Human Factors in Accident Prevention

- **Instructor:** Diana Rodriguez Coca
- **Contact:** dmrodri@okstate.edu
  - 520EN
  - 405-744-9631
- **Online Office Hours:**
  - By appointment (email instructor)

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Instructor

Doctor of Philosophy, Industrial Engineering
May 2020
Oklahoma State University

Master of Science, Industrial Engineering
March 2006
Universidad de los Andes, Bogotá D.C. – Colombia

Bachelor of Science: Industrial Engineering
September 2000
Escuela Colombiana de Ingeniería, Bogotá D.C. – Colombia

Research Interests
- Hazardous materials
- Humanitarian logistics
- Redesign of Medical equipment
- Education in engineering

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Human Factors in Accident Prevention

- Tuesdays Live streaming (9:50 am – 11:25 am)
  - Zoom
- Fridays recorded (2:00 pm - 3:35pm)
  - Canvas

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Human Factors in Accident Prevention

Class SWJT Monitor: Wang Minghao
Email: 1960204154@qq.com

Class OSU Monitor: Ryan Laronde
Email: ryan.e.laronde@okstate.edu

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Human Factors in Accident

FPST 3213 6

Human Factors in Accident Prevention

Do you believe this topic is important for you? Why?

FPST 3213 7

Healthy Use of Laptops Everywhere

https://www.youtube.com/watch?v=xUzi9k9d0EI

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Human Factors in Accident Prevention

Catalog Description:

Human factors and workplace ergonomics as it relates to the prevention of accidents and workplace injuries. Fundamentals and techniques of task analysis.

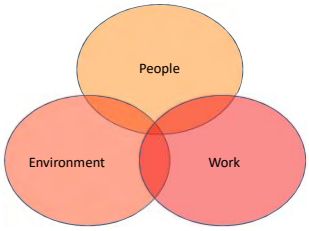
Prerequisites:

FPST 2023, STAT 2013, and
GENT 2323 or ENSC 2113

FPST 3213 9

Ergonomics' Definition

- The study of the relationship between people, work and the physical environment



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Human Factors in Accident Prevention

Course Objectives:

Topics include:

- Anthropometry,
- Biomechanics,
- Workplace design,
- Equipment design,
- Human reliability and human error,
- Manual materials handling
- Industrial Athlete/Fitness for Duty
- Environmental factors (noise, vibration, temperature extremes)

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Human Factors in Accident Prevention

Learning Objectives:

1. Understand the basic principles of human movement and behavior in the workplace.
2. Be aware of how external conditions affect people in the workplace.
3. Complete mathematical analysis to assess risk in the workplace.
4. Be familiar with the standards related to ergonomics and human factors.

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Human Factors in Accident Prevention

Learning Outcomes:

1. Identify common industrial processes in assembly and manufacturing and how they can be improved based on human factors.
2. Effective operation in teams.
3. Consider global workforce issues.
4. Able to apply state-of-the-art techniques to human factors and ergonomic issues.

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Human Factors in Accident Prevention

The final *exam is a mandatory* online comprehensive examination. All students will take the exam on Friday May 20 at 2:00 pm.

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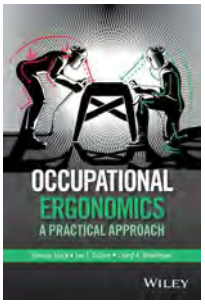
Human Factors in Accident Prevention

Required Texts:

Stack, T., Wilhelmsen, C. A., Ostrom, L. T. (2016). Occupational Ergonomics: A Practical Approach. United Kingdom: Wiley.



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Reading Assignments, Homework,

Reading Assignments
- Listed in Course Outline/Schedule
- Expected to be completed before each class

Homework and Team Project
- Must be submitted in Canvas by established due date
- **Late work will not be accepted**
- Handwritten work will not be accepted unless specifically directed by instructor.

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Team Project

- Ergonomic Risk Factor Evaluations of High Risk Professions
- 5 students/team
  - Report
  - Presentation

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Team Project

Industry Specific Ergonomic Control Plan
1. Transportation
2. Toys manufacturing industry
3. Automobile manufacturing industry
4. Cement manufacturing industry
5. Chemical fertilizers manufacturing industry
6. Steel manufacturing industry
7. Textile manufacturing industry
8. Electronics manufacturing industry
9. Electricity production

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Team Project

- Review of available Injury and Illness data for the occupation/product
- Review of common physical tasks associated with the profession/product
- Review of ergonomic risk factors associated with the tasks/products
- Suggested ergonomic controls that could be implemented to either eliminate or mitigate the risks
- Discussion of costs vs benefit of implementing controls vs. doing nothing

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Human Factors in Accident Prevention

Grading:
Course grades will be determined with the following:

	Qty	Percentage
Homework	10	20%
Team Project	1	35%
Midterm	1	20%
Final	1	25%
Total		100%

A – 85% - 100%
B – 75% - 84%
C – 60% - 74%
F – 0% - 59%

An "F" grade will not count for transfer credit for any FPST curriculum course.

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OSU FPST 3213 - Human Factors in Accident Prevention
Spring 2022

Week	Date	Topic(s)	Reading	Homework
1	3/1	Course Introduction	Syllabus	
	3/4	What is Ergonomics?	Ch2	HW1
2	3/8	MSD & CT	Ch 15	HW2
	3/11	MSD & CT (cont.)		
3	3/15	Physical & Environmental Stressors	Ch 10	HW3
	3/18	Physical & Environmental Stressors		
4	3/22	Physical & Environmental Stressors Team project - activity (computers)	Ch 6, Ch 15	
	3/25	Anthropometry	Ch 3	HW4
5	3/29	Anthropometry (cont.)		
	4/1	Biomechanics	Ch 7	HW5
6	4/5	No class - Holiday		
	4/8	Midterm Exam		
7	4/12	Workplace Design	Ch 4, Ch 11	HW6
	4/15	Equipment Design	Ch 9	HW7
8	4/19	Work Design	Ch 5	HW8
	4/22	Human Reliability	Ch 8	
9	4/26	Human Reliability (cont.)		
	4/29	Manual Materials Handling / NIOSH	Ch 12	
10	5/3	No class - Holiday		
	5/6	NIOSH/WISHA Lifting Equations		HW9
11	5/10	Team Project - Presentations		
	5/13	Snook Tables/ REBA / RULA	Ch 14	HW10
12	5/17	Team Project - Presentations (cont.)		
	5/20	Final Exam		

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Student Responsibilities

- A. Obtain Textbook & course materials
- B. Complete Required Coursework
- C. Attend Lectures and seminars
- D. Avoid Academic Misconduct
- E. Demonstrate Appropriate behavior
- F. Communicate in a Professional Manner

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Reminders

Distinguish Seminar Series is schedule for March 30 at 7 pm (OK time)

FPST 3213 23

5 minutes break

FPST 3213 24

OSHA and Ergonomics

What does OSHA stand for?

OSHA

The Occupational Safety & Health Administration

- Created by the Williams-Steiger Occupational Safety & Health Act of 1970 (aka – "OSHAct")
- Signed into law Dec. 29, 1970 by Richard Nixon

OSHA's Mission

To save lives, prevent injuries and protect America's workers

- By:
  - Providing for research
  - Establishing separate but dependent responsibilities and rights for employers/employees
  - Maintaining reporting & recordkeeping system
  - Establishing safety training programs
  - Developing & enforcing safety standards
  - Evaluating and approving state safety programs
- Through:
  - Strong, fair, and effective enforcement
  - Outreach, education, and compliance assistance
  - Partnerships and other cooperative programs

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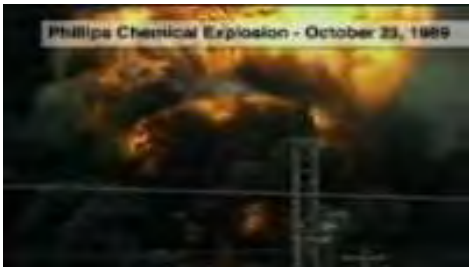
Intro to OSHA



https://www.youtube.com/watch?v=YBrXfwDgz0w

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History

- OSHA has been working on ergonomic issues for more than two decades

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History

OSHA Ergonomics Chronology

Early 1980s	OSHA begins discussing ergonomic interventions with labor, trade associations and professional organizations. OSHA issues citations to Hanes Knitwear and Samsonite for ergonomic hazards.
August 1983	The OSHA Training Institute offers its first course in ergonomics.
May 1986	OSHA begins a pilot program to reduce back injuries through review of injury records during inspections and recommendations for job redesign using NIOSH's Work Practices Guide for Manual Lifting.
October 1986	The Agency publishes a Request for Information on approaches to reduce back injuries resulting from manual lifting. (57 FR 34192)
July 1990	OSHA/UAW/Ford corporate-wide settlement agreement commits Ford to reduce ergonomic hazards in 96 percent of its plants through a model ergonomics program.
August 1990	The Agency publishes "Ergonomics Program Management Guidelines for Meatpacking Plants."
Fall 1990	OSHA creates the Office of Ergonomics Support and hires more ergonomists.
November 1990	OSHA/UAW/GM sign agreement bringing ergonomics programs to 138 GM plants employing more than 300,000 workers. Throughout the early 90s, OSHA signed 13 more corporate-wide settlement agreements to bring ergonomics programs to nearly half a million more workers.
July 1991	OSHA publishes "Ergonomics: The Study of Work," as part of a nationwide education and outreach program to raise awareness about ways to reduce musculoskeletal disorders.
July 1991	More than 30 labor organizations petition Secretary of Labor to issue an Emergency Temporary Standard.

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History

OSHA Ergonomics Chronology

January 1992	OSHA begins a special emphasis inspection program on ergonomic hazards in the meatpacking industry.
April 1992	Secretary of Labor denies petition.
August 1992	OSHA publishes an Advance Notice of Proposed Rulemaking on ergonomics.
1993	OSHA conducts a survey of general industry and construction employers to obtain information on the extent of ergonomics programs in industry and other issues.
March 1995	OSHA begins a series of meetings with stakeholders to discuss approaches to a draft ergonomics standard.
January 1997	OSHA/NIOSH conference on successful ergonomic programs held in Chicago.
April 1997	OSHA introduces the ergonomics web page on the Internet.
February 1998	OSHA begins a series of national stakeholder meetings about the draft ergonomics standard under development.
March 1998	OSHA releases a video entitled "Ergonomic Programs That Work."
February 1999	OSHA begins small business (Small Business Regulatory Enforcement Fairness Act (SBREFA)) review of its draft ergonomics rule and makes draft regulatory text available to the public.
April 1999	OSHA's Assistant Secretary receives the SBREFA report on the draft ergonomics program proposal, and the Agency begins to address the concerns raised in that report.
November 1999	OSHA publishes proposed ergonomics program standard.

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History

- November 23, 1999 OSHA released a proposed ergonomics standard…and it was terminated almost immediately
- Ergonomics Program. | Occupational Safety and Health Administration (osha.gov)

Unknown, Unknown, "16." Accident Prevention Manual for Business & Industry: Administration and Programs, by Philip Hagan et al., National Safety Council, 2015, pp. 401–402.

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Why do you think it was terminated almost immediately????

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OSHA

- Policy
  - Before issuing any "citation" alleging ergonomic hazards, OSHA will consider the evidence and determine if:
    - whether an ergonomic hazard exists
    - whether that hazard is recognized
    - whether the hazard is causing, or is likely to cause, serious physical harm to employees
    - whether a feasible means exists to reduce the hazard

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OSHA

- Good faith efforts = no enforcement efforts
- No citations issued but ergonomic hazards exist
  - Issue an ergonomic hazard alert letters (EHAL)
    - Recommendations on how to reduce hazards
    - List of available resources
    - OSHA has an EHAL Follow-up procedure
      - Follow-up within 12 months of issuing an EHAL
      - Ergonomic Hazard Alert Letter Follow-up Policy | Occupational Safety and Health Administration (osha.gov)

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OSHA Today

- Directives and Enforcement Policies
  - Inspection Guidance for Poultry Slaughtering and Poultry Processing Establishments. OSHA Memorandum, (October 28, 2015)
  - Inspection Guidance for Inpatient Healthcare Settings. OSHA Memorandum, (June 25, 2015)
  - Ergonomic Hazard Alert Letter Follow-up Policy. OSHA Directive CPL 02-00-144, (April 11, 2007)
  - https://www.osha.gov/SLTC/ergonomics/index.html

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OSHA

- Industry specific guidelines exist
  - What if you are not in one of those industries?
- What will the OSHA enforcement program entail?
  - OSHA has been assessing MSD-related issues in complaints, referrals, and targeted inspections

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OSHA

- What about construction?
  - Where appropriate in the construction industry, OSHA will continue to evaluate MSD-related issues through targeted inspections and response to worker complaints

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OSHA

- Will OSHA notify employers who have high rates of MSDs?
  - Yes. Part of Site Specific Targeting (SST)
  - Annual notification
    - Employers in the OSHA Data Initiative who report high Lost Workday Injury and Illness rates at their establishment(s)
    - Recommendation to seek assistance to address hazards

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California Repetitive Motion Injury Prevention standard

- In 1993, Assembly Bill 110 Section 6357 to the Labor Code required the California Occupational Safety and Health Standards Board ("Standards Board") to adopt:
  - "[O]n or before January 1, 1995... standards for ergonomics in the workplace designed to minimize instances of injury from repetitive motion."

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California Repetitive Motion Injury Prevention standard

- Mid-1993
  - the Standards Board was relying on the Division of Occupational Safety and Health's public Ergonomics Advisory Committee to develop an ergonomics standard for adoption
- Late 1993
  - the California Notice Registry contained the ergonomics standard (8 CCR Section 5110) proposed by the Division based on the public advisory committee
- Late 1994
  - the Standards Board voted down Section 5110
    - Two large public hearings
    - Over 6,500 written comments

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California Repetitive Motion Injury Prevention standard

- Early 1995
  - Standards Board was sued by the California Labor Federation
    - Three named injured workers
    - Failure to "adopt" a standard "to minimize instances of injury from repetitive motion"
    - The Superior Court ordered the Standards Board to develop and adopt a standard December 1996

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California Repetitive Motion Injury Prevention standard

- Late 1995, the Standards Board published a proposed repetitive motion standard
- Late 1996
  - Standards Board adopted 8 CCR Section 5110 entitled "Repetitive Motion Injuries."

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California Repetitive Motion Injury Prevention standard

- The Office of Administrative Law approved 8 CCR Section 5110 on 3 June 1997, and the new repetitive motion injury standard became legally enforceable in California on 3 July 1997
- Title 8 Index (ca.gov)

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California Repetitive Motion Injury Prevention standard

- Further lawsuits ensued
  - Late 1999, Appellate Court concluded "that, except for one conspicuous exemption [small employer exemption], the regulation [8 CCR Section 5110] is valid…"

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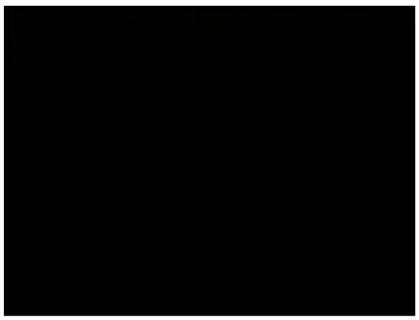
OSHA - Ergonomics



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Do you follow OSHA standards in China?

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What does MEM stand for?

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China regulations

- Ministry of Emergency Management
- Law of the People's Republic of China on Work Safety
- Law of the People's Republic of China on Occupational Diseases Prevention and Control

FPST 3213 50

Ministry of Emergency Management

- Oversee the management of a wide range of natural and made-made disasters.

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The Law of the People's Republic of China on Safe Production

- Rights and responsibilities of workers, employers and government agencies in creating and maintaining a safe workplace

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The Law of the People's Republic of China on Safe Production

- Employees have the right to stop any work they deem to be unsafe. Employers may not cut the pay, benefits, or dismiss any worker who stops work for reasons of safety (Article 52).
- Workers cannot be fired or retaliated against for criticizing or reporting their employer for work safety concerns, or for refusing orders to perform unsafe work (Article 51).
- Employers must provide employees with proper safety equipment suitable to the nature of their work, and keep that equipment up-to-date and in working order (Articles 32, 33).
- Employers must also provide safety training, and not allow any worker who has not had proper training to work on the job site (Article 25).

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The Law of the People's Republic of China on Safe Production

- Employers must purchase work-related injury insurance for all employees (Article 48).
- The trade union may monitor workplace safety conditions, raise suggestions, and participate in the investigation into workplace accidents (Article 57).
- Workers have the right to participate in the management of work safety through the trade union. When a company changes its work safety guidelines it should take into account the suggestions of the trade union (Article 5).
- Journalists have the right to report on violations of workplace safety for the purposes of educating the public (Article 74).

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Law of the People's Republic of China on Occupational Diseases Prevention and Control

- Amend the second paragraph of Article 2 to say: "Occupational diseases referred to in this Law refer to diseases caused by exposure to dust, radioactive substances and other toxic and harmful factors in the professional activities of workers employed by enterprises, institutions and individual economic organizations." "

FPST 3213 55

Law of the People's Republic of China on Occupational Diseases Prevention and Control

- Article 3 shall be amended to: "The prevention and treatment of occupational diseases shall adhere to the principle of prevention-oriented and combined prevention and control, establish a mechanism for the responsibility of employers, supervision by administrative organs, self-discipline of the industry, participation of workers and social supervision, and implement classification management and comprehensive governance." "

FPST 3213 56

Law of the People's Republic of China on Occupational Diseases Prevention and Control

- Article 7 shall be changed to Article 8 and amended to read: "The State encourages and supports the development, development, promotion and application of new technologies, new processes, new equipment and new materials conducive to the prevention and treatment of occupational diseases and the protection of the health of workers, strengthens basic research on the mechanism and occurrence of occupational diseases, and improves the level of science and technology for the prevention and treatment of occupational diseases;

FPST 3213 57

Conclusion

- The study of the relationship between people, work and the physical environment
  - OSHA
  - China government

FPST 3213 58

To do list

1. Team Project: Submit team members.
   (5 students per team)

1. Read Ch 2 before the next class

FPST 3213 59

1

What is Ergonomics?

