **Force** is exerted through a **longer** moment arm than the **resistance**
  - **Force** has a **mechanical advanta** over the **resistance**.

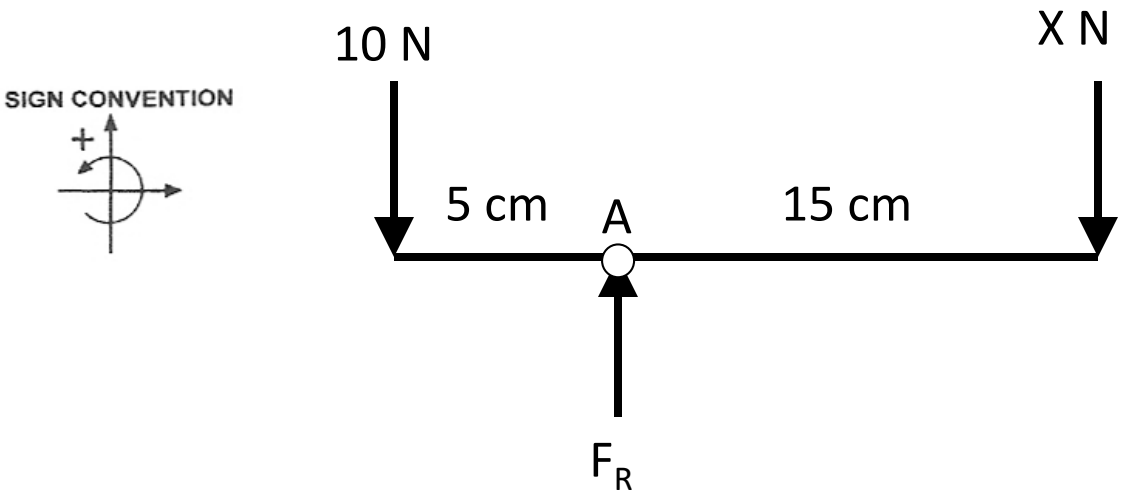


Skeletomuscular Levers

- Third-class
  - Fulcrum is at the **end**.
  - **Force** is exerted through a **shorter** moment arm than the **resistance**
  - **Resistance** has a **mechanical advantage** over the **force**.
  - **Higher internal force** in the body than external force outside the body.



