Chapter 12

Musculoskeletal Disorders

Supplementary Material from:
Applied Ergonomics.
Overview

- Work Posture and Muscle Fatigue
- Cumulative Trauma Disorders (CTDs)
- CTDs of the Upper Extremities
- Musculoskeletal Disorders of the Back
- Musculoskeletal Disorders of the Leg
- Addressing Musculoskeletal Disorders
Work Posture and Muscle Fatigue
Metabolism

Sufficient Oxygen → Aerobic Metabolism

- Nutrients
- Lactic Acid
- Work
- Heat
- Carbon Dioxide

Anaerobic Metabolism
Metabolism

Aerobic Metabolism

Anaerobic Metabolism

Limited Oxygen

Nutrients

Lactic Acid

HEAT

WORK

Carbon Dioxide
Isometric Contraction and Fatigue

PAIN INTENSITY LEVELS:
- INTOLERABLE
- VERY SEVERE
- SEVERE
- MODERATE
- NOTICEABLE

CONTRACTION TIME (SEC)

55%
40%
(25%) MVC
Shoulder Moments
Work Postures

- Muscles create moments about joints to counteract the moments created by external forces acting on the body.
- Work postures can be classified as good or bad by looking at the moments created by the task at each joint:

**Large Moment + Static Posture = INJURY**
Shoulder Flexion

Average Time (min) for young males to reach significant muscle fatigue (severe pain)

Horizontal Distance

Weight held in hand (N)
Neck Inclination and Fatigue

Average time (min) for young females to reach significant muscle fatigue (severe pain)

Average of five young females

Task
50 min in position with 10-min. rest

Head tilt \( \alpha \) (degrees)
Neutral Posture

- Posture where stress to joints, muscles, vertebrae and tissue is the least
  - Arms at sides
  - Torso, Neck upright
- Body is strongest and most at rest in this posture
Musculoskeletal Disorder Processes

1. **Muscle Fatigue**

   - Required Manual Exertion
   - Frequent or Prolonged Muscle Tension
     - Mechanical Irritation of Tendons
       - Inflammation of Tendon
         - Tendon Pain
       - Inflammation of Synovia and Bursa
         - Chronic Joint Pain
     - Muscle Fatigue
       - Ischemia, Retained Metabolites
         - Edema and Heat
       - Muscle Pain
       - Muscle Spasm
       - Immobilization of Joint
         - 1. Fibrous Reaction
           - 2. Muscle Contracture
           - 3. Reduced Joint Mobility
           - 4. Reduced Muscle Strength
           - 5. Reduced Tendon Motion
         - Functional Disability
     - Acute Muscle Fatigue
       - Reduced Strength and Coordination
Cumulative Trauma Disorders (CTDs)

also called Repetitive Stress Injuries (RSIs)
Musculoskeletal Disorder Processes

CTDs

1. Fibrous Reaction
2. Muscle Contracture
3. Reduced Joint Mobility
4. Reduced Muscle Strength
5. Reduced Tendon Motion

Functional Disability
Cumulative Trauma Disorders (CTDs)

- **Cumulative**
  - develop gradually over periods of weeks, months, years
  - result of repeated stresses on a particular body part
- **Trauma**
  - bodily injury from mechanical stresses
- **Disorders**
  - physical ailments
  - abnormal conditions
Costs Associated with CTDs

- **Incidence (all industries, 1987)**
  - 355 per 100,000 workers for all workers
  - 3920 per 100,000 for meat product workers

- **NIOSH study**
  - 22% of all VDT workers had some type of CTD problem.