2

Ergonomics

- Derived from two Greek words:
  - Ergon = Greek for “work”
  - Nomos = Greek for “laws of”
- Term 1st used in 1857 by Wojciech Jastrzebowski
  - “An Outline of Ergonomics, or the Science of Work”

FPST 3213 3

3

History of Ergonomics

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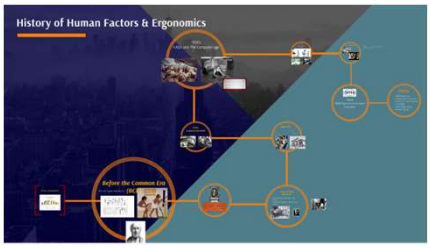

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4

Ergonomics	Human Factors
• How work affects people	• Human machine interface
• Reduce fatigue	• Reduce the potential for human errors

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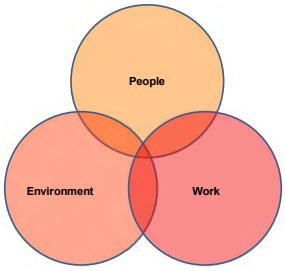
5

Ergonomics / Human Factors



Prevent musculoskeletal disorders.

Reduce the potential for human errors.

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6

OSHA - Ergonomics

FPST 3213 7

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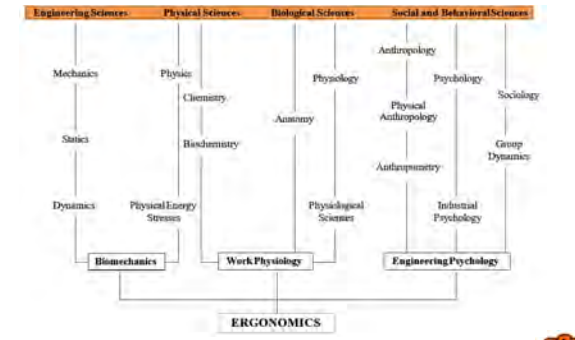
Ergonomics and Other Sciences



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Ergofacts

- 2.3 million people worldwide die from work-related accidents and diseases every year.
- 270 million people suffer work injuries/year
- 60 million suffer from short or long term illnesses related to their work annually

International Labor Organization (ILO)

FPST 3213 9

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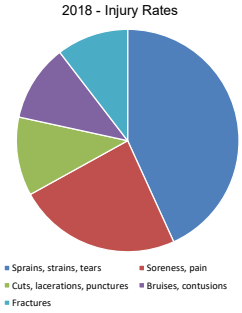
Bureau of Labor Statistics

https://www.bls.gov/iif/soii-data.htm

Nonfatal occupational injury and illness incidence rates for cases with days away from work by selected nature of injury or illness, all ownerships

Nature of injury or illness	Incidence rate per 10,000 full-time workers	
	2017	2018
Sprains, strains, tears	35.0	34.0
Soreness, pain	17.1	18.7
Cuts, lacerations, punctures	8.9	9.0
Bruises, contusions	8.6	8.8
Fractures	8.7	8.2

https://www.bls.gov/iif/soii-chart-data-2018.htm#BLS_table_13



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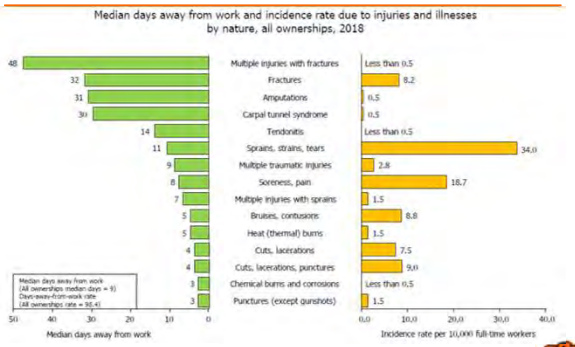
Bureau of Labor Statistics

https://www.bls.gov/iif/soii-data.htm



https://www.bls.gov/iif/soii-charts-2018.pdf 11

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Bureau of Labor Statistics

BLS defines musculoskeletal disorders (MSDs) to include cases where the nature of the injury or illness is:

- Pinched nerve
- Herniated disc
- Meniscus tear
- Sprains
- Strains
- Tears
- Pain
- Swelling
- Carpal Tunnel Syndrome
- Etc

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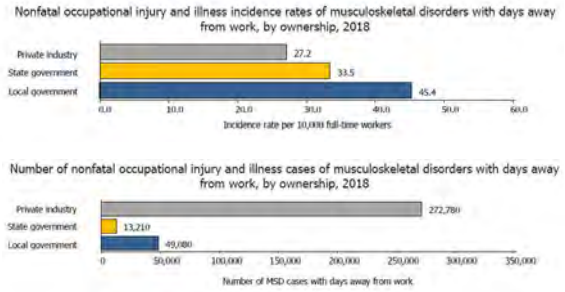
Bureau of Labor Statistics

https://www.bls.gov/iif/soii-data.htm



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Bureau of Labor Statistics

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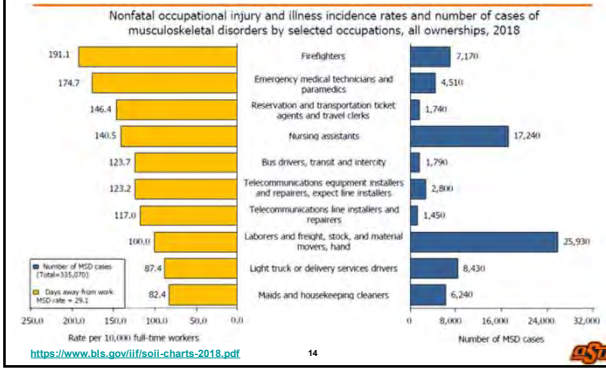

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14

Ergonomic Injury by Body Part

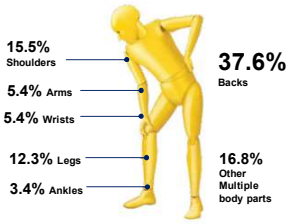
Number of MSD cases in 2018

335,070

Part of body	%
Back	37.6
Shoulders	15.5
Arms	5.4
Wrists	5.4
Hands	2.4
Legs	12.3
Ankles	3.4
Foot	1.2
Other Multiple body parts	16.8

https://www.bls.gov/iif/oshwc/osh/case/msd_cd_r2_00_2018.xlsx

https://www.bls.gov/iif/soii-data.htm#msd



Primary contributing factors for musculoskeletal injuries:

• Force • Frequency • Posture • Duration

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Ergofacts

- MSDs require 38% more days away from work than other injuries
- 400,000 – 600,000 injuries per year

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Ergofacts

- Musculoskeletal Disorders (MSD's) account for 33% of all workers compensation costs
- Direct Costs of MDSs are approximately
  $50 Billion per year
- Indirect costs are $5 to every $1 of direct costs

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OSHA Estimator

https://www.osha.gov/safetypays/

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18

MSD's - musculoskeletal disorder

- It is an injury or disorder to the human body's musculoskeletal (or "movement") system
  - Think of an MSD as a "movement system disorder"
- Micro-trauma to the soft tissues begins to outrun the body's recovery system developing into an MSD
- There is no singular cause of MSDs.

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MSD's

- Affect:
  - Muscles
  - Joints
  - Tendons
  - Ligaments
  - Nerves
- Can be chronic or acute

FPST 3213 20

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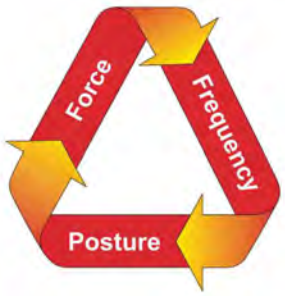
Risk Factors

- Frequency
- Awkward posture
- Forceful exertion
- Static posture
- Mechanical contact
- Stress
- Temperature
- Vibration
- Duration

FPST 3213 21

21

Ergonomics Triangle



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Other Factors

- Obesity Epidemic
- Opioid Addiction Epidemic
- Aging Workforce
  - Disability accommodations
- Fitness for duty
- Gender

FPST 3213 23

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Obesity Epidemic

*BMI ≥30, or ~30 lbs. overweight for 5' 4" person.
Data: Behavioral Risk Factor Surveillance System (1985, 2008, 2016), CDC.
Source: D. Blumenthal and S. Seervai, "Rising Obesity in the United States Is a Public Health Crisis," *To the Point*, the Commonwealth Fund, Apr. 23, 2018.

https://www.cdc.gov/obesity/data/prevalence-maps.html

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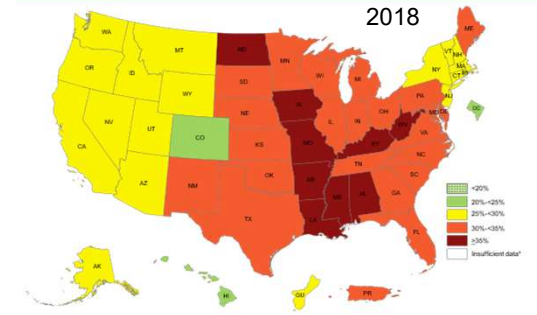
Obesity Epidemic



https://www.cdc.gov/obesity/data/prevalence-maps.html

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Opioid Addiction Epidemic

130+ People died every day from opioid-related drug overdoses[3] (estimated)

10.3 m People misused prescription opioids in 2018[1]

47,600 People died from overdosing on opioids[2]

2.0 million People had an opioid use disorder in 2018[1]

808,000 People used heroin in 2018[1]

81,000 People used heroin for the first time[1]

2 million People misused prescription opioids for the first time[1]

15,349 Deaths attributed to overdosing on heroin (in 12-month period ending February 2019)[2]

32,656 Deaths attributed to overdosing on synthetic opioids other than methadone (in 12-month period ending February 2019)[2]

SOURCES
1. 2019 National Survey on Drug Use and Health. Mortality in the United States, 2018
2. NCHS Data Brief No. 329, November 2018
3. NCHS, National Vital Statistics System. Estimates for 2018 and 2019 are based on provisional data

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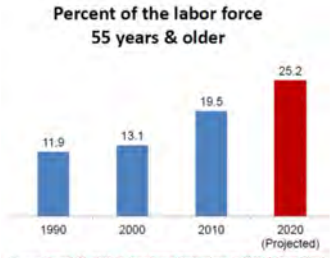
Aging Workforce



Source: Toossi, M. 2012. "Labor Force Projections to 2020: A More Slowly Growing Workforce." *Monthly Labor Review* (January, 2010–2020).

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Characteristics of an Aging Workforce

PHYSICAL	PHYSIOLOGICAL	PSYCHOSOCIAL
DECREASED STRENGTH, FLEXIBILITY, BALANCE	DECREASED OXYGEN INTAKE	DIFFERENT SHIFT PREFERENCES
DECREASED VISION	RISING SYSTEMIC BLOOD PRESSURE	DIFFERENT TRAINING AND LEARNING STYLES
DECREASED REACTION TIME AND SPEED	FASTER ONSET OF FATIGUE	CAN TEND TO EXPERIENCE DISENFRANCHISEMENT WITH THEIR WORK AND COWORKERS
DECREASED HEARING	GREATER SUSCEPTIBILITY TO EXTREME TEMPERATURES	
DECREASED MANUAL DEXTERITY AND FEEDBACK		
DECREASED BODY FAT		

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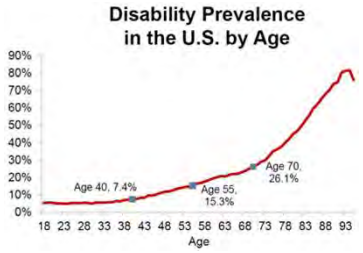
Disability accommodations



Source: Calculations by Cornell University, Employment and Disability Institute, 2010 American Community Survey, Public Use Microdata Samples (PUMS). Estimates are for civilian non-institutionalized population.

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MSD's - musculoskeletal disorder

https://www.youtube.com/watch?v=KLkAC_eN2Hw

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Ergonomically Designed or Not

- To determine if equipment, tool, or device is ergonomically designed, we need to ask 3 questions:

  1. **WHO (user) was it designed for?**
  2. **WHAT task was it designed for?**
  3. **WHAT environment will it be used in?**

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People will find their comfort zone

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Adjustable Platforms

Workplace Design

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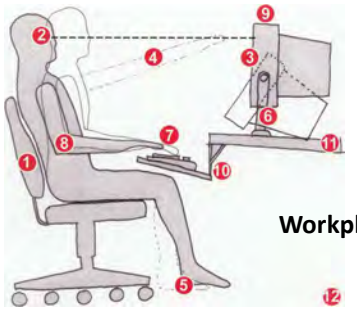
Ergonomic Computer Workstation



Workplace Design

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Hazards – Computer Workstations

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Controls - Computer Workstations

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Importance of Posture

https://www.youtube.com/watch?v=aLY03KrcpKI

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Ergonomic Program

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Ergonomic Program Elements

- Management Commitment
- Worker Involvement
- Worksite Analysis
- Medical Management
- Training & Education
- Ongoing Evaluation

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Proactive vs. Reactive Ergonomics

- Proactive Ergonomics
  - Making changes BEFORE injuries occur
- Reactive Ergonomics
  - Making changes AFTER injuries occur
- It's easier to build it in than to bolt it on

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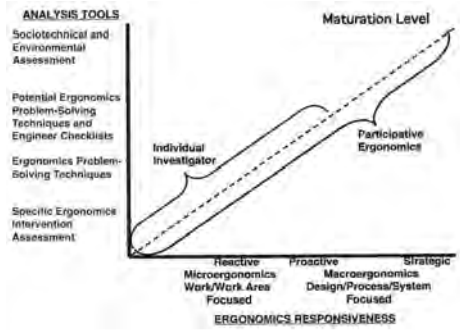
Level of Responsiveness



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Benefits of a Robust Ergonomics System

- Higher production
- Higher quality
- Higher compliance
- Lower workers' compensation costs
- Employment longevity
- Safe working conditions
- Higher quality of life
- Increased morale

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Problem Solving Process

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Problem Solving Process

- Identifying Jobs with Ergonomics Opportunities
- Defining the Job Demands
- Identify Risk Factors by Body Part for Each Task of Concern
- For Each Risk Factor, Ask Why It Is Present Until a Dead End is Reached

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Problem Solving Process

- Develop Strategies for How to Address the Root Causes and Generate at Least Three Solutions for Each Task of Concern
- Choose the Solution(s) That Will Substantially Reduce the Ergonomic Problems and Be Withing the Affordable Cost Guidelines for the Plant

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Class activity

Apply the problem-solving process to the following activity

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Planting a Tree

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Problem Solving Process

- Identifying Jobs with Ergonomics Opportunities
- Defining the Job Demands

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Responsibilities

1. Select a site
2. Collect and inspect tools
3. Dig the hole
4. Transport tree to location
5. Place and position tree into hole
6. Cut binding on root ball
7. Back-fill the hole
8. Stabilize tree
9. Water and fertilize the tree
10. Clean up work area

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Problem Solving Process

- Identify Risk Factors by Body Part for Each Task of Concern
- For Each Risk Factor, Ask Why It Is Present Until a Dead End is Reached

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Task Steps	Hazards
1. Select Site	Above/below ground obstacles/utilities
2. Collect and Inspect Tools	Condition of tools
3. Dig the Hole	Back strain, blisters, slips/trip/fall
4. Transport Tree to location	Back strain, obstacles, tree too heavy
5. Place and Position Tree into hole	Back strain, obstacles, eye injury
6. Cut binding on root ball	Foreign body in eye, cuts/scrapes,
7. Back fill the hole	Back strain, blisters
8. Stabilize tree	Striking hand/fingers, rope burn
9. Water and fertilize the tree	Slip wet surface, chemical exposure
10. Clean up work area	Slip/trip, damaged tools

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Task Steps	Hazards
1. Select Site	Above/below ground obstacles/utilities
2. Collect and Inspect Tools	Condition of tools
3. Dig the Hole	Back strain, blisters, slips/trip/fall
4. Transport Tree to location	Back strain, obstacles, tree too heavy
5. Place and Position Tree into hole	Back strain, obstacles, eye injury
6. Cut binding on root ball	Foreign body in eye, cuts/scrapes,
7. Back fill the hole	Back strain, blisters
8. Stabilize tree	Striking hand/fingers, rope burn
9. Water and fertilize the tree	Slip wet surface, chemical exposure
10. Clean up work area	Slip/trip, damaged tools

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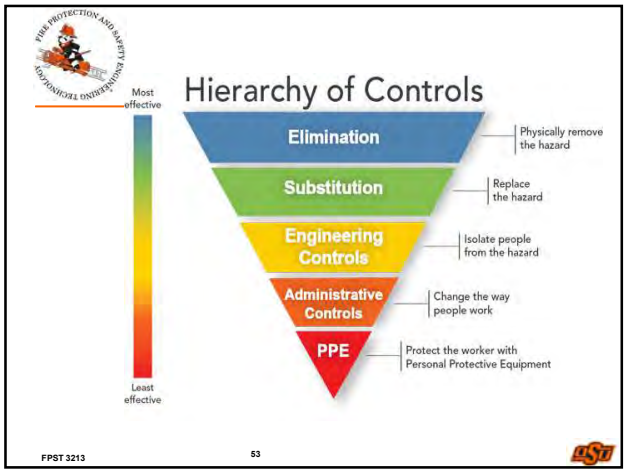

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Problem Solving Process

- Develop Strategies for How to Address the Root Causes and Generate at Least Three Solutions for Each Task of Concern
- Choose the Solution(s) That Will Substantially Reduce the Ergonomic Problems and Be Withing the Affordable Cost Guidelines for the Plant

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Task Steps	Potential Hazards	Recommended Controls
1. Select Site	Above/below ground obstacles/utilities	Call One-Ok, check plans, consider future growth
2. Collect and Inspect Tools	Condition of tools	Inspect all equipment, do not use if defective.
3. Dig the Hole	Back strain, blisters, slips/trip/fall	Get help, dig will small shovel of dirt, move smoothly, wear gloves, and slip resistant shoes, lift with your knees.
4. Transport Tree to location	Back strain, obstacles, tree too heavy	Use mechanical device,
5. Place and Position Tree into hole	Back strain, obstacles, eye injury	Get help, use mechanical device, wear safety glasses
6. Cut binding on root ball	Foreign body in eye, cuts/scrapes,	Wear safety glasses and gloves, cut away from body. Watch for recoil of binding
7. Back fill the hole	Back strain, blisters	See number 3
8. Stabilize tree	Striking hand/fingers, rope burn	Wear gloves, keep hands off stakes
9. Water and fertilize the tree	Slip wet surface, chemical exposure	Slip resistant shoes, check MSDS and follow mfg precautions
10. Clean up work area	Slip/trip, damaged tools	Discard/repair damaged tools, avoid water mud accumulations.