Static Modeling- Problem #1



$\sum F_V = 0$: $F_R - 10 - X = 0$

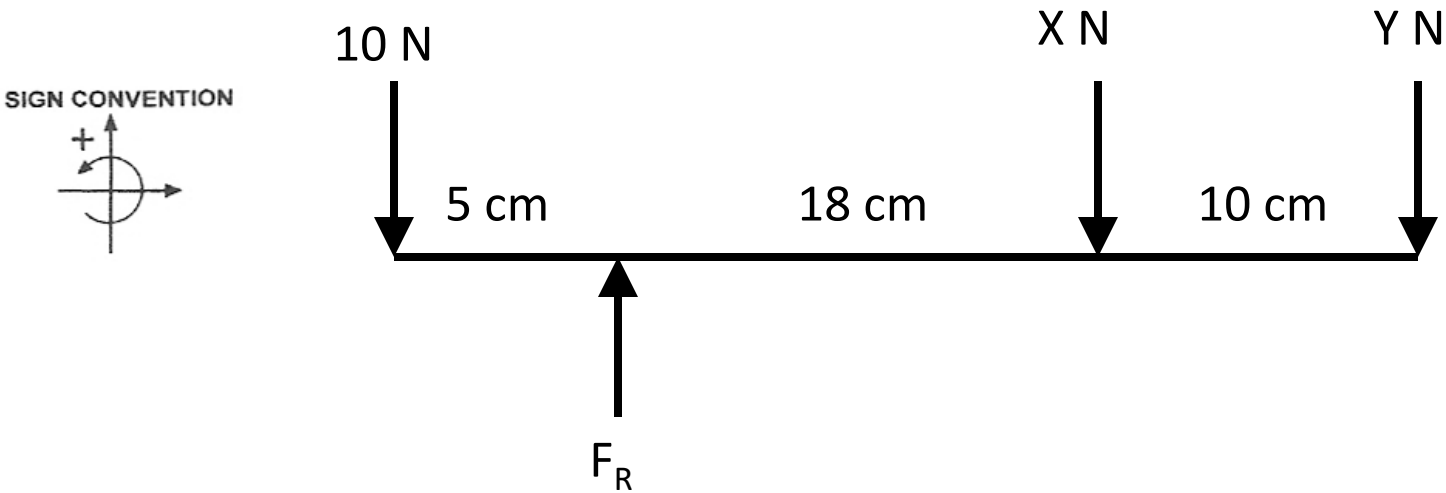
$\sum F_H = 0$: N/A

$\sum M_A = 0$: $10N * 5\ cm - XN * 15\ cm = 0$

$X = (10N * 5\ cm) / 15\ cm = 3.33\ N$

$F_R = 10 + X = 13.33\ N$

Static Modeling- Problem #2



$\sum F_V = 0$: $F_R - 10 - X - Y = 0$

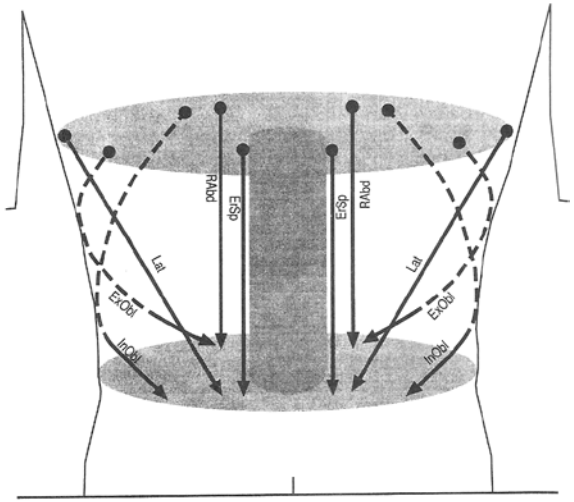
$\sum F_H = 0$: N/A

$\sum M_A = 0$: $10N * 5\ cm - XN * 18\ cm - YN*(18+10)\ cm = 0$

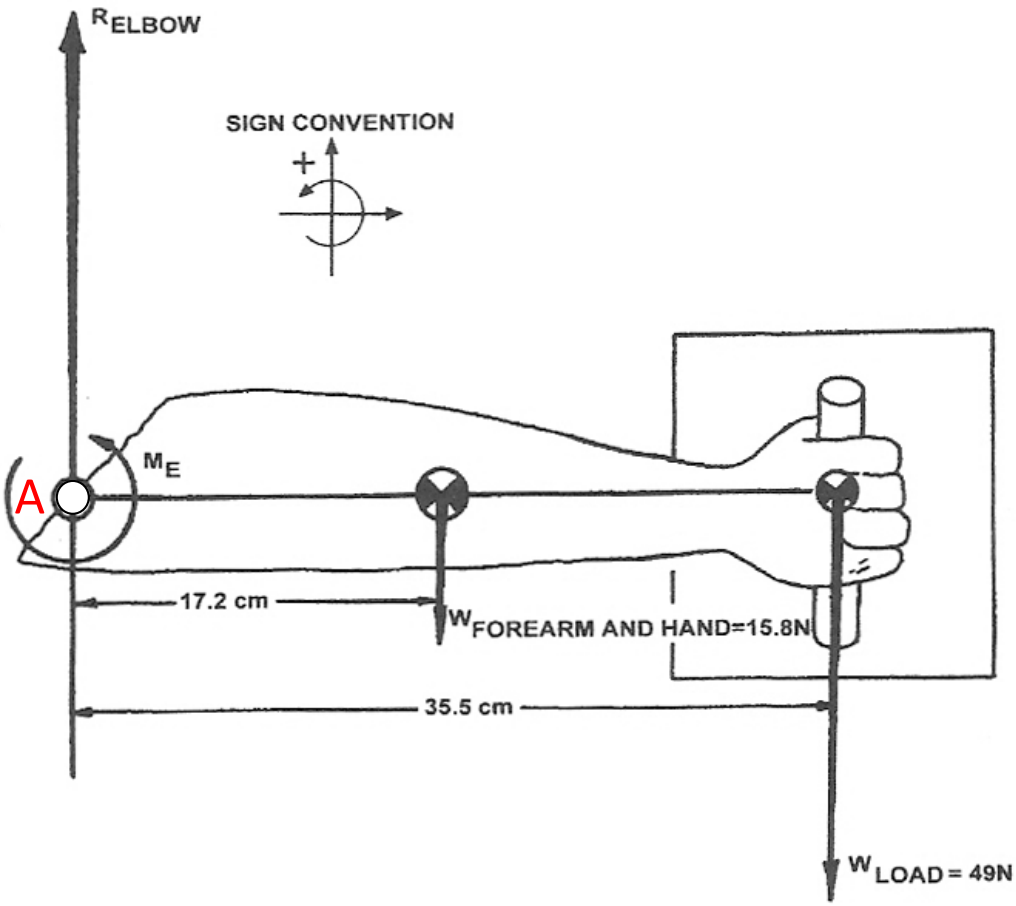
- ✓ 2 equations with 3 unknowns
- ✓ System is statically indeterminate

Static Modeling- Indeterminate

- Static indeterminacy
  - Number of unknowns > number of equations
  - Infinite number of possible solutions
  - Requires additional information to solve
    - Making assumptions or simplification
    - Muscle force estimation using EMG



In-Class Exercise



$\sum F_V = 0$:

$R_{ELBOW} - W_{FOREAR\ AND\ HAND} - W_{LOAD} = 0$

$R_{ELBOW} - 15.8N - 49N = 0$

$R_{ELBOW} = 64.8N$

$\sum F_H = 0$: N/A

$\sum M_A = 0$:

$M_E - M_{FOREAR\ AND\ HAND} - M_{LOAD} = 0$

$M_E - 0.172m*15.8N - 0.355m*49N = 0$

$M_E = 20.1NM$