- **Average worker's compensation cost per claim:**
  - All CTDs: $14,726
  - Carpal Tunnel Syndrome: $29,000

- **Estimated average total cost per injury:**
  - All CTDs: $20,000
  - Carpal Tunnel Syndrome: $100,000
Costs Associated with CTDs

- OSHA fined the Morell Company $4.33 Million for CTD related problems (1988)
- Samsonite Company settled with OSHA for $495,000 for CTD related problems (1992)
- More recent Lawsuits:
  - Boeing Company successfully sued by one employee for $1.16 M for a CTD related problem using an antidiscrimination law similar to the ADA.
  - Miami Herald reporter initiated a suit for $11.5 M against IBM and other keyboard manufacturers for CTD related injuries
Tendonitis Injuries

- Tendonitis and tenosynovitis injuries are thought result from a large number of micro-traumas to the connective tissues in the tendon.
- Micro-traumas occur regularly in connective tissues. Whether CTDs develop or not seems to depend on the number of micro-traumas and the time available for recuperation.
- Micro-traumas are caused by excessive tensile and shear force on the tendon.
Tendon Disorders

- **Tendonitis**
  - inflammation of the tendon causing pain when tendon placed under tension
  - injuries usually occur at or near joints where the tendon rubs ligaments and bones.

- **Tenosynovitis**
  - inflammation of both tendon and surrounding synovial tissue

- **Stenosing tendonitis**
  - inflammation of both the tendon and the synovial tissue
  - dramatic increase in the friction between the tendon and the tendon sheath
  - synovium swells and constricts tendon
CTDs of the Upper Extremities
Tendon Disorders

- **De Quervain's Disease**
  Stenosing tendonitis of the flexor tendons of the thumb.

- **Trigger Finger**
  (stenosing tenosynovitis crepitans)
  Stenosing tendonitis of flexor tendons of the fingers causing snapping or jerking movements.
Tendon Disorders

- **Tennis Elbow**
  (lateral epicondylitis)
  tendonitis of the elbow extensor muscles at the lateral epicondyle
  (also called pitcher's and bowler's elbow).

- **Golfer's Elbow**
  (medial epicondylitis)
  tendonitis of muscles producing forearm rotation at the medial epicondyle.
Tendon Disorders

- **Ganglionic Cysts**
  (Bible bumps)
  tenosynovitis causing the formation of a cyst filled with synovial fluid in the synovial sheath
  usually occurs in extensor tendons of fingers.
Tendon/Muscle Disorders

- Rotator Cuff Injuries
  - tendonitis or tear of the tendons for the major muscles of the shoulder at medial head of humerus.
Tendon/Bursa Injuries

- Ligaments form a sealed joint capsule that encases a joint and contains fluid to lubricate and protect the tissues.

- Where ligaments are subject to friction, bursa sacks provide lubrication.

- Inflammation of a tendon can irritate adjoining bursa tissues creating bursitis.
Neurovascular Disorders

- Some CTD injuries result in compression or damage to both nervous tissue and vascular tissue.
- Thoracic Outlet Syndrome (CTS)
  - Compression of nerves and muscles between neck and shoulder.
Vibration Syndrome

- Also called Vibration-Induced White Finger, Traumatic Vasospastic Disease and Reynald’s Syndrome.
- Blanching of the fingers due to complete vasoconstriction of the digital arteries.
Carpal Tunnel Syndrome
Carpal Tunnel Syndrome
Carpal Tunnel Syndrome

- **Symptoms**
  - Pain, numbness, and tingling in the areas of the hand innervated by the median nerve primarily at night.
  - Weakness and loss of dexterity in the hand.
  - Atrophy of the thenar muscle at the base of the thumb.

- **Diagnosis**
  - Performance and tactile sensitivity tests.
  - Nerve conduction velocity tests.