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Choose the solution

- $$$$$$$$$$
- Worker's health vs tools/equipment

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People will find the easier way

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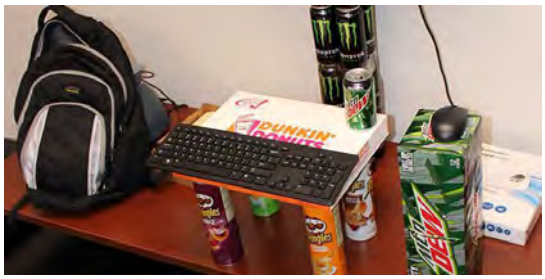
People will make it work



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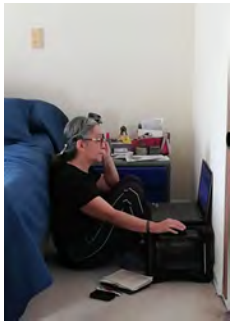
People will find their comfort zone



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Healthy Use of Smartphones

https://www.youtube.com/watch?v=OtvsRYksQHM

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Summary

- MSD are real!!!
- Ergonomic design key questions?
- Ergonomic vs Human Factors
- Problem solving process
- Ergonomics is more than a regulatory guideline or requirement

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To do list

- HW What is Ergonomics?

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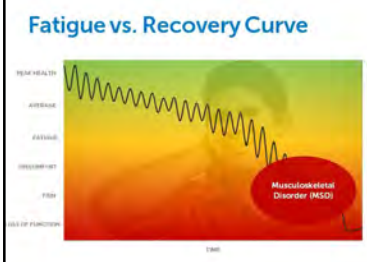
Musculoskeletal Disorders and Cumulative Trauma

Part 1

Understanding MSD's



An injury or disorder to the human body's musculoskeletal (or "movement") system

Muscles, tendons, ligaments, nerves, soft tissue, bones, and blood vessels.

Micro-trauma
↓
Muscle imbalance

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Factors

- Force
- Posture
- Compression
- Repetition
- Duration
- Vibration
- Temperature

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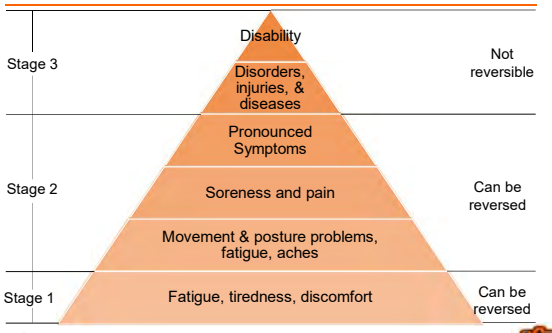
Mountain peaking through the fog



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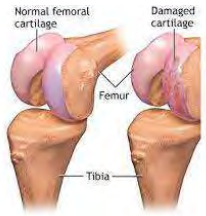
Cartilage



- Absorb shock to protect the bone

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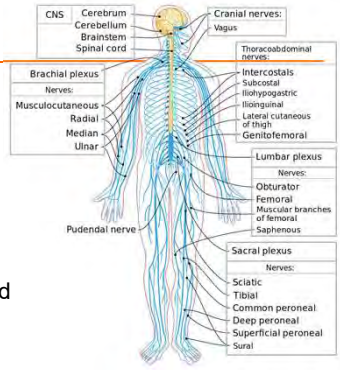
Nerves

- Control voluntary and involuntary movement



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Muscle Pain

- Cramp
- Delayed Onset Muscle Soreness (DOMS)
- Chronic exposure to static loads prevents proper recovery and can lead to permanent damage

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Tendon - Strains

- A strain is an injury to a tendon
  - Repetitive movements
  - Awkward posture

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Ligament - Sprains

- A sprain is stretching or tearing of a ligament

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Strains and sprains

- Inflammation is a natural protective response
  - Tenosynovitis
  - Tendonitis
  - Bursitis
  - Planter fasciitis
  - Achilles' tendonitis

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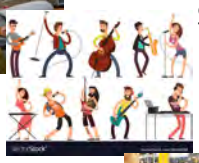
MSDs by profession



Carpal Tunnel

Thoracic Outlet

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Lower limb

Planter Fasciitis

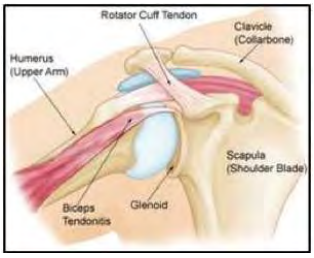
- Highly repetitive movements

Planter Fasciitis

- Sometimes mistaken for or the result of heel spurs
- Heel spur
  - Hook of bone that can form on the heel bone, or calcaneus, of the foot

Tendonitis

- Caused by repeated tension, motion, bending, or being contact with a hard surface



https://www.youtube.com/watch?v=T8SWKH18FIQ

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Tendonitis

- Repetitive motions
  - Awkward positions
  - Frequent overhead reaching
  - Vibration
  - Forceful exertion

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Achilles' Tendonitis

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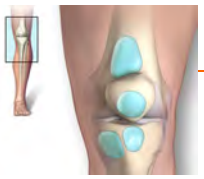
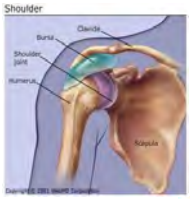
Bursitis

- Bursa - Fluid filled Sack
  - Prevents friction in joints
  - Acts like a cushion
- Bursitis – toughening from friction





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Bursitis

- Bunions are a form of bursitis

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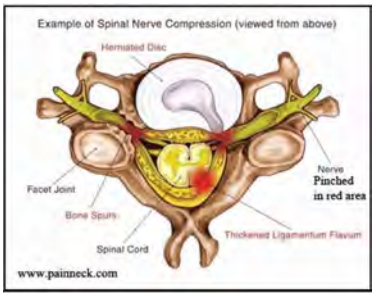
Nerve Compression



- Motor nerve
- Sensory nerve

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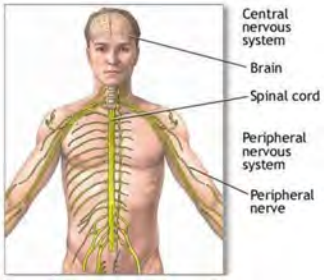
Neuritis

General inflammation of the peripheral nervous system



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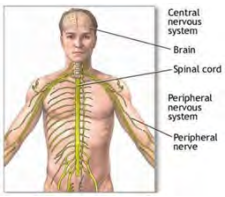
Neuritis

- Usually, a secondary problem from another type of injury/illness
  - Poisoning
    - lead, arsenic, mercury
  - Nerve compression
  - Acute Injury
  - Stroke



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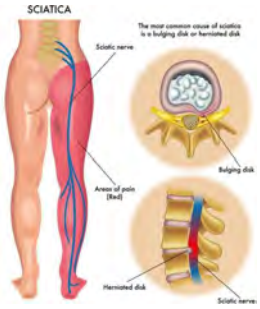
Nerve Compression

- Inflammation of or injury to the sciatic nerve
- Most common cause is a herniated disk



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Blood Vessel Compression

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Knee

Janitors, road construction workers, carpet layers.

Figure 13.25 The complex knee (Adapted with permission Lippincott Williams & Wilkins, Baltimore, MD)

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Knee

TABLE 13.2 Risk Factors for Knee Disorders

Risk	Extrinsic Risk	Intrinsic Risk	OA	Meniscal Disorders	Knee Bursitis
Kneeling	X		X	X	X
Squatting	X		X	X	
Crawling	X		X	X	
Stair/laddering climbing	X		X	X	
Lifting/carrying/moving	X		X	X	
Walking	X		X		
Standing up form a kneel/squat/crawl	X		X	X	
Chair sitting (while driving)	X			X	
BMI		X	X		
Past knee injury/surgery		X	X		
Age		X	X		
Using the knee as a hammer	X				X
Prolonged contact stress against the patella other than when kneeling	X				X
Physical intensive habits/hobbies that could affect the knee		X	X	X	

Source: Adapted from Reid (2010).

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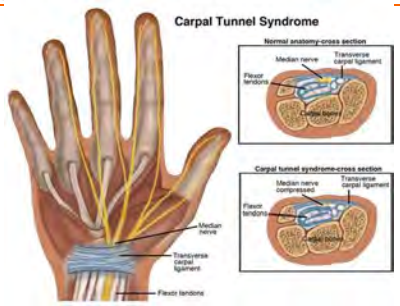
Upper limb

Carpal Tunnel Syndrome

- Compression of the median nerve in the wrist
- Common Work Tasks
  - Buffing, grinding, sanding, polishing, assembly work, typing, keying, cashiering, playing musical instruments, surgery, packing, housekeeping, cooking, butchering, hammering, scissor work

Carpal Tunnel Syndrome



https://www.youtube.com/watch?v=z-SeJh5-nOo
https://www.youtube.com/watch?v=rQJNrkq7Ils

Carpal Tunnel Syndrome

- There are six occupational risk factors for CTS:
  - Exertion of force over 1 kg (2.2lbs)
  - Duration of the shortest wrist operation greater than 10 seconds
  - Lack of a change in tasks
  - Lack of breaks for at least 15% of the day
  - Manual supply of parts and equipment to workstations
  - Lack of job rotation

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Cubital Tunnel Syndrome

- Compression of the ulnar nerve below the notch of the elbow
- Common causes
  - Resting elbow on a hard surface
  - Reaching over obstructions
  - Keeping the elbow bent for a long time can stretch the nerve behind the elbow
    - Common during sleep

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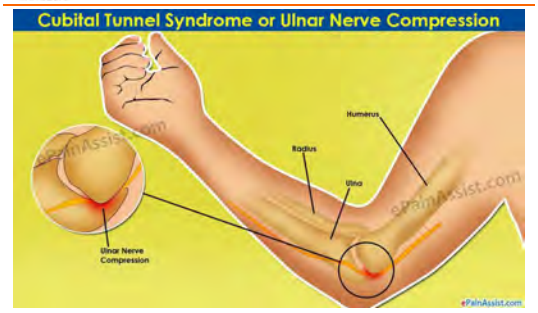
Cubital Tunnel Syndrome



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Guyon Canal Syndrome

- Entrapment of the ulnar nerve as it passes through the wrist
- Common causes
  - Prolonged extension and flexion of the wrist
  - Repeated pressure on the palm
- Common Tasks
  - Playing musical instruments
  - Bricklaying
  - Use of pliers
  - Hammering
  - Soldiering

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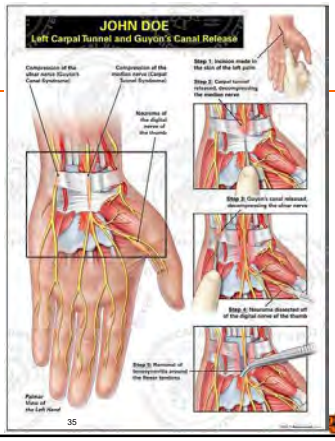
Guyon Canal Syndrome



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De Quervain's Syndrome

- Symptoms:
  - Pain and swelling near the base of your thumb
  - Difficulty moving thumb and wrist when grasping or pinching
  - A "sticking" or "stop-and-go" sensation in your thumb
- Causes
  - Forceful gripping
  - Hand twisting or wringing

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De Quervain's Syndrome

- Common Tasks
  - Buffing, grinding, polishing, sanding, pushing, pressing, sawing, tool use, turning controls

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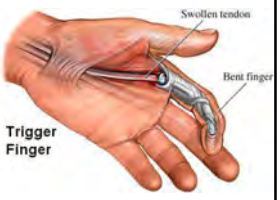
Trigger Finger

- Symptoms:
  - Finger stiffness, particularly in the morning
  - A popping or clicking sensation as you move your finger
  - Tenderness or a bump (nodule) in the palm at the base of the affected finger
  - Finger catching or locking in a bent position, which suddenly pops straight
- Common Tasks
  - Trigger operated tools
  - Hand tools with sharp edges
  - Handles too far apart



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White Finger (Raynaud's Disease)

- Results from closure of digit arteries caused by vaspospasms by vibration
- Common Tasks
  - Chain Saws, jackhammering, vibrating tools, too small tools, working in the cold.

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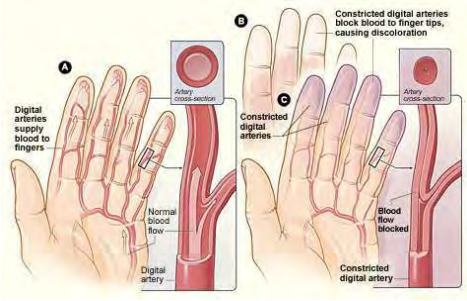
White Finger (dead finger)



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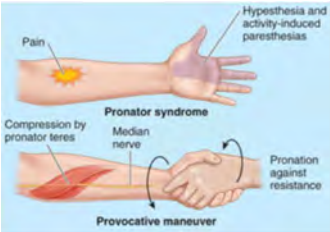
Ganglion Cyst

- Cystic Tumor
- Common Tasks
  - Buffing, grinding, polishing, standing, pushing, pressing, use of pliers, turning controls such as on a motorcycle, inserting screws and holes, or forceful handwringing

FPST-3213 41

Pronator Teres Syndrome

- Compression of the median nerve in the top third of the forearm.
- Common Tasks
  - Soldering, buffing, grinding, polishing or sanding



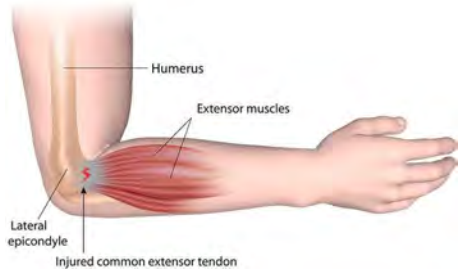
FPST-3213 42

Epicondylitis – Tennis Elbow

- Symptoms
  - Pain or burning on the outer part of your elbow
  - Weak grip strength that
- Common Tasks
  - Turning screws
  - Small parts assembly
  - Hammering
  - Meat cutting
  - Playing musical instruments
  - Playing tennis, pitching, bowling

FPST-3213 43

Epicondylitis – Tennis Elbow



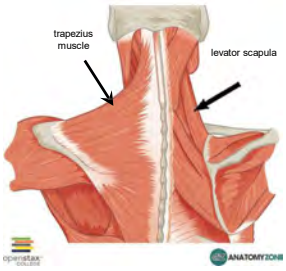
FPST-3213 44

Neck Tension Syndrome

FPST-3213 45

Neck Tension Syndrome

An irritation of the levator scapulae and trapezius muscle of the neck



FPST-3213 46

Neck Tension Syndrome

- Symptoms
  - Headache
  - Fatigue
  - Aching discomfort at the back of the neck and the upper back.
  - Spasms in the neck and dull pain in the upper arm, elbow, forearm and hands

FPST-3213 47

Neck Tension Syndrome

- Causes
  - Computer mouse more than 25 hours per week
  - Localized muscle fatigue due to repetitive motion or static, sustained contraction
    - Lack of oxygen supply
- Common Tasks
  - Conveyor belt assembly, computer use, small part assembly, packing, load carrying in hands or on shoulder, overhead work, cashiers.

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Neck Tension Syndrome

FPST-3213 49

Neck Tension Syndrome

FPST-3213 50

Thoracic Outlet Syndrome

FPST-3213 51

Thoracic Outlet Syndrome

FPST-3213 52

Thoracic Outlet Syndrome | Mark's Story

https://www.youtube.com/watch?v=ILXn_j3NZIE

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Thoracic Outlet Syndrome

- Symptoms vary on the compressed structures
  - Neurological
    - Compression of the brachial plexus
    - Numbness or tingling in your arm or fingers
    - Pain or aches in your neck, shoulder or hand
    - Weakening grip
    - Arm fatigue with activity

FPST-3213 54

Thoracic Outlet Syndrome

- Vascular
  - Veins or arteries are compressed
  - Bluish discoloration of your hand
  - Arm pain and swelling, possibly due to blood clots
  - Weak or no pulse in the affected arm
  - Cold fingers, hands or arms
  - Throbbing lump near your collarbone

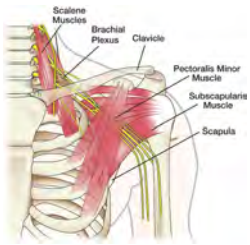
FPST-3213 55

Thoracic Outlet Syndrome

- Blood vessels or nerves (Brachial plexus) in the space between your collarbone and your first rib (thoracic outlet) are compressed

FPST-3213 56

Thoracic Outlet Syndrome

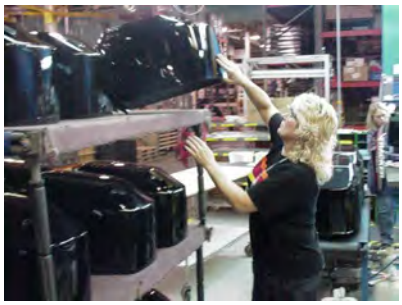


FPST-3213 57

Thoracic Outlet Syndrome

FPST-3213 58

Thoracic Outlet Syndrome



FPST-3213 59

Introduction to musculoskeletal disorders

https://www.youtube.com/watch?v=RTNmYcUjGgI

FPST-3213 60

To do list

- HW 01 is posted due by Friday

FPST-3213 61

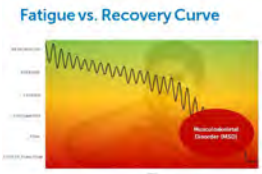
Questions?

FPST-3213 62

Musculoskeletal Disorders and Cumulative Trauma

Part 2

Understanding MSD's



- An injury or disorder to the human body's musculoskeletal (or "movement") system
- Muscles, tendons, ligaments, nerves, soft tissue, bones, and blood vessels.

