Biomechanics

Agenda

- Review
- Musculoskeletal disorders
- Biomechanical modeling
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
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
  o High force
    ✓ Heavy loads
    ✓ Loads held away from the body
  o Awkward postures
    ✓ Overhead reaches
    ✓ Reaching behind the body
  o Static loading
  o Repetition
  o 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
  - 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
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

![Diagram of a free body diagram showing a lever with forces and distances labeled. The force is 10 N acting at 15 cm to the left of the fulcrum, and an unknown force (? N) acting at 15 cm to the right of the 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 advantage** 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

\[ \sum F_V = 0: \quad F_R - 10 - X = 0 \]
\[ \sum F_H = 0: \quad \text{N/A} \]
\[ \sum M_A = 0: \quad 10N \times 5 \text{ cm} - XN \times 15 \text{ cm} = 0 \]
\[ X = \frac{(10N \times 5 \text{ cm})}{15 \text{ cm}} = 3.33 \text{ N} \]
\[ F_R = 10 + X = 13.33 \text{ N} \]
Static Modeling- Problem #2

\[ \sum F_V = 0: \quad F_R - 10 - X - Y = 0 \]
\[ \sum F_H = 0: \quad \text{N/A} \]
\[ \sum M_A = 0: \quad 10N \times 5 \text{ cm} - XN \times 18 \text{ cm} - YN \times (18+10) \text{ cm} = 0 \]

✓ 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

Σ \( F_V = 0 \):
\( R_{ELBOW} - W_{FOREAR AND HAND} - W_{LOAD} = 0 \)
\( R_{ELBOW} - 15.8N - 49N = 0 \)
\( R_{ELBOW} = 64.8N \)

Σ \( F_H = 0 \): N/A

Σ \( M_A = 0 \):
\( M_E - M_{FOREAR AND HAND} - M_{LOAD} = 0 \)
\( M_E - 0.172m \times 15.8N - 0.355m \times 49N = 0 \)
\( M_E = 20.1NM \)