- **Treatment**
  - Rest and immobilization using wrist splints.
  - Carpal tunnel release surgery.
Risk Factors Associated with CTDs:

- Occupational Factors:
  - Posture
  - Force
  - Repetition
  - Mechanical stresses
  - Vibration
  - Temperature
  - Repeated exposure without adequate rest

- Non-occupational Factors:
  - Gender
  - Hypertension
  - Arthritis
  - Pregnancy
  - Use of Oral Contraceptives
  - Diabetes
  - Gynecological surgery
  - Alcoholism
  - Post- or pre-menopause
Musculoskeletal Disorders of the Back
Structure of the Spine
Anatomy of the Vertebral Column

- Cervical Curvature
- Thoracic Curvature
- Lumbar Curvature
- Sacrum
- Coccyx

Cervical Vertebra

Lumbar Vertebra
Structure of the Spine

- gray matter
- ventral root
- spinal nerve
- dorsal root and ganglion
- rami communicantes
- spinal cord
- pia mater
- arachnoid
- dura mater
- intervertebral foramen
Spinal Architecture

- **Muscles and ligaments**
  - Maintain structure/ keep spine from buckling
  - Limited force generating

- **Muscles and ligaments keep spine from collapsing**
  - These are what give back strength
  - Work much like guy wires on a radio tower or a ship’s mast
Intervertebral Discs

- Nucleus pulposus - gel like substance
  - Limited shock absorber; allows movement
- Annulus - elastic wall with crisscrossing fibers
- End plates- Thin cartilage structure between disc and vertebra
  - Provides nutrients to disk
Intervertebral Disc
Vertebral Movement

• Facet joints
  - Small bony joints covered with soft tissue that help movement and keep structure.
Herniated Disc
“Slipped” Disc

Herniation into root of spinal nerve

Spinal nerve
Ruptured Disc

RUPTURED DISC

Nucleus Pulposus

Extruded Nucleus Pulposus

Disrupted Annulus Fibrosis

Annulus Fibrosis
Back Problems

- Extremely prevalent and costly
  - 75,000,000 Americans have back problems
  - 6,500,000 Americans in bed each day with back pain
  - 80% working adults develop back pain during career
  - $7,400 per back claim

- Include:
  - Low-back pain
  - Low-back impairment: reduced ability
  - Low-back disability: lost time due to injury
  - Low-back compensation: reimbursement for medical expenses, lost wages
Low-Back Pain Risk Factors

- Individual physical factors, e.g.,
  - Weight
  - Physique
  - Gender
- Psychological factors, e.g.,
  - Depression
  - Anxiety
  - Job dissatisfaction
- Task demand factors, e.g.,
  - Posture
  - Speed
  - Repetition
- Environmental factors, e.g.,
  - Workplace design
  - Slippery floors
  - Distractions
Garg & Moore’s (1992) Risk Factors

- Personal Risk Factors
  - Age [+]
  - Gender [x]
  - Body size [x]
  - Physical fitness [x]
  - Lumbar mobility [x]
  - Strength [x]
  - Medical history [+]
  - Years of employment [x]
  - Smoking [+/-]
  - Psychosocial [+]
  - Structural abnormalities [+]

- Job Risk Factors
  - Heavy physical work [+]
  - Lifting [+]
  - Bending, stretching, reaching [+]
  - Twisting [+]
  - Pushing and pulling [+]
  - Prolonged sitting, standing [+]
  - Accidents [+]
  - Whole body vibration [+]

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  - Prolonged sitting, standing [+]
  - Accidents [+]
  - Whole body vibration [+]
Musculoskeletal Disorders of the Leg
Leg Problems

- Bursitis of the knee from kneeling
- Prepatellar bursitis from vibration while standing
Addressing Musculoskeletal Disorders
Medical/Rehabilitation

- Physical therapy
- Medication
- Surgery
Surgical Repair of the Spine
Addressing Musculoskeletal Disorders

- Recognizing High-Risk Situations
  - Hazard Zone Jobs
  - RULA

- Solutions
  - “Administrative” Solution
  - Engineering Solutions
“Administrative” Solutions

- Job enlargement
- Working rest
- Cross-training
- Job rotation
- Part-time workers
- Training
- Exercise
- Stress reduction
- Supports/braces
- Ergonomics/safety program
  → Engineering solutions
  → Other administrative solutions (above)
Recognizing High-Risk Situations: Hazard Zone Jobs [Box 12.1]

1. Awkward Postures
2. High Hand Force
3. Highly Repetitive Motion
4. Repeated Impact
5. Heavy, Frequent, Awkward Lifting
6. Hand-Arm Vibration
Recognizing High-Risk Situations: Rapid Upper Limb Assessment (RULA) Technique

RULA Employee Assessment Worksheet

Complete this worksheet following the step-by-step procedure below. Keep a copy in the employee’s personnel folder for future reference.