Micro-trauma

Muscle imbalance

FPST 3213 3

Back Disorders

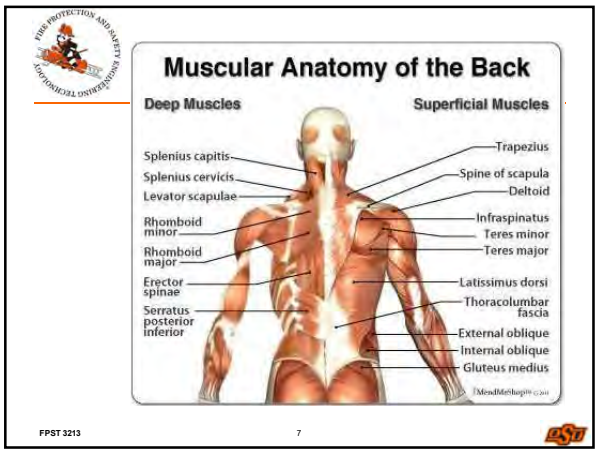
FPST 3213 4

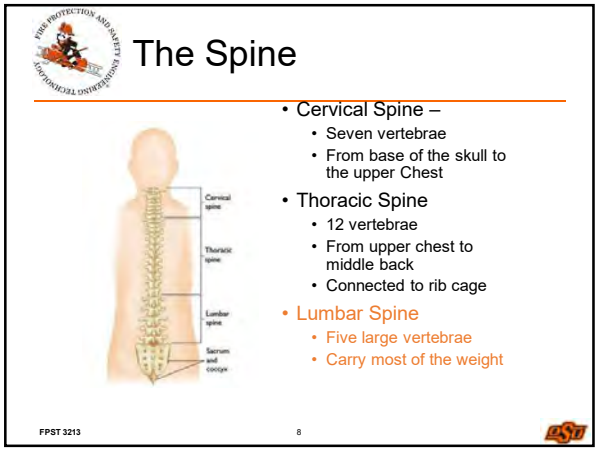
The Back

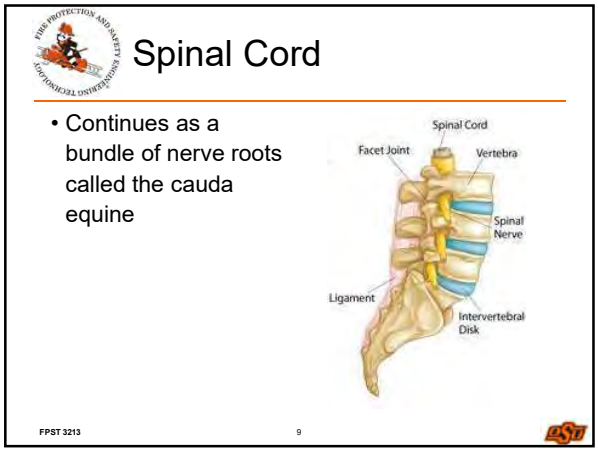
FPST 3213 5

The Back

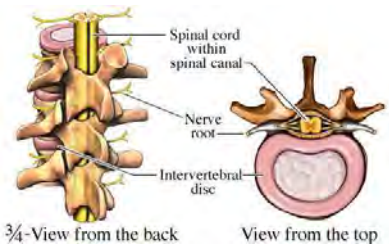
FPST 3213 6


Muscular Anatomy of the Back
Deep Muscles
Superficial Muscles
Splenius capitis
Splenius cervicis
Levator scapulae
Rhomboid minor
Rhomboid major
Erector spinae
Serratus posterior inferior
Trapezius
Spine of scapula
Deltoid
Infraspinatus
Teres minor
Teres major
Latissimus dorsi
Thoracolumbar fascia
External oblique
Internal oblique
Gluteus medius
FPST 3213
7


The Spine
Cervical spine
Thoracic spine
Lumbar spine
Sacrum and coccyx
• Cervical Spine –
• Seven vertebrae
• From base of the skull to the upper Chest
• Thoracic Spine
• 12 vertebrae
• From upper chest to middle back
• Connected to rib cage
• Lumbar Spine
• Five large vertebrae
• Carry most of the weight
FPST 3213
8


Spinal Cord
• Continues as a bundle of nerve roots called the cauda equine
Spinal Cord
Facet Joint
Vertebra
Spinal Nerve
Ligament
Intervertebral Disk
FPST 3213
9

Spinal Cord and Nerves



FPST 3213 10

Intervertebral Disks

- Made up of:
  - Nucleus pulposus
    - Jelly-like center of the disk
  - Annulus fibrosus
    - The flexible outer ring of the disk

FPST 3213 11

Spinal MSDs

- New use
- Misuse
- Overuse
- Disuse

FPST 3213 12

Classifications of spinal MSDs

- Discogenic: disc hernia (most common at L 4-5 and L 5-S1)
- Neurological: nerve irritation, compression and/or tumors involving nerve roots
- Muscular/ligamentous tension: resulting from stress and nerve or ligament tension
- Trauma: acute injury or cumulative type
- Strain: small tears within the muscle/tendon
- Postural imbalance: creates uneven stresses on the musculoskeletal system
- Spasm: muscle contraction that produces an uncontrolled contraction

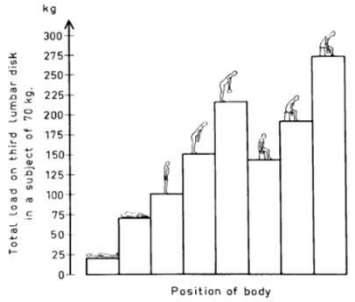
FPST 3213 13

Classifications of spinal MSDs

- Weakness: poor muscle tone
- Myofascitis: inflammation and tenderness of the muscle and the sheaths that envelop the muscle known as the fascia
- Structural: spondylolysis – a defect of the bony segment joining the articulations above and below a given segment
- Scoliosis: abnormal curve of the spine
- Compression fractures
- Dislocation degenerative disease annular tears
- Osteoarthritis: degenerative disorder that affects the facet joints and disk
- Stenosis – narrowing of a channel.

FPST 3213 14

Lumbar disc pressures in different positions of the body



FPST 3213 15

Back Injuries Facts

- More than one million back injuries are sustained in the workplace every year
- Back injuries account for one in every five injuries and illnesses in the workplace

FPST 3213 16

Back Injury Facts

- Up to 1/3 of back injuries could be prevented through a better designed job workspace
- Back injuries made up 41% of ergonomic injury cases
- In the US, back disorders account for over 24% of all occupational injuries and illnesses involving days away from work
- US workers who suffered ergonomic injuries required an average of 12 days to recuperate before returning to work

FPST 3213 17

The Back

FPST 3213 18

The Back

FPST 3213 19

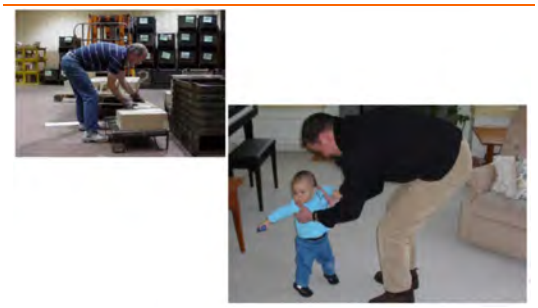
The Back

FPST 3213 20

The Back

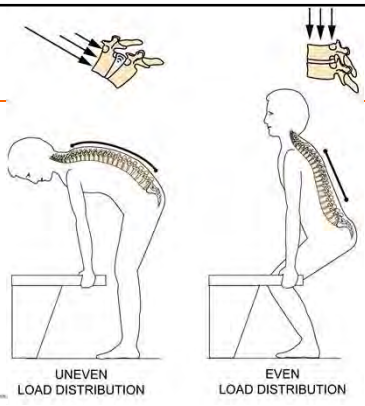
FPST 3213 21

Is work the only exposure?



FPST 3213 22

Spinal Loading vs Posture



FPST 3213 23

Posture: Proper Lifting Technique

FPST 3213 24

NIOSH Hazard Evaluation Checklist Risk of Back Pain in Manual Tasks

Risk Factors (TABLE 2.7)	Yes	No
1. General		
1.1 Does the load handled exceed 23 kg?		
1.2 Is the object difficult to bring close to the body because of its size, shape, or bulk?		
1.3 Is the load hard to handle because it lacks handles or cut-outs or does it have slippery surfaces hard edges?		
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?		
1.7 Is most of the load handled by only one hand, arm, or shoulder?		
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contaminants?		
1.9 Does the task require working in a confined area?		
2. Specific		
2.1 Does lifting exceed five lifts per minute?		
2.2 Does the vertical lift distance exceed 1 m?		
2.3 Do carries last longer than 1 min?		
2.4 Do tasks that require large sustained pushing or pulling forces exceed 30 s duration?		
2.5 Do extended reach static holding tasks exceed 1 min?		

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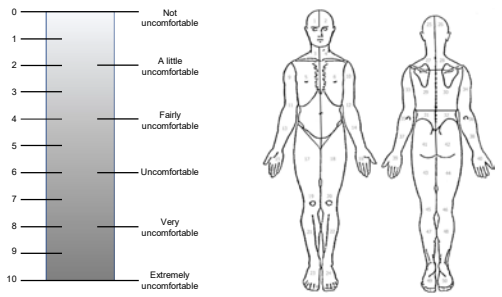
Body Diagram for Pain Rating



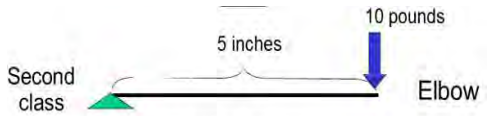
FPST 3213 26

Chronic Low Back Pain

https://www.youtube.com/watch?v=DkRnZNAnWfE

FPST 3213 27

Why is closer better?

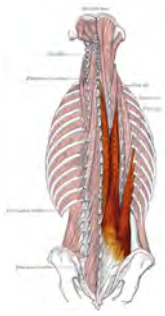


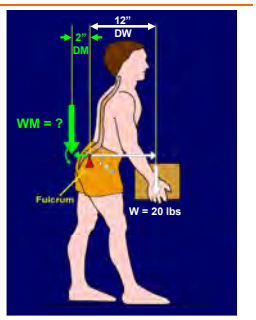
Weight X Distance = Moment
10 pounds X 5 inches = 50 inch pounds
- Note - cut the moment in half by cutting distance in half

NOTE: Moment = Force * Distance (N . in)
For purpose of the example we are assuming that Moment = Weight * Distance (in.lb force)

FPST 3213 28

How much force is developed by erector spinae?





FPST 3213 29

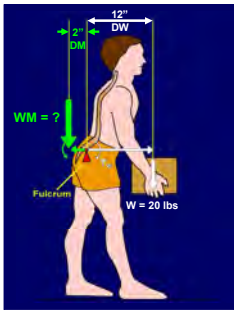
How much force is developed by erector spinae?

WM = ?

Moment 2 = Moment 1

(W) X (DW) = Moment 1

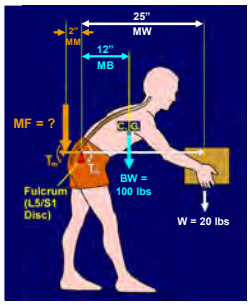
(WM) X (DM) = Moment 2



FPST 3213 30

Add Reaching

How much force is developed by erector spinae?

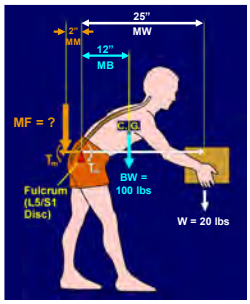


FPST 3213 31

Add Reaching

MF = ?

Moment 2 = Moment 1 + Moment 3



FPST 3213 32

Conclusion

With a 20 lb box the erector spinae supports 120 lb.

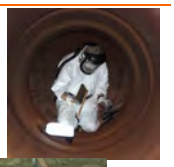
With reaching and a body weight of 100 lb in CG, the erector spinae supports 850 lb

Biomechanics

FPST 3213 33

Effects of Restricted Workspace on Spine Loading

- Underground Mines, Utility Vaults, Confined Spaces, cable handling
- Stooping, Kneeling, twisting
- 13-20% reduction in lifting capacity
- Tissue loading on the spine
- Static muscle fatigue



FPST 3213 34

Rules of Thumb

- If the load is not close, the pressure is gross.
- If the back is bent, one will not prevent.
- If muscles are slack, you will hurt your back.

FPST 3213 35

It's all about workplace design

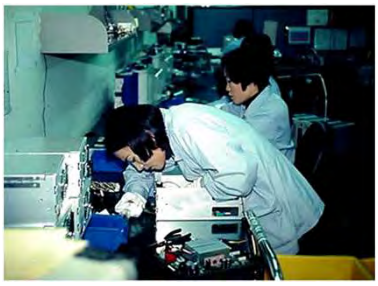
The condition forces the behavior

FPST 3213 36

Text Neck Syndrome

FPST 3213 37

Text Neck Syndrome



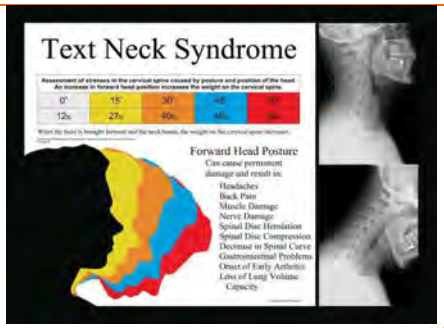
FPST 3213 38

Could Tech Neck be the Cause of your Headaches or Neck Pain?

https://www.youtube.com/watch?v=yjVw6oLPuB0

FPST 3213 39

Text Neck Syndrome



FPST 3213 40

Text Neck Syndrome

- The cervical vertebrae may form bone spurs for stability, ligaments become thicker, and muscles can become tightened to counteract the strain

FPST 3213 41

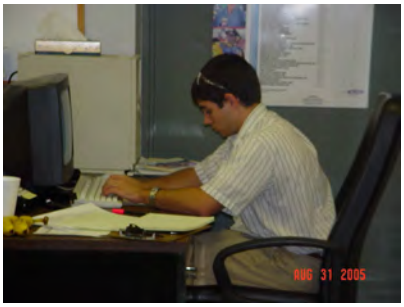
Stand up Straight! Love Mom

FPST 3213 42

Text Neck Syndrome

FPST 3213 43

Text Neck Syndrome



FPST 3213 44

Sitting is the New Smoking

FPST 3213 45

Sitting

- Tightened muscles
  - Leads to the neck, hip and shoulder flexors contracting resulting in stress, strain and muscle tension
- Weakness
  - Overstretched areas cause a lack of strength in the back, scapular stabilizers, buttocks, and core
- Decreased cardiovascular health
  - Being sedentary does not challenge the heart by pumping blood vigorously
  - Affect endurance, metabolism, blood pressure, cholesterol levels and overall cardiovascular health

FPST 3213 46

Sitting

- Obesity risk increases
- Diabetes (type 2) risk increases
- Psychological stressors

FPST 3213 47

Sitting

- Altered digestion
- Cancer risk increases
- Overall mortality

FPST 3213 48

Is standing any better?

FPST 3213 49

Standing

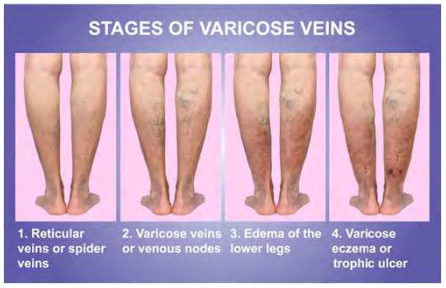
- Working regularly in a standing position
  - Sore feet
  - Leg swelling
  - Varicose veins
  - General muscular fatigue
  - Low back pain
  - Stiffness in the neck and shoulders
  - These are common complaints among sales people, machine operators, assembly-line workers and others whose jobs require prolonged standing.

FPST 3213 50

Standing

- Keeping the body upright requires considerable muscular effort
- Standing reduces the blood supply to the loaded muscles
  - It is a static posture
- Causes blood pooling in the legs and feet

FPST 3213 51



http://www.westfloridaveincenter.com/2018/01/can-varicose-veins-lead-complications/

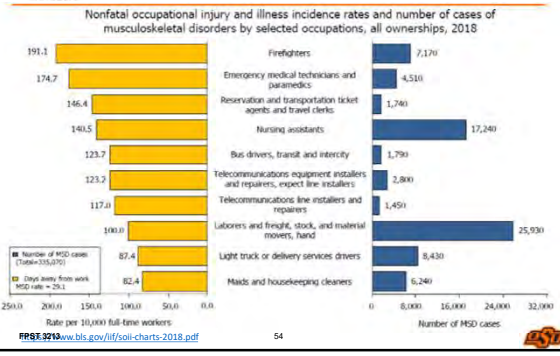
FPST 3213 52

Some Advantages

- Reach is greater in standing that in sitting.
- Lumbar disc pressure are lower.
- It can be maintained with little muscular activity and requires no attention.

FPST 3213 53

MSD Summary



FPST 3213 www.bls.gov/iif/soii-charts-2018.pdf 54

Statistics On Lifting Injuries

- Lifting Injuries Aren't Just Back Injuries

LIFTING RESULTS IN:

30% of Shoulder WMSDs

22% of Elbow WMSDs

43% of Back WMSDs

13% of Hand/Wrist WMSDs

FPST 3213 55

Hi-Risk Occupations

- Six occupations accounted for more than 25% of ergonomic injuries
  - Heavy and Tractor-Trailer Truck Drivers
  - Laborers and Freight
  - Stock and Material Movers
  - Nursing Assistants
  - Janitors and Cleaners
  - Registered Nurses

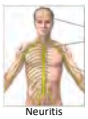
FPST 3213 56

MSD Summary

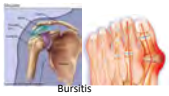
Planter Fasciitis

Tendonitis

Achilles' Tendonitis



Neuritis



Bursitis

Carpal Tunnel

Guyon Canal

De Quervain's

Cubital Tunnel

Blood Vessel Compression

Nerve Compression

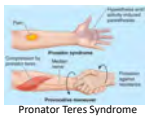
FPST 3213 57

MSD Summary

Trigger Finger

White Finger (Raynaud's Disease)

Ganglion Cyst


Pronator Teres Syndrome

Epicondylitis – Tennis Elbow

Neck Tension Syndrome

Text Neck Syndrome

Thoracic Outlet Syndrome

Chronic Low Back Pain

FPST 3213 58

Minimizing musculoskeletal disorders

https://www.youtube.com/watch?v=u9eSSL6klsA

FPST 3213 59

To Do List

- HW 2
- Read Chapter 10

FPST 3213 60

Environmental Stressors

Part 1

Environmental Stressors

- Lighting and color
- Noise
- Thermal conditions
- Vibration
- Ventilation

FPST 3213 3

Lighting

https://soa.utexas.edu/sites/default/disk/urban_ecosystems/urban_ecosystems/09_03_fa_kwallek_riosvelasco_ml.pdf

FPST 3213 4

Lighting

- The Hawthorn Study
  - Professor Elton Mayo, conducted a study at the Hawthorne Works of the Western Electric Company.
- Productivity increased in both treatment groups

Management and the Worker. By F. J. ROETHLISBERGER and WILLIAM J. DICKSON. '(Cambridge, Mass: Harvard University Press (Oxford University Press). 1939. Pp. xxiv +615. 26s. 6d.)

FPST 3213 5

Hawthorn Studies

- Results had nothing to do with workplace lighting
- Psychological factors are more important than physiological, and
- That sociological and anthropological factors are more important than economic

FPST 3213 6

Hawthorn Studies

- The Hawthorne Effect
  - Also referred to as the "observer effect"
  - A type of reactivity in which individuals modify an aspect of their behavior in response to their awareness of being observed

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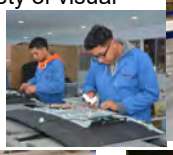
https://www.youtube.com/watch?v=o4XX90lqT6E&feature=emb_rel_end

FPST 3213 8

Lighting

- Wide variety of visual demands



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Basic characteristics of visual demands

- Size and a three-dimensional shape of the object being viewed
- Contrast between the object and the background
- Viewing distance
- Motion of the object
- Field of view around the task
- Sensitivity of the visual task to error
- Frequency of task
- Time available to perform task

FPST 3213 10

Lighting

- Illuminance
  - The amount of light falling on a work of service or task
  - Measured with an illuminance meter in Lux

FPST 3213 11

Lighting

- Luminance
  - Measure of light reflected off the surface
  - Measured with a photometer candela/m2

FPST 3213 12

Lighting

- The Illuminating Engineering Society of North America (IESNA)
  - Comprehensive lighting design guide
  - Lighting level should not vary more than 30% from these recommended levels for quality purposes.
  - The measured illuminances should be within 10%

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Recommended Range of Illuminance for Various Areas and Tasks Typical in Work Settings

Type of Activity or Area (TABLE 8.1)	Illuminance (lux)	
	Horizontal	Vertical
Public/Service areas		
Exit from building	10	10
Walkways (minimum)	10	22 (at 1.8 m above path)
Parking lots (uniformity ratio 15:1)	2	1
For security	5	2.5
Lobbies	100	30
Copy rooms	100	30
Mail-sorting rooms	500	30
Rest rooms	100	30
Stairways	50	—
Elevators	50	30
Conference rooms		
Meetings	300	50
Video conferences	500	300

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Recommended Range of Illuminance for Various Areas and Tasks Typical in Work Settings

Type of Activity or Area (TABLE 8.1) - (Continued)	Illuminance (lux)	
	Horizontal	Vertical
Office areas		
Open-plan office, intensive VDT use	300	50
Open-plan office, intermittent VDT use	500	50
Private office	500	50
Control panels, VDT observation	100	30
Drafting/graphic-art work		
Computer workstations only	100	30
Mix of computer and paper-based tasks	300	30
High-contrast media	500	100
Low-contrast media	1000	300
Reading tasks		
VDT screens (data processing)	30	30
Keyboard	300	—
6-point type, maps, telephone books	500	—
Inkjet/laser printer, typewriter output (at 8 points or larger)	500	—

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Recommended Range of Illuminance for Various Areas and Tasks Typical in Work Settings

Type of Activity or Area (TABLE 8.1) - (Continued)	Illuminance on Task Plane
Basic industrial tasks	
Visual demands are not high: Coarse processing of raw material,[1] warehousing and storage of bulky items with large labels, loading inside trucks and freight.	100
Performance of visual tasks—high-contrast items or large size: Medium processing of raw materials, wrapping, packing, labeling, shipping and receiving, picking stock and classifying, warehousing and storage of small items with small labels, manufacture of large components, simple assembly or inspection, rough bench or machine work, coarse manual crafts[2]	300
Performance of visual tasks—medium-contrast items or small size: Fine processing of raw materials, manufacture of medium-size components, rough grinding, medium buffing and polishing, ordinary automatic machines, maintenance work, medium craft work	500
Performance of visual tasks—low-contrast items or very small size: Very fine processing of raw materials, fine component manufacturing, difficult assembly and inspection, fine automatic machines, medium grinding, fine buffing and polishing, fine manual crafts	1000
Performance of exacting visual tasks: Extra-fine bench or machine work (fine grinding); exacting assembly and inspection, precision manual arc welding, exacting manual crafts	3000

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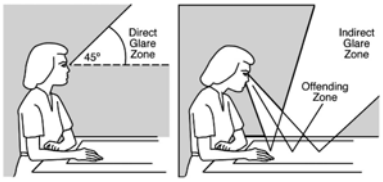
Lighting and quality issues

- Glare
  - Exceptionally brilliant and distracting or uncomfortable amount of light



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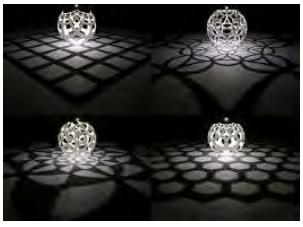
Lighting and quality issues

- Shadows
  - The opposite of glare.



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Lighting and quality issues

- Room appearance
  - Balance the brightness of room walls and ceilings

FPST 3213 19

Lighting and quality issues

- Natural sunlight

FPST 3213 20

Lighting and quality issues

- Age of the user

FPST 3213 21

Lighting design

- Lighting best provided by combination of ambient room lighting and specific task lighting
- Design must balance illumination levels with implementation and operation cost
- Selection should consider “color rendering”

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Lamp types

Incandescent

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Lamp types

Fluorescent

FPST 3213 24

Lamp types

High intensity discharge (mercury vapor, metal halide, high pressure sodium)

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Lamp types

Low pressure sodium

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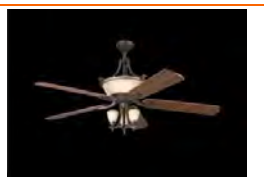
FPST 3213 27

FPST 3213 28

FPST 3213 29

Direct and indirect luminaries

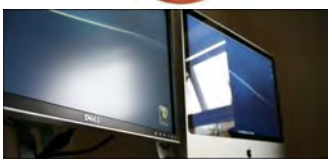
- Luminary
  - A fixture that produces, controls, and distributes light face down word or face upward
- Desk lamps
  - Avoid using as task lighting whenever possible



FPST 3213 30

Computer workplace lighting

- Minimize glare
- Anti-reflection coding on screens
- Antiglare filters
- Lower ambient lighting
- Paint walls



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Computer workplace lighting

- Avoid use of items with reflective surfaces in the room
- Last resort, tilt the screen downward
- Install screens at right angles to windows

FPST 3213 32

Computer workplace lighting

FPST 3213 33

Computer workplace lighting

FPST 3213 34

Dark room lighting

Biggest challenge is with means of egress related to exit light signage and a minimum illumination requirement

FPST 3213 35

Inspection workplace lighting

- Product and material inspection is one of the most demanding visual tasks
- Minimize illumination reflectance
- Paint walls and ceilings
- Darker floor tile and carpeting
- Eliminate ambient overhead lighting

FPST 3213 36

Questions for Lighting Surveys and Focus Groups

TABLE 10.7 Questions for Lighting Surveys and Focus Groups
How is the light in your workstation?
How satisfied are you with the lighting in your work environment?
How satisfied are you with the lighting in your workstation?
Does the lighting affect your work performance?
Does the light disturb your work performance?
Does the lighting level cause slips, trips, and falls?
Does the lighting cause tiredness in the eyes?
Do you need to change posture for better viewing because of the lighting?
Additional artificial light would improve my work environment
More windows, natural light would improve my work environment
Better maintenance of lighting would improve my work environment
A better mix of natural and artificial light would improve my work environment
Better use of color would improve my work environment
Any other suggestions?

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Items from the Eye Complaint Questionnaire

TABLE 10.8 Items from the Eye Complaint Questionnaire
1. I have difficulty seeing
2. My eyelids feel heavy
3. My eyes hurt
4. My eyes water
5. My eyes burn
6. My eyes are tired
7. I have a strange feeling around my eyes
8. My eyes itch
9. My eyes are red
10. My eyes are dry
Note: Scored on a seven-point Likert scale, where 1 = "not at all" and 7 ="very much."

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Summary

- The furniture and materials determine the balance of luminance seen by workers.
- Large targets - higher and far way
- Small targets – lower down and closer
- Natural light, a view out of the window, and control over light.
- Administrative controls.

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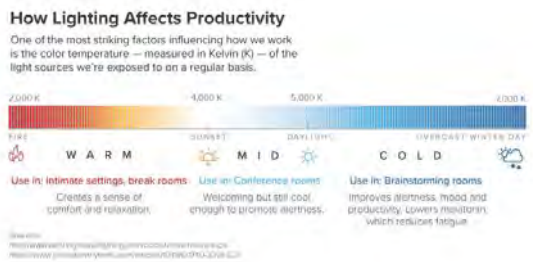
Environmental Stressors

Color

FPST 3213 40

Light and Color



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Color

- Purpose isn't to inspire workers but to reduce eyestrain improve visibility and increase efficiency.
- Influence of color has not been thoroughly examine

FPST 3213 42

Light Reflective Values (LVR) of the path colors

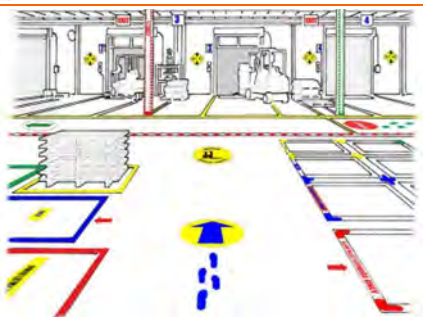
Color or Surface Texture	Light Reflectance Value (LRV) %	Color or Surface Texture	Light Reflectance Value (LRV) %
White	85	Dark Grey	30
Light cream	75	Dark Red	13
Light Grey	75	Dark Brown	10
Light Yellow	75	Dark Blue	8
Light Green	65	Dark Green	7
Light Blue	65	Wood	63
Medium Yellow	65	Satin Wood	34
Medium Grey	55	Concrete	55
Medium Green	52	Cardboard / Paperboard	30
Medium Blue	35	Black	5

FPST 3213 43

Color

- Workplace guidelines
  - Ensure uniform reflectivity avoid primary colors
  - Pastel colors are generally preferred for walls and work services
  - Use warm colors on walls with windows
  - Green and blue-green wall colors are good for tasks that require high concentration
  - Provide contrast between the work surface and the components being assembled
  - Provide screens to block out distracting items
  - Use bright colors to highlight critical parts of the machine
  - Selection of color scheme should be coordinated with the decisions about illumination type

FPST 3213 44



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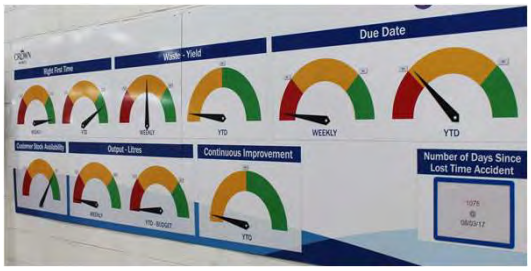

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A Workplace That Shines

FPST 3213 49

5's Factory

- Sort
- Set in Order
- Shine
- Standardize
- Sustain

FPST 3213 50

Noise's Definition

Noise is unwanted sound considered unpleasant, loud or disruptive to hearing.

FPST 3213 51

Noise's Definition

From a physics standpoint, noise is indistinguishable from sound, as both are vibrations through a medium, such as air or water.

The difference arises when the brain receives and perceives a sound.

FPST 3213 52

Noise

Sound level meter (dB)

Dosimeter Decibel (dB)

FPST 3213 53

Noise

- Contributes to hearing loss
  - Noise induced hearing loss covered in FPST 2343
- Annoys and distracts people
- Interferes with communications
- Alters performance

FPST 3213 54

Contributes to hearing loss

- 85 dBA – 8 hours/day, +dBA – time.
- Duration of exposition, level, and susceptibility.
- Hearing conservation programs:
  - OSHA 1983
  - NIOSH 1972,1998

FPST 3213 55

Distraction

- The higher the demand for concentration the lower the noise levels should be
- General rule for office or production equipment Noise should be kept below 50 dBA
- Must consider the needs for both communication and speech privacy

FPST 3213 56

ANSI 12.2-1995

- Criteria for evaluating room noise suggests using NCB (noise-criteria-balanced) curves to evaluate acceptable noise levels in spaces

FPST 3213 57

Recommended NCB Curves and Sound Pressure Levels for Several Categories of Activity (Beranek 1989a)

TABLE 8.5 - Acoustical Requirements	NCB Curve	Approximate L_A (dBA)
Listening to faint musical sounds or distant microphone pickup used (concert halls, opera houses, recital halls)	10 to 15	18 to 23
Excellent listening conditions (large auditoriums, large drama theaters, large churches)	Not to exceed 20	28
Close microphone pickup only (broadcast, television, and recording studios)	Not to exceed 25	33
Good listening conditions (small auditoriums, small theaters, small churches, music rehearsal rooms, large meeting and conference rooms or executive offices, conference rooms for 50 people with no amplification)	Not to exceed 30	38
Sleeping resting or relaxing (Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, etc.)	25 to 40	38 to 48
For good listening conditions (private or semiprivate offices, small conference rooms, classrooms, libraries, etc.)	30 to 40	38 to 48
Conversing or listening to the radio and TV (living rooms in dwellings)	30 to 40	38 to 48

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Recommended NCB Curves and Sound Pressure Levels for Several Categories of Activity (Beranek 1989a)

TABLE 8.5 - Acoustical Requirements - (Continued)	NCB Curve	Approximate L_A (dBA)
Moderately good listening conditions (large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc.)	35 to 45	43 to 53
Fair listening conditions (lobbies, laboratory work spaces, drafting and engineering rooms, general secretarial areas)	40 to 50	48 to 58
Moderately fair listening conditions (light maintenance shops, industrial-plant control rooms, office and computer equipment rooms, kitchens and laundries)	45 to 55	53 to 63
Just acceptable speech and telephone communication (shops, garages, etc.)	50 to 60	58 to 68
Speech not required but no risk of hearing damage	60 to 75	63 to 78

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Noise levels

Noise Criterion	Octave Band Center Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	Sound Pressure Levels (dB)							
NC-15	47	36	29	22	17	14	12	11
NC-20	51	40	33	26	22	19	17	16
NC-25	54	44	37	31	27	24	22	21
NC-30	57	48	41	35	31	29	28	27
NC-35	60	52	45	40	36	34	33	32
NC-40	64	56	50	45	41	39	38	37
NC-45	67	60	54	49	46	44	43	42
NC-50	71	64	58	54	51	49	48	47
NC-55	74	67	62	58	56	54	53	52
NC-60	77	71	67	63	61	59	58	57
NC-65	80	75	71	68	66	64	63	62
NC-70	83	79	75	72	71	70	69	68

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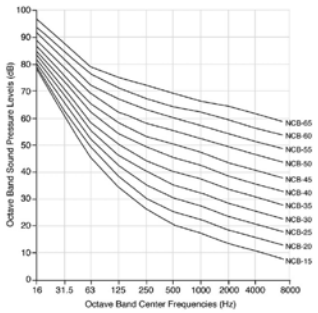
NCB curves (adapted from Beranek 1989a)



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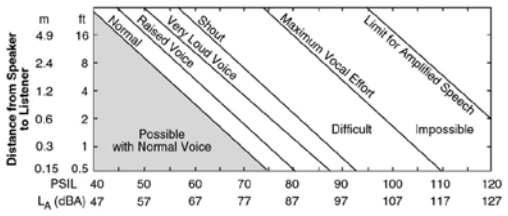
Interference with communication

- Method for rating speech interference affects of noise is called "preferred speech interference level" (PSIL)
  - PSIL used to indicate whether or not there will be a communications problem.

FPST 3213 62

Preferred speech interference levels (PSIL) as a function of distance and ease of communications (adapted from Webster 1969)



FPST 3213 63

Approaches to reducing noise in the workplace

- Reduce the level or altering the noise generated
- Use barriers
- Absorbing reflected noise

- PPE

FPST 3213 64

Approaches to reducing noise in the workplace

- Background music
  - No conclusive proof music increases productivity
  - Most if not all workers enjoy listening to music
  - However those who do not enjoy the music will probably complain

FPST 3213 65

FPST 3213 66

Questions?

FPST 3213 67

1

Environmental Stressors

Part 2

2

Environmental Stressors

- Lighting and color
- Noise
- Thermal conditions
- Vibration
- Ventilation

FPST 3213 3

3

Thermal Stressors

FPST 3213 4

4

Thermal Stressors

- Human Factors is concerned with how thermal stressors impact productivity

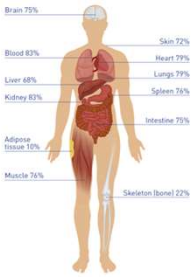
Hot Danger Zone
Warm Discomfort Zone
Thermal Comfort Zone
Cold Discomfort Zone
Cold Danger Zone

FPST 3213 5

5

Thermal environments

- Principal concern is movement of heat to and from the person



Water composition of tissues and organs by weight. Adapted from Pivarnik and Palmer 1994

FPST 3213 6

6

Heat Stress

FPST 3213 7

7

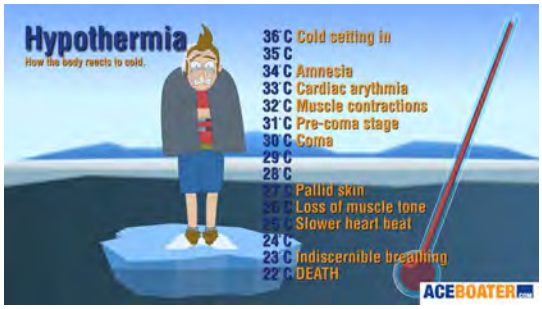
Heat Stress

- Can add to the cardiopulmonary burden thus increasing:
  - the likelihood of fatigue
  - frequency of accidents
  - overexertion injuries
  - decrease in quality
  - decrease in productivity

FPST 3213 8

8

Cold Stress



FPST 3213 9

9

Cold Stress

- Cold stress is more associated with loss of cognitive function
  - e.g. reasoning, memory, attention

FPST 3213 10

10

Thermal Stressors

- ASHRAE
  - American Society of Heating, Refrigerating and Air-Conditioning Engineers
  - Standard 55 – Thermal Environmental Conditions for Human Occupancy
  - Standard 62 - Ventilation for Acceptable Indoor Air Quality

FPST 3213 11

11

Thermal Balance - Models

- The body as a whole
  - Heat exchange between the person and the environment
  - $S = M - E \pm R \pm C - W$

where

S is the heat gained or lost by the body
M is the metabolic energy production
E is the heat dissipated through evaporation (sweating)
R is the radiant heat to or from the environment
C is the convection to or from the environment
W is the work accomplished by the worker
S = 0 when the body is in thermal balance with the environment

FPST 3213 12

12

Thermal Balance

- Heat transfer on a local patch of skin
  - Considers heat gained or lost to the environment at a local patch of skin
  - Main pathways are conduction and convection

FPST 3213 13

13

Thermal Condition Assessment

- <u>Environment</u>
  - Minimum requirements for environmental assessment:
    - Air temperature
    - Humidity
    - Air speed

FPST 3213 14

14

Thermal Condition Assessment

- Air temperature or Dry bulb temperature

FPST 3213 15

15

Thermal Condition Assessment

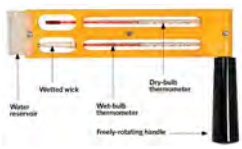
- Humidity or the amount of water vapor in the air
  - Limits the rate of the evaporative cooling of sweat

FPST 3213 16

16

Thermal Condition Assessment

- To assess humidity measure dry bulb and psychrometric wet bulb temperatures and then find the humidity. (Air speed greater than 3 m/s)
- Natural wet bulb temperature. Similar to psychrometric wet bulb temperature except air motion is simply the ambient air movement



Wetted wick

FPST 3213 17

17

Thermal Condition Assessment

- Air speed or movement or air around a person.
  - Useful for cool discomfort and cool stress.