A. Arm & Wrist Analysis

Step 1: Locate Upper Arm Position

1. Adjust...

Step 2: Locate Lower Arm Position

1. Adjust...

Step 3: Locate Wrist Position

1. Adjust...

Final Upper Arm Score

Final Lower Arm Score

Final Wrist Score

Step 4: Wrist Twist

Final Wrist Score

Step 5: Look-up Posture Score in Table A

Table A

Step 6: Add Muscle Use Score

Table B

Step 7: Add Force/Load Score

Table C

Step 8: Find Row in Table C

Final Wrist & Arm Score

SCORES

B. Neck, Trunk & Leg Analysis

Step 9: Locate Neck Position

Step 10: Locate Trunk Position

Step 10a: Adjust...

Step 11: Leg

Legs: 1

Legs: 2

Legs: 3

Legs: 4

Legs: 5

Legs: 6

Legs: 7

Legs: 8

Legs: 9

Legs: 10

Legs: 11

Table C

Posture & Score

Muscle Use Score

Force/Load score

Final Neck, Trunk & Leg Score

Step 12: Look-up Posture Score in Table B

Table B

Step 13: Add Muscle Use Score

Step 14: Add Force/Load Score

Step 15: Find Column in Table 1

The completed score from the Neck/Trunk & Leg analysis is used to find the column on Chart C.

Final Score

Subject:

Company:

Department:

Date:_/___/

Scorer:

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediately
Engineering Solutions

- Analyze jobs.
- Prioritize jobs: high-risk first.
- (Re-) Engineer the job to address
  - Hand/Wrist Problems
  - Shoulder/Neck/Elbow Problems
  - Lower Back Problems
  - Leg Problems
- Mechanize the job.
- Automate the job.
  - “4Ds” tasks:
    - Dangerous
    - Difficult
    - Dirty
    - Disappointing
Engineering Solutions to Hand/Wrist Problems

- Repetition/duration
  - Reduce lifetime use of the joint.
  - e.g., foot-operated controls

- Joint deviation
  - Keep wrist in the neutral position.
  - e.g., workstation geometry, “ergonomic” hand tools

- Force
  - Reduce force duration and amount.
  - e.g., power tools, automation
Engineering Solutions to Shoulder/Neck/Elbow Problems

- Repetition/duration
  - Reduce lifetime use of joint.
  - Minimize one-sided work.
  - e.g., material handling equipment

- Joint deviation
  - Keep the upper arm vertical downward.
  - e.g., keep elbows below shoulders, work below elbow level; sit-stand workstation

- Force
  - Reduce force duration and amount.
  - e.g., material handling equipment
Engineering Solutions to Lower Back Problems

- Address three basic problems:
  - Underuse of the back
    - (e.g., prolonged sitting)
    - Provide for postural variation
  - Whole-body vibration
    - (e.g., in trucks)
    - Shock absorbers, dampers
  - Overuse of the back
    - (e.g., twisting)
    - Redesign the workstation/task
Engineering Solutions to Leg Problems

• Problems:
  – Bursitis of the knee from kneeling
  – Prepatellar bursitis from vibration while standing

• Solutions:
  – Reduce time on the knees
  – Use knee pads or mats
Summary

- Work Posture and Muscle Fatigue
- Cumulative Trauma Disorders (CTDs)
- CTDs of the Upper Extremities
- Musculoskeletal Disorders of the Back
- Musculoskeletal Disorders of the Leg
- Addressing Musculoskeletal Disorders