FPST 3213 18

18

Thermal Condition Assessment

- Globe temperature is the internal temperature of a blackened hollow (thin-walled) copper sphere
  - Designed it to be responsive to radiant heat

FPST 3213 19

19

Thermal Condition Assessment

- Work demands
  - Metabolic rate reflects the amount of heat generated inside the body

FPST 3213 20

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Thermal Condition Assessment

Category	Representative Metabolic Rate (W)	Representative Activities
Sedentary	110	Resting, sitting with no regular activity
Light	200	Sitting with light manual work such as writing, typing, using small tools, inspection, and driving Standing with light hand work such as minding a drilling or milling machine Intermittent walking at slow speed
Moderate	300	Sustained hand and arm work with little effort Walking Pushing and pulling lightweight carts
Heavy	400	Intense arm and truck work Carrying, lifting or pushing/pulling heavy materials Fast walking
Very heavy	500	Very intense activities such as shoveling or digging, which require frequent breaks.

FPST 3213 21

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National Weather Service Wind Chill Chart

National Weather Service Wind Chill Chart

Air Speed		Temperature [°C]																	
m/sec	mph	4	2	−1	−4	−7	−9	−12	−15	−18	−21	−23	−26	−29	−32	−34	−37	−40	−43
		Temperature [°F]																	
Calm	Calm	40	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45
2	5	2	−1	−4	−7	−11	−14	−17	−20	−24	−27	−30	−33	−37	−40	−43	−46	−50	−53
4	10	1	−3	−6	−9	−13	−16	−20	−23	−27	−30	−34	−37	−40	−44	−47	−51	−54	−58
7	15	0	−4	−7	−11	−14	−18	−21	−25	−29	−32	−36	−39	−43	−46	−50	−53	−57	−61
9	20	−1	−4	−8	−12	−15	−19	−23	−26	−30	−34	−37	−41	−45	−48	−52	−56	−59	−63
11	25	−1	−5	−9	−13	−16	−20	−24	−27	−31	−35	−39	−42	−46	−50	−53	−57	−61	−65
13	30	−2	−6	−10	−13	−17	−21	−25	−28	−32	−36	−40	−43	−47	−51	−55	−59	−62	−66
16	35	−2	−6	−10	−14	−18	−22	−25	−29	−33	−37	−41	−44	−48	−52	−56	−60	−64	−67
18	40	−3	−7	−11	−14	−18	−22	−26	−30	−34	−38	−41	−45	−49	−53	−57	−61	−65	−69
20	45	−3	−7	−11	−15	−19	−23	−27	−31	−34	−38	−42	−46	−50	−54	−58	−62	−66	−70
22	50	−3	−7	−11	−15	−19	−23	−27	−31	−35	−39	−43	−47	−51	−55	−59	−63	−67	−71
25	55	−4	−8	−12	−16	−20	−24	−28	−32	−36	−40	−44	−48	−52	−56	−60	−64	−67	−71
27	60	−4	−8	−12	−16	−20	−24	−28	−32	−36	−40	−44	−48	−52	−56	−60	−64	−68	−72
Time to Frostbite								30 min		10 min		5 min							

*Special precautions must be taken when the wind chill is lower than −27°C (−17°F).

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Thermal Condition Assessment

- Clothing
  - Influences the rate of heat exchange by convection and radiation and modifies the rate of evaporative cooling
  - The Clo is the unit of thermal resistance used to quantity the insulation provided by clothing

$$1\ \text{Clo} = 0.155\ \text{K} \cdot \text{m}^2 \cdot \text{W}^{-1}$$

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Thermal Condition Assessment

Insulation Required (Clo Units) to Maintain Thermal Balance

Temperature (°C)	Activity			
	Resting[a]	Slow Walking	Normal Walking	Fast Walking
21	1.5	0.7	0.4	0.3
10	3.1	1.5	0.9	0.7
−1	4.7	2.3	1.5	1.1
−18	7.2	3.5	2.3	1.

[a] When asleep, metabolic energy expenditure drops to 0.8 MET, so more insulation is required.

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Thermal Condition Assessment

Work Demands	Air Temperature					
	10ºC 50ºF	12ºC 54ºF	14ºC 57ºF	16ºC 61ºF	18ºC 64ºF	20ºC 68ºF
Sedentary	2.4–3.9	2.2–3.5	2.0–3.2	1.8–2.9	1.6–2.5	1.4–2.2
Light	1.3–2.7	1.2–2.5	1.1–2.2	1.0–2.0	0.9–1.7	0.7–1.5
Moderate	0.9–2.0	0.8–1.8	0.7–1.6	0.7–1.5	0.6–1.3	0.5–1.1
Heavy	0.7–1.6	0.6–1.4	0.5–1.3	0.5–1.1	0.4–1.0	0.4–0.9

The higher level of insulation helps maintain minimum discomfort, and the lower value is the least required to avoid extreme discomfort based on the equations provided in the text. While the cold stress threshold is 10C (see section on cold stress), caution must be exercised in allowing extreme discomfort.

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Thermal Condition Assessment

Clothing	clo
Sleeveless blouse, light cotton skirt, sandals	0.3
Shorts, open-neck shirt with short sleeves, light socks, sandals	0.3–0.4
Long lightweight trousers, open-neck shirt with short sleeves	0.5
Long lightweight trousers, open-neck shirt with long sleeves	0.6
Cotton fatigues, lightweight underwear, cotton shirt and trousers, cushion-sole socks and boots	0.7
Typical business suit; pant suit (with full jacket)	1.0
Typical business suit and cotton coat (lab coat)	1.5
Heavy traditional European business suit, long cotton underwear, long-sleeved shirt, woolen socks, shoes; suit includes trousers, jacket, and vest	1.5–2.0

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Thermal Comfort Zone

- Temperature
  - Ankles and head should not change by more than 3ºC (5ºF)
- Humidity
  - Below 55% or preferable in the summer months
  - Where feasible, values above 25% shall be used for extended exposure (more than two hours)
- Airspeed
  - Local draft can make a workplace feel very cool even when it is well within the comfort guidelines for dry bulb temperature
  - Allowing fans and worker discretion can increase the level of comfort for those who may feel unacceptably warm

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Thermal Comfort Zone

- Workload
- Clothing
- Radiant heat
  - The difference between dry bulb and globe temperature defines the amount of radiant heat present in the workplace

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Warm Discomfort and Heat Stress

- The exposure limits are based on an index for the environment called WBGT

Wet bulb glob temperature WBGT

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Heat Stress

- Heat stress
- Controls
  - Individual
  - Engineering
  - Administrative

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Heat Stress Controls

- Personal protection

Circulating air systems

Circulating water systems

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Heat Stress Controls

Passive cooling systems

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Cold Stress Controls

- Individual
- Engineering controls
- Administrative controls

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Cold Stress Controls

- Personal protection
  - Adequate insulated clothing
  - Hydration
  - Balanced diet

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Screening for Heat Stress

Screening for Heat Stress—Checklist*

Job	Analyst
	Date
Description of Climate, Work Demands, Clothing	Special Conditions

Complete the following checklist for each potential heat stress situation.

Job Factor	Yes	No
Obvious sweating		
Environment perceived to be warm		
Work requires a break at least every 2 hours		
Wearing regular work clothes would be more comfortable		
Reports of fatigue, weakness, loss of coordination, dizziness, headaches, nausea, heat exhaustion, cramps		
Absenteeism, employee irritability, or worsening employee relations can be associated with these work conditions		
Increases in accidents and injuries and/or decreases in production and quality indices can be associated with these work conditions		

A yes to the presence of any of these job factors would indicate that a further investigation and controls are appropriate.

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Screening for Heat Stress

Screening for Thermal Stress—Observational Analysis*

Job	Analyst
	Date
Description of Climate, Work Demands, Clothing	Special Conditions

Complete the following matrix by consensus of observers very familiar with the workplace and possible exposure situations. Table of scores and qualitative descriptors for each of the categories follows on the next page.

Scores	−3	−2	−1	0	+1	+2	+3
				Ideal Zone			
Air temperature							
Humidity							
Thermal radiation							
Air movement							
Workload							
Clothing							
Worker opinion							

Actions should be taken to bring scores outside of the ±1 range into this range.

* This observational method is adapted from J. Malchaire, H. J. Gebhardt, and A. Piette, "Strategy for evaluation and prevention of risk due to work in thermal environments," *Annals of Occupational Hygiene* 43:367–376, 1999.

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Summary

1. Operators should remain in thermal balance with the environment while carrying out critical and generic tasks
2. Work must be designed so that skin temperatures remain in a range defined as comfortable
3. Fluid should be readily at hand to prevent dehydration
4. Ventilation should be sufficient to support human health and performance
5. Workers should be protected from high radiant heat and ultraviolet radiation

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Vibration

Do you think we are expose to any vibration right now?

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Vibration's definition

Periodic back-and-forth motion of the particles of an elastic body or medium, commonly resulting when almost any physical system is displaced from its equilibrium condition and allowed to respond to the forces that tend to restore equilibrium.

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Vibration

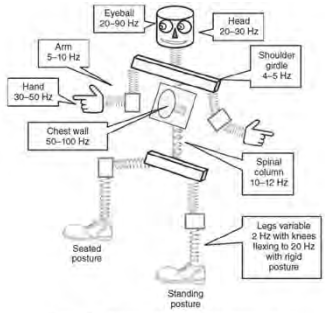

Figure 10.1 Resonance frequencies of the human body

Frequency (F) – The frequency of a vibration, measured in hertz (Hz), is simply the number of to and for movements made in each second.

Resonance – Every object tends to vibrate at one particular frequency called the natural frequency.

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Vibration

- ACGIH TLVs (ISO 5349, ANSI S3.34) for
  - Hand-Arm Vibration
  - Upper Limb
  - Whole Body Vibration

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Vibration Injuries

- Hand-Arm Vibration (HAVS)
  - Hand and arm vibration syndrome, white finger, raynaud's phenomenon.
  - Some evidence supports exposure to hand and arm vibration contributing to carpal tunnel and ulnar nerve entrapment
- Whole Body Vibration (WBV)
  - Headaches, nausea, motion sickness, insomnia, shakiness, back problems

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Hand Arm Vibration Syndrome (HAVS)

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Whole Body Vibration (WBV)

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TABLE 10.1 Sources of Vibration

Industry	Type of Vibration	Common Source of Vibration
Agriculture	Whole body	Tractors
Military, commercial, and general aviation	Whole body	Aircraft
Military and others	Whole body and hand-arm	Boats
Boiler making	Hand-arm	Pneumatic tools
Construction	Whole body	Heavy equipment vehicles
	Hand-arm	Pneumatic tools, jackhammers
Diamond cutting	Hand-arm	Vibrating hand tools
Forestry	Whole body	Tractors
	Hand-arm	Chain saws
Foundries	Hand-arm	Vibrating cleaners
Furniture manufacture	Hand-arm	Pneumatic chisels
Iron and steel	Hand-arm	Vibrating hand tools
Lumber	Hand-arm	Chain saws
Machine tools	Hand-arm	Vibrating hand tools
Mining	Whole body	Vehicle operation
	Hand-arm	Rock drills
Riveting	Hand-arm	Hand tools
Rubber	Hand-arm	Pneumatic stripping tools
Sheet metal	Hand-arm	Stamping equipment
Shipyards	Hand-arm	Pneumatic hand tools
Shoe-making	Hand-arm	Pounding machine
Stone dressing	Hand-arm	Pneumatic hand tools
Textile	Hand-arm	Sewing machines, looms
Transportation	Whole body	Vehicles

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Hand Arm Vibration Syndrome (HAVS)

- Hand Arm Vibration Syndrome (HAVS)

The Stockholm Workshop Scale for the classification of Cold-Induced Raynaud's Phenomenon in the Hand-arm Vibration Syndrome *

STAGE	GRADE	DESCRIPTION
0		No attacks.
1	Mild	Occasional attacks affecting only the tips of one or more fingers
2	Moderate	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers.
3	Severe	Frequent attacks affecting all phalanges of the most fingers.
4	Very Severe	As in stage 3, with trophic skin changes in the finger tips.

* The staging is made separately for each hand. In the evaluation of the subject, the grade of the disorder is indicated by the stages of both hands and the number of affected fingers on each hand; example "2L(2) / 1R(1)", "- / 3R(4)", etc.

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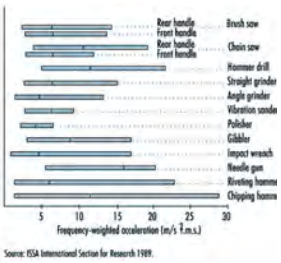
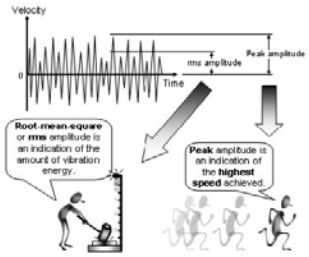
Hand and Arm Vibration





https://reliabilityweb.com/articles/entry/how_is_machine_vibration_described/

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Vibration Measurement

- Vibration measurement
  - Magnitude of acceleration RMS
  - Frequency (Cycles per second or hertz (Hz))
  - Direction
  - Exposure time
  - Point of application
  - Clothing
  - Body size
  - Body posture
  - Body tension

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Vibration Measurement

- Accelerometers
  - Specialized devices for home-body vibration
    - Impact
    - No impact
  - Device directly mounted to vibrating object

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Vibration Measurement

- Evaluation of human vibration RMS acceleration compared against reference levels
- ACGIH has established TLV's
  - Whole body
  - Hand and arm

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Vibration Hand and Arm

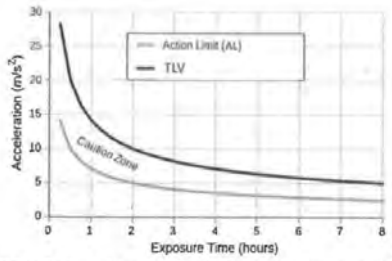

FIGURE 1. Relationship between exposure time [hours] and A(8) acceleration [m/s²].

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Example

- String trimmers are around 20 m/s^2 rms
- What is the daily operating limit?

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Vibration Hand and Arm

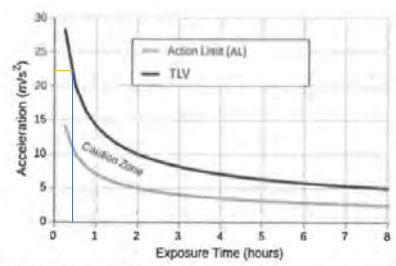

FIGURE 1. Relationship between exposure time [hours] and A(8) acceleration [m/s²].

The daily limit for operating a string trimmer is around 30 minutes

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Vibration

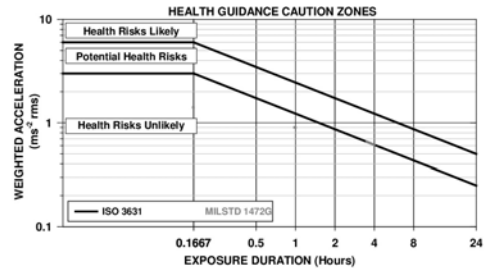

Figure 16. ISO 2631-1 Health Guidance Caution Zones
Plot includes more conservative lower boundary defined in MIL STD 1472G exposures at 3.5 hours and below [2, 3]

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Vibration Controls

- Source control
- Receiver control

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Vibration Controls

- Path control
  - Gloves are more common
    - More effective for high frequencies
  - Reduce the weight of the object held
  - Use larger gripping surfaces to better distribute forces in the hand

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Ventilation

Carbon Dioxide or CO_2 is a greenhouse gas that is natural and harmless in small quantities, but as levels rise it can affect productivity and sleep.

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Ventilation

As buildings and homes become more energy-efficient and airtight, this means we have less fresh air.

- Recycle air to conserve energy

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What do my CO_2 levels mean?

250-400ppm	Normal background concentration in outdoor ambient air
400-1,000ppm	Concentrations typical of occupied indoor spaces with good air exchange.
1,000-2,000ppm	Complaints of drowsiness and poor air
2,000-5,000ppm	Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea.
>40,000ppm	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma and even death.

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Ventilation

$$N = \frac{60Q}{Vol}$$

Where:

- N = number of air changes per hour
- Q = Volumetric flow rate of air in cubic feet per minute (cfm)
  Area*speed
- Vol = Space volume $L \times W \times H$, in cubic feet

$$Rp = \frac{N * D * h}{60}$$

Where:

- R_p = ventilation rate per person (CFM per person, L/s per person)
- N = Air changes per hour
- D = Occupant density (occupants per square foot, occupants per square meter)
- h = Ceiling height (ft, meters)

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Ventilation rate

- Range *15 - 60 cfm per person*
- Most common range *15 - 35 cfm per person*
- Average range *15 - 20 cfm per person*

Cubic feet per minute (cfm)

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What are the effects of CO_2?

High levels are directly correlated to low productivity and high sick leave making this a crucial concern in offices, schools and home environments.

Restlessness

Drowsiness

Increased heart rate and blood pressure

Sweating

Headache

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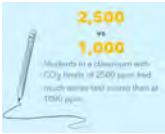
What are the effects of CO_2?

At home

Fresh air will help you get a better night's sleep.

At school



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Measuring CO_2

- CO_2 Monitor

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Reducing CO_2

- Ventilation
- Amount of people
- Length of time in an enclosed space
- Regularly replace air filters in indoor fan systems

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Reducing CO_2

- <u>Plants:</u>

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To do list

- Read chapter 6,15
- I will post HW 3.
- Next week
  - Tuesday – Bring computers.

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Team Project

Team Project

- Ergonomic Risk Factor Evaluations of High Risk Professions

FPST 3213 3

Team Project

Ergonomic work design is an important aspect in prevention of injuries, but sometimes the work tasks cannot be modified due to operational, engineering, or economic constraints.

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Team Project

- The risks discussed in the paper and presentation should focus on **Ergonomic or Human Factor risks only**.

FPST 3213 5

Team Project

- Review of available Injury and Illness data for the occupation
- Review of common physical tasks associated with the profession
- Review of ergonomic risk factors associated with the tasks
- Suggested ergonomic controls that could be implemented to either eliminate or mitigate the risks
- Discussion of costs vs benefit of implementing controls vs. doing nothing

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Team Project

- Review of available Injury and Illness data for the occupation: All team members

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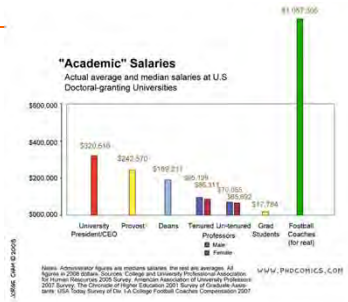

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The Compelling Display of Health & Safety Information to Achieve Desired Decision Making

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Achieving EH&S Data Display Excellence

- The presentation of complex ideas and concepts in ways that are
  - Clear
  - Precise
  - Efficient

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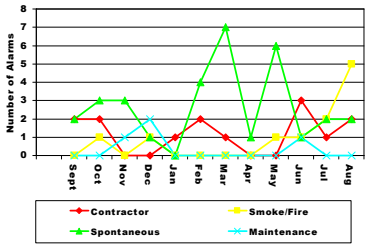
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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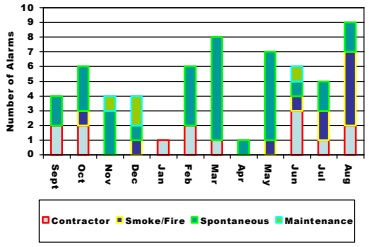
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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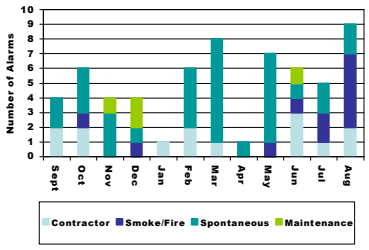
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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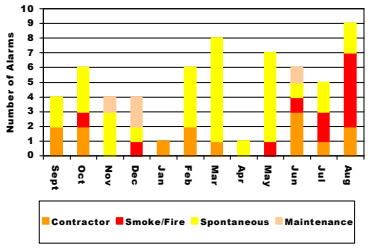

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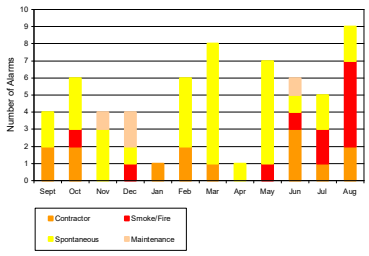
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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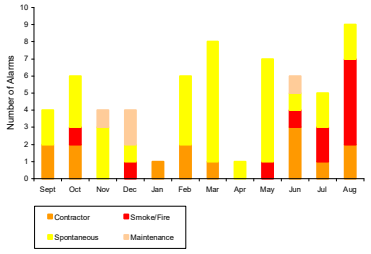
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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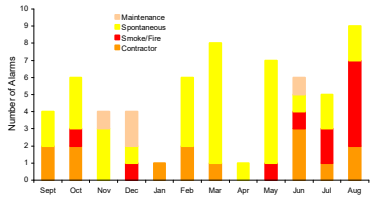
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge



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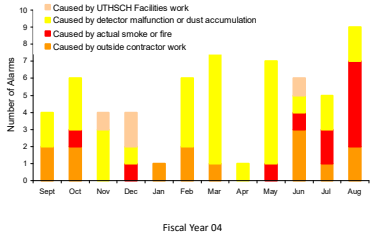
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge (FY04)



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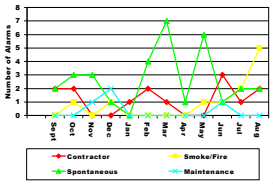
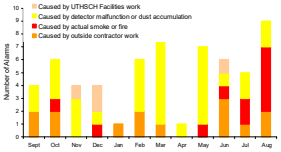
Results of the Great UTHSC-H Nuisance Fire Alarm Challenge





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COLLABORATIVE LABORATORY INSPECTION PROGRAM (CLIP)

- During October 2005, 80 Principal Investigators for a total of 316 laboratory rooms were inspected
- A total of 30 CLIP inspections were performed

PI Inspections:

	Total PI's	#Without Lab Violations	# With Lab Violations	%Without Lab Violations	%With Lab Violations
May 2005	94	53	41	56.38	43.62
June 2005	78	40	38	51.28	48.72
July 2005	84	54	30	64.29	35.71
August 2005	74	54	20	72.97	27.03
September 2005	69	39	30	56.52	43.48
October 2005	80	50	30	62.50	37.50

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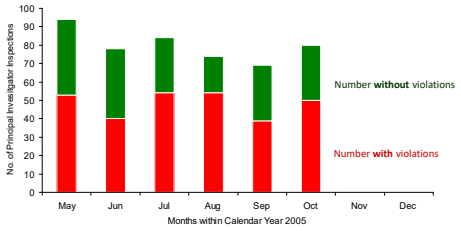
2005 Collaborative Laboratory Inspection Program (CLIP) Inspection Activities and Compliance Findings



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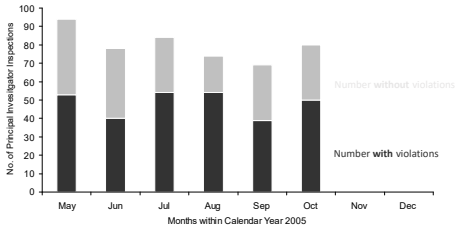
2005 Collaborative Laboratory Inspection Program (CLIP) Inspection Activities and Compliance Findings



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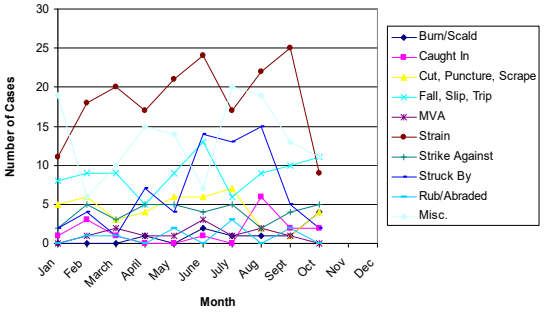
2005 Workers' Compensation by Injury Type



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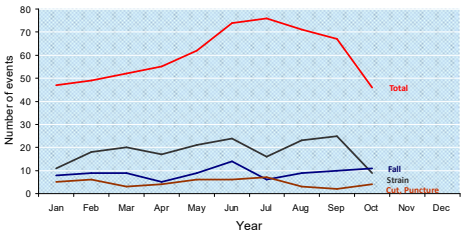
2005 Total Number of Monthly Workers Compensation Claims inclusive of the three most frequent identifiable classes of injuries



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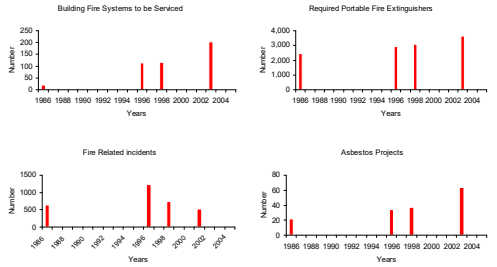
Growth in Occupational Safety Responsibilities 1986 to 2003



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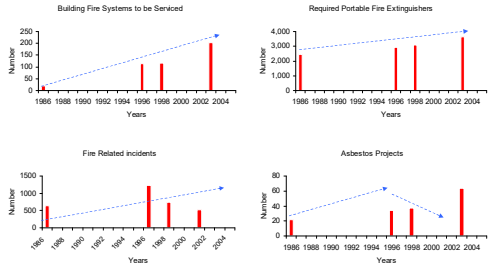
Growth in Occupational Safety Responsibilities 1986 to 2003



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Team Project

- Review of common physical tasks associated with the profession: All team members

FPST 3213 27

Team Project

One task per student:

- Review of ergonomic risk factors associated with the tasks
- Suggested ergonomic controls that could be implemented to either eliminate or mitigate the risks
- Discussion of costs vs benefit of implementing controls vs. doing nothing

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Example

Task

Flipping burgers with a weighted spatula

FPST 3213 29

Flipping burgers with a weighted spatula

- Review of ergonomic risk factors associated with the task

Hazards

Carrying the load of both burgers and the weighted spatula with one wrist can lead to strain and tendonitis/MSDs

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Flipping burgers with a weighted spatula

- Suggested ergonomic controls that could be implemented to either eliminate or mitigate the risks

Proposed controls

Rotate the worker every 4 hours (administrative control)

Give the worker a wrist brace (PPE)

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Flipping burgers with a weighted spatula

- Discussion of costs vs benefit of implementing controls vs. doing nothing

Cost/Benefit

Cost of wrist brace: $20

Cost of rotating employee: pay the worker's replacement $10/hr, the same as the worker

Cost of doing nothing: $0 initially

If worker gets carpal tunnel: worker's comp is $267 per week while they are away from work

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Submissions

The first submission is due by

March 22th by 11:59pm.

You will need to submit **two** documents for the first submission:

1. An outline of your case study.
2. List of tasks that will be analyzed and the name of the student assigned to a particular task.

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Submissions

You will submit your final report by **May 2, by 11:59pm.**

The written report must be typewritten; at least seven pages of 11-point font text, double spaced with one-inch margins on all sides. Drawings and other supporting materials must be appended. The seven pages must not include appendices or the bibliography. The report should cite at least three peer reviewed journal articles or government research findings in a reference list. Write the paper in active voice and in a manner that no section is identifiable as being written by a different author.

All group members should contribute equally to all parts of the assignment.

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Rubric

Criteria	Exemplary (3)	Competent (2)	Fair (1)	Poor (0)
Context of and Purpose for Writing Includes considerations of audience, purpose, and the circumstances surrounding the writing task(s).	Demonstrates a thorough understanding of context, audience, and purpose that is responsive to the assigned task(s) and focuses all elements of the work.	Demonstrates adequate consideration of context, audience, and purpose and a clear focus on the assigned task(s) (e.g., the task aligns with audience, purpose, and context).	Demonstrates awareness of context, audience, purpose, and to the assigned task(s) (e.g., begins to show awareness of audience's perceptions and assumptions).	Demonstrates minimal attention to context, audience, purpose, and to the assigned task(s) (e.g., expectation of instructor or self as audience).
Content Development - Injury and Illness data Logical presentation of evidence, conclusion/recommendation that addresses the topic	Uses appropriate, relevant, and compelling content to illustrate mastery of the subject, conveying the writer's understanding, and shaping the whole work.	Uses appropriate, relevant, and compelling content to explore ideas within the context of the discipline and shape the whole work.	Uses appropriate and relevant content to develop and explore ideas through most of the work.	Uses appropriate and relevant content to develop simple ideas in some parts of the work.
Content Development - Physical tasks Logical presentation of evidence, conclusion/recommendation that addresses the topic	Uses appropriate, relevant, and compelling content to illustrate mastery of the subject, conveying the writer's understanding, and shaping the whole work.	Uses appropriate, relevant, and compelling content to explore ideas within the context of the discipline and shape the whole work.	Uses appropriate and relevant content to develop and explore ideas through most of the work.	Uses appropriate and relevant content to develop simple ideas in some parts of the work.
Content Development - Risk factors Logical presentation of evidence, conclusion/recommendation that addresses the topic	Uses appropriate, relevant, and compelling content to illustrate mastery of the subject, conveying the writer's understanding, and shaping the whole work.	Uses appropriate, relevant, and compelling content to explore ideas within the context of the discipline and shape the whole work.	Uses appropriate and relevant content to develop and explore ideas through most of the work.	Uses appropriate and relevant content to develop simple ideas in some parts of the work.
Content Development - Ergonomic controls Logical presentation of evidence, conclusion/recommendation that addresses the topic	Uses appropriate, relevant, and compelling content to illustrate mastery of the subject, conveying the writer's understanding, and shaping the whole work.	Uses appropriate, relevant, and compelling content to explore ideas within the context of the discipline and shape the whole work.	Uses appropriate and relevant content to develop and explore ideas through most of the work.	Uses appropriate and relevant content to develop simple ideas in some parts of the work.
Content Development - costs vs benefit Logical presentation of evidence, conclusion/recommendation that addresses the topic	Uses appropriate, relevant, and compelling content to illustrate mastery of the subject, conveying the writer's understanding, and shaping the whole work.	Uses appropriate, relevant, and compelling content to explore ideas within the context of the discipline and shape the whole work.	Uses appropriate and relevant content to develop and explore ideas through most of the work.	Uses appropriate and relevant content to develop simple ideas in some parts of the work.
Genre and Disciplinary Conventions Formal and informal rules inherent in the expectations for writing in particular forms and/or academic fields (Following APA format/FPST writing guide, correct page length).	Demonstrates detailed attention to and successful execution of a wide range of conventions particular to a specific discipline and/or writing task (s) including organization, content, presentation, formatting, and stylistic choices.	Demonstrates consistent use of important conventions particular to a specific discipline and/or writing task(s), including organization, content, presentation, and stylistic choices.	Follows expectations appropriate to a specific discipline and/or writing task(s) for basic organization, content, and presentation.	Attempts to use a consistent system for basic organization and presentation.
Sources and Evidence (Deductions for too few sources (at least three), non-first sources*, improper in-text citations, improper reference section)	Demonstrates skillful use of high-quality, credible, relevant sources to develop ideas that are appropriate for the discipline and genre of the writing.	Demonstrates consistent use of credible, relevant sources to support ideas that are situated within the discipline and genre of the writing.	Demonstrates an attempt to use credible and/or relevant sources to support ideas that are appropriate for the discipline and genre of the writing.	Demonstrates an attempt to use sources to support ideas in the writing.

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Presentation

You will present your research to the class in a presentation during **May 10 or May 17** lectures. Presentations should be 1**5 minutes** in length and of professional quality (including business casual dress).

You are required to submit your presentation by **May 6 by 11:59 pm.**

FPST 3213 36

Rubric

Criteria	Exemplary (3)	Competent (2)	Fair (1)	Poor (0)
Organization	Organizational pattern (specific introduction and conclusion, sequenced material within the body, and transitions) is clearly and consistently observable and is skillful and makes the content of the presentation cohesive.	Organizational pattern (specific introduction and conclusion, sequenced material within the body, and transitions) is clearly and consistently observable within the presentation.	Organizational pattern (specific introduction and conclusion, sequenced material within the body, and transitions) is intermittently observable within the presentation.	Organizational pattern (specific introduction and conclusion, sequenced material within the body, and transitions) is not observable within the presentation.
Language	Language choices are imaginative, memorable, and compelling, and enhance the effectiveness of the presentation. Language in presentation is appropriate to audience.	Language choices are thoughtful and generally support the effectiveness of the presentation. Language in presentation is appropriate to audience.	Language choices are mundane and commonplace and partially support the effectiveness of the presentation. Language in presentation is appropriate to audience.	Language choices are unclear and minimally support the effectiveness of the presentation. Language in presentation is not appropriate to audience.
Delivery	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation compelling, and speaker appears polished and confident.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation interesting, and speaker appears comfortable.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation understandable, and speaker appears tentative.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) detract from the understandability of the presentation, and speaker appears uncomfortable.
Supporting Material	A variety of types of supporting materials (explanations, examples, illustrations, statistics, analogies, quotations from relevant authorities) make appropriate reference to information or analysis that significantly supports the presentation or establishes the presenter's credibility/authority on the topic.	Supporting materials (explanations, examples, illustrations, statistics, analogies, quotations from relevant authorities) make appropriate reference to information or analysis that generally supports the presentation or establishes the presenter's credibility/authority on the topic.	Supporting materials (explanations, examples, illustrations, statistics, analogies, quotations from relevant authorities) make appropriate reference to information or analysis that partially supports the presentation or establishes the presenter's credibility/authority on the topic.	Insufficient supporting materials (explanations, examples, illustrations, statistics, analogies, quotations from relevant authorities) make reference to information or analysis that minimally supports the presentation or establishes the presenter's credibility/ authority on the topic.
Central Message - Injury and Illness data	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported.)	Central message is clear and consistent with the supporting material.	Central message is basically understandable but is not often repeated and is not memorable	Central message can be deduced, but is not explicitly stated in the presentation.
Central Message - Physical tasks	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported.)	Central message is clear and consistent with the supporting material.	Central message is basically understandable but is not often repeated and is not memorable	Central message can be deduced, but is not explicitly stated in the presentation.
Central Message -Ergonomic risk factors	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported.)	Central message is clear and consistent with the supporting material.	Central message is basically understandable but is not often repeated and is not memorable	Central message can be deduced, but is not explicitly stated in the presentation.
Central Message - Suggested ergonomic controls	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported.)	Central message is clear and consistent with the supporting material.	Central message is basically understandable but is not often repeated and is not memorable	Central message can be deduced, but is not explicitly stated in the presentation.
Central Message -Costs vs benefit	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported.)	Central message is clear and consistent with the supporting material.	Central message is basically understandable but is not often repeated and is not memorable	Central message can be deduced, but is not explicitly stated in the presentation.
Presentation Design	Template, size fonts, images, amount of information in the slides			

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Grading

Team Project Report	**20%**
• First submission	4%
• Final submission	16%
Presentation	**10%**
Group evaluation	**5%**

You will be responsible for an individual evaluation for each of your group members for the final submission. Include a description of the contributions of everyone in the group.

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Team Project

Industry Specific Ergonomic Control Plan

1. Transportation
2. Toys manufacturing industry
3. Automobile manufacturing industry
4. Cement manufacturing industry
5. Chemical fertilizers manufacturing industry
6. Steel manufacturing industry
7. Textile manufacturing industry
8. Electronics manufacturing industry
9. Electricity production
10. Rice production
11. Seafood production

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Team Project - Groups

Industry	Members
Transportation	Haokai Huang Ziheng Fang Zitai Zhou Jiachen Wang Liu Sha
Toys manufacturing industry	Junping Jiang Yujia Jiang Tianxiang Jia Tongyuan Zhang Jiaxin Li

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Team Project - Groups

Industry	Members
Automobile manufacturing industry	Lifan Lu Xinyu Liu Xuanchen Li Haoyu Wang Haijing Wen
Cement manufacturing industry	Zihan Qiu Kejie Zhou Zihao Han Zhongpei Wang Wenhao Hu

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Team Project - Groups

Industry	Members
Chemical fertilizers manufacturing industry	Wanyun Rao Zhiyuan Sun Zhihan Huang Liuyi Bian Zhuoxin Luo
Steel manufacturing industry	Haijia Tang Xinhao Liu Ruohan Guo Changgen Xie Minghao Wang

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Team Project - Groups

Industry	Members
Textile manufacturing industry	Zhenwei Wu Yu Cui Hongtu Zhou Shiyi Zhu Ruiyi Tang
Electronics manufacturing industry	Lili Wang Lanjing Wang Yuting Wu Yilan Xu Yufeng Zheng

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Team Project - Groups

Industry	Members
Electricity production	Xintao Yang Wenqi Song Meihao Cheng Zeyin Lin Yuchen Zhou
Rice production	Qinann Zeng Mingxun Zhou Qingyao Shi Zhifeng Zhang Xuefeng Han

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Team Project - Groups

Industry	Members
Seafood production	Qihang Zhou Junkan Fan Zhengjie Jiang Xinwei Fu

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To do list

The first submission is due by

March 22by 11:59pm

You will need to submit **two** documents for the first submission:

1. An outline of your case study.
2. List of tasks that will be analyzed and the name of the student assigned to a particular task.

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Outline

Topic	Possible source	Responsible	Due date
Introduction			
Data analysis			

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Task

Task 1	Basic description	Responsible
Cooking burgers	Flipping burgers with a weighted spatula	Student 1

FPST 3213 48

Anthropometry

Part 1

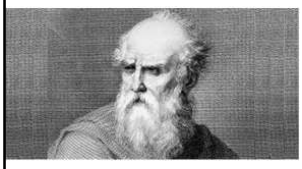
Objectives

- Know what Anthropometry is
- Know the types of measurements that can be made
- Understand how anthropometry is used for ergonomics and workplace design

Anthropometry

- From the Greek
  - Anthro- : man
  - pometry: measurements
  - Literal meaning: “measurement of humans”
- A branch of anthropology

Vitruvius – 15 BC



https://www.davincilife.com/vitruvianman.html

- Vitruvius
  - Roman author, architect, civil engineer and military engineer
  - First century Roman architect and author of "De Architectura libri X” (the 10 books on Architecture).

The Vitruvian Man

He proposed that a properly constructed temple should reflect and relate to the parts of the human body

https://www.davincilife.com/vitruvianman.html

Anthropometry

- Leonardo da Vinci
  - Vitruvian Man

Four Books of Human Proportions

- Albrecht Dürer - 1471-1528
  - "Four Books on Human Proportion of 1528"
- Dürer's books may be regarded as the beginnings of modern scientific anthropometry

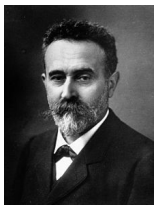
Four Books of Human Proportions

"If you wish to make a beautiful human figure, it is necessary that you probe the nature and proportions of many people: a head from one; an arm, leg from another…"

Four Books of Human Proportions

History of Anthropometry

- 1883- Alphonse Bertillon



History of Anthropometry

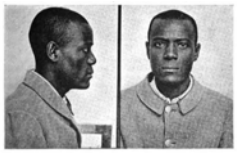
Sir Francis Galton 1822-1911

Eugenics Propaganda

- Aryan vs. non-Aryan
  - associated by many with the racial ideologies and atrocities committed by the Nazis

1903 The West Case

Will West



William West

1903 The West Case

Anthropometric Data

- What are some valuable ways that anthropometric data can be used?

Anthropometry

- Anthropometry is a valuable tool for guiding the health and nutritional status of individuals and populations

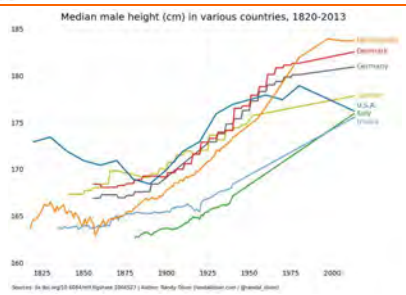
Anthropometric Data

- Furniture dimensions
- Clothing sizes
- Operator Controls
- Vehicle interiors
- Airplane seat widths
- Door heights
- Exit access
- Cell phone widths
- Shoe sizes
- Tools

Anthropometric Data

Are the body dimensions of the human population constant over the time?

Anthropometric Data



Anthropometric Data

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

Anthropometric Measuring Techniques

- Weight
- Height
- Posture:
  - Standing
  - Sitting
- Arm Span
- Head Length
- Head Breadth
- Ear-to-Head Height
- Reach
- Grip strength
- Limb length

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Anthropometric Measuring Tools

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Anthropometric Measuring Tools

- Goniometer
  - Precision angular measurement

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Anthropometric Measuring Tools

- Calipers

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Anthropometric Measuring Tools

- Spreading caliper
  - measure distance between two points where one or both points may not be on a flat surface

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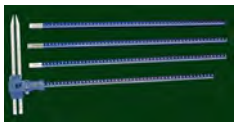
Anthropometric Measuring Tools

- Anthropometer



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Anthropometric Measuring Tools

- Measuring grip strength

Factors Affecting Anthropometry

Factors Affecting Anthropometry

- Human Diversity
  - Gender differences
  - Age differences
  - Growth and development
  - Environment
  - Aging – perceptual and cognitive abilities
  - Nutrition
  - Life style

Growth and Development

- At birth:
  - 7-8 pounds
  - 18" length
    - Torso represents 70%
- 20 years later
  - Body length increases three to four times
  - Weight increases 20 times
  - Linear proportions change
    - Torso accounts for only 52% of the stature

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Growth and Development

At 40, we begin to shrink

- Accelerates with age
- Women shrink more than men
- Believed to occur in the intervertebral discs of the spine

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Examples of Anthropometric Uses

- Driving
  - The mismatch of a heavy-vehicle operator's station to a driver could produce blind spots that limit safe operation
- Respirators
  - The misfit of a respirator could result in serious health effects in firefighting, hazardous waste cleanup
- Aircraft
  - Inadequate crew station geometry was found to be a contributor to some crew members injuries during ejection from an aircraft

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Anthropometric Differences in Workgroups

- 2002 NIOSH Study
  - The increasing demands for anthropometric information for the design of machinery and PPE
  - The study identified differences in various body measurements between occupational groups in the USA.
- Fire fighter gloves
- Fire truck seatbelts
- Truck cab designs
- Fall protection harnesses

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Work design or modification

Do the workers fit in the workplace?

Does the design of the equipment have any adverse effect on the worker's safety or productivity?

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Work design or modification

Factors need to be considered:

1. Safe clearances or heights – examples, doorways or walkways
2. Safe reach distances – examples, equipment controls
3. Code requirements
4. Safety features – examples, machine guards
5. Workstation design for work flows.

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Use of Anthropometric Data

Designing for the maximum, the average or minimum population?

Use of Anthropometric Data

- Designing for the maximum population
  - Examples, heights of doorways, sizes of an escape hatches, strength of rope ladders, strength of the workbenches
- Designing for the minimum population
  - Examples: distance of a control button from the operator, force required to operate the controls

Use of Anthropometric Data

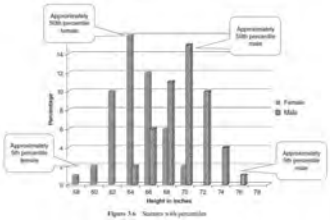
- <u>Designing for the average</u>
  - There is no “average” individual
  - A person may be average on one or two body dimensions, but not all of them
  - Should only be done after careful consideration of the situation and never as an easy way out

Use of Anthropometric Data

- Designing for adjustable range
  - The obvious preferred method
  - Examples: automobile seats, office chairs, desk heights, footrests
  - Adjustable range is from XXX to XXX

Use of Anthropometric Data

- Designing for adjustable range
  - Adjustable range is from the 5th percentile female to the 95th percentile male



Use of Anthropometric Data

- Define the population that will use the equipment
  - Children, women, US civilians, age group, etc.
- Determine the body dimensions important in the design
  - Sitting height as a basic factor in a seat to roof dimension in automobiles
- Determine what principle should be applied
  - Design for extremes
  - Design for adjustability
  - Design for average
- Select the relevant population to be accommodated
  - Locate anthropometric tables appropriate for the population
- Allow for appropriate special clothing as applicable
- Build a full-scale mock-up

Modern Uses of Anthropometrics

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Modern Uses of Anthropometrics

- Boone Pickens Stadium
  - 2016 – 60,218
  - 2017 – 56,790
  - 2016 – 12-16” wide
  - 2017 – 20” wide

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Modern Uses of Anthropometrics

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Modern Uses of Anthropometrics

Anthropometry Today

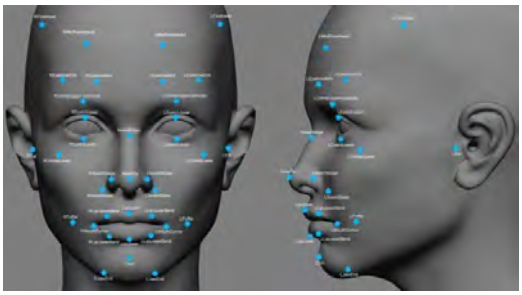
Anthropometry Today

- Biometrics
- Sports Performance – Tools to measure human movement include video, accelerometer, medical imaging, and 3-D motion capture
- Dynamic anthropometry

Anthropometry Today

- Changes in humans overtime
- Hand Geometry
- Face Location
- Multibiometrics

Facial Recognition Technology



Facial Recognition Technology

Identification → Authentication

Measurement → Match

Facial Recognition Technology

- Forensics: criminal identification and prison security
- Prevention of unauthorized access to ATMs, cellular phones, workstations, and computer networks
- Automobiles: replace keys with key-less entry and key-less ignition
- Border control and national ID cards

Biometrics in Use

BenGurion Airport:
Hand Geometry

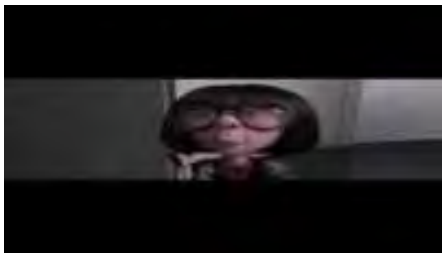
INSPASS:
Hand Geometry

Heathrow
Airport- Iris

FacePass:
Face Verification

Grocery Store
Payment: Fingerprint

Biometrics in Use



https://www.youtube.com/watch?v=239jmYOhF9c

Anthropometric tables

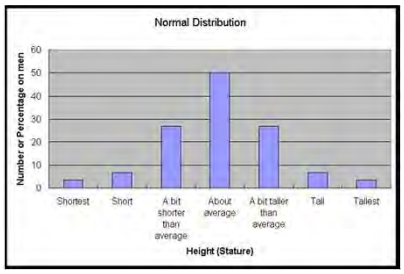
- Frequency distribution
  - Mean
  - Median
  - Standard deviation
  - Percentiles

Average Male Height Worldwide

TABLE 3.1 Height in Inches for Males Aged 20 and Over and Number of Examined Persons, Mean, Standard Error of the Mean, and Selected Percentiles, by Race and Ethnicity and Age

Race and Ethnicity	Number of Examined Persons	Mean	Standard Error of the Mean	Percentile 5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[a]												
20 years and over	5647	69.3	0.08	64.3	65.4	66.2	67.5	69.3	71.2	72.5	73.0	74.1
20–29 years	895	69.4	0.13	64.4	65.5	66.5	67.4	69.4	71.5	72.6	73.1	74.1
30–39 years	948	69.5	0.14	64.4	65.4	66.3	67.5	69.5	71.6	72.6	73.3	74.2
40–49 years	934	69.6	0.17	64.9	66.0	66.6	67.6	69.6	71.5	72.6	73.5	74.4
50–59 years	938	69.5	0.13	64.5	65.8	66.3	67.7	69.7	71.3	72.3	72.8	74.4
60–69 years	932	68.8	0.10	63.9	64.8	65.7	66.9	69.0	70.7	71.9	72.6	73.6
70–79 years	646	68.2	0.13	63.6	64.6	65.2	66.3	68.2	70.0	70.9	71.9	72.7
80 years and over	354	67.2	0.15	62.5	63.7	64.4	65.5	67.3	69.2	69.9	70.4	71.5

Whom to Design for?



Design principles
- Design for extremes
- Design for adjustability
- Design for average

Basic statistical functions

- The examples that follow are for a Population
- If the data is a Sample then the calculation changes

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Problems

- Anthropomorphic measurements (feet):

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

Units

1.62 feet = 49.37 cm

1 foot = 30.48 cm

Basic statistical functions

- Median – the "middle" of a sorted list of numbers

Median

Total amount of data is an odd number

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.67
1.75
1.80
1.86
1.99
2.10

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Median even number

Total amount of data is an even number

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.63
1.67
1.75
1.80
1.86
1.99
2.10

Median even number

Total amount of data is an even number

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.63
1.67
1.75
1.80
1.86
1.99
2.10

the **median** is the average of the middle two **numbers**

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Basic statistical functions

- Mean – the average of a data set

$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.71615385
- What is the sample standard deviation?
- What is the population standard deviation?

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.72
- What is the sample standard deviation?
- What is the population standard deviation?

Basic statistical functions

- The standard deviation is a measure of the amount of variation or dispersion of a set of values.

Standard Deviations

Standard Deviation-Sample

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

N = number of data points
X = each data point
$\overline{x}$ = Mean of the sample data points

Standard Deviation-Population

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

X_i = is an individual value
μ = is the average of the population
N = is the total number of the population

Standard Deviations

1.55	-0.17	0.0289					
1.57	-0.15	0.0225					
1.58	-0.14	0.0196					
1.59	-0.13	0.0169					
1.61	-0.11	0.0121					
1.62	-0.1	0.01					
1.62	-0.1	0.01					
1.67	-0.05	0.0025					
1.75	0.03	0.0009					
1.8	0.08	0.0064					
1.86	0.14	0.0196					
1.99	0.27	0.0729					
2.1	0.38	0.1444					
		0.3667	0.028208	0.167951		0.167907	
1.72						=STDEV.P(D3:D15)	

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.72
- What is the population standard deviation?
  - 0.17
- What is the sample standard deviation?
  - ?

Understanding Variance

- "What is the Variance?"
  - Formally, it is the expectation of the squared deviation of a random variable from its mean
  - Informally, it measures how far a set of (random) numbers are spread out from their average value

Variance

$$S^2 = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

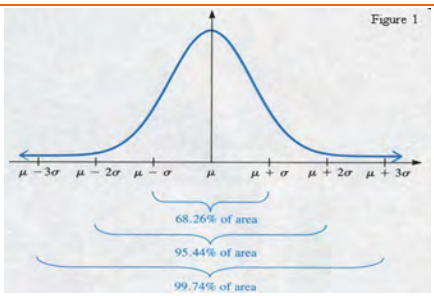
S^2 = sample variance

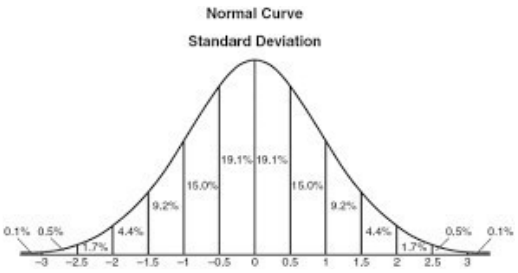
x_i = the value of the one observation

$\bar{x}$ = the mean value of all observations

n = the number of observations

Statistical Characteristics





Expected value – Example 1

The amount of mustard dispensed from a machine is normally distributed with a mean of **0.9** ounce and a standard deviation of **0.1** ounce. If the machine is used **500** times, approximately how many times will it be expected to dispense **1** or more ounces of mustard?

Expected value

The expected value is calculated by multiplying each of the possible outcomes by the likelihood each outcome will occur and then summing all of those values.

$$E(X) = \sum_{i=1}^{n} x_i \, . p(x_i)$$

Standard Normal Table (Z)

Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for $z = 1.25$ the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2969	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

If one standard deviation is added to the mean, the result is 1.0 oz 1.0 = 0.1+0.9

1.0 is the valuable that we need to look for in the Z table

Standard Normal Table (z)

Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for z = 1.25 the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
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1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
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2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

FPST-3213 82

0.5 - 0.3413 (from table) = 0.1587

15.9% of the data falls at or above 1 standard deviation

FPST-3213 83

Expected value

$$E(X) = \sum_{i=1}^{n} x_i \,.\, p(x_i)$$

500*0.159 =79.5 or 80

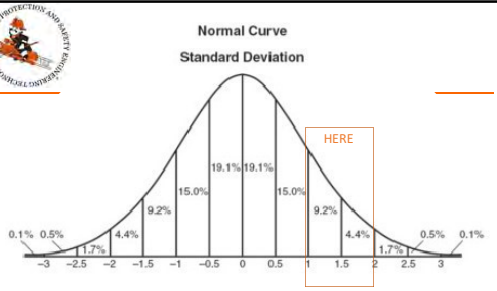
It will be expected to dispense **1** or more ounces of mustard 80 times

FPST-3213 84

Expected value – Example 2

A college mathematics lecture class has **184** students. The scores on the midterm exam are normally distributed with a mean of **72.3** and a standard deviation of **8.9**. How many students can be expected to receive a score between **81 and 90**?

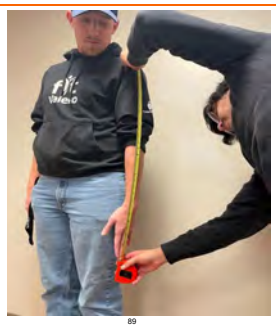
- 1 standard deviation = 8.9
- Mean + 1 standard deviation 72.3 + 8.9 = 81.2
- 90.1 on the exam is 2 standard deviations from the mean



- Looking at the bell curve, between 1 and 2 standard deviations from the mean accounts for (9.2 + 4.4) 13.6% of the class

- Expected value = 184*(0.136) = 25 students
- It is expected that 25 students scored between 81 and 90

In class exercise



In class exercise

- Stand up straight will your arm straight down to your side.
- Place the end of the measuring tape at the top of the shoulder.
- Extend the measuring tape down the arm, until the tip of the middle finger is reached.
- Record the length of the arm (to the nearest centimeter) in the provided table.

Only one member per team needs to submit the table. This assignment is due by the end of the class period.

Anthropometry

Part 2

Objectives

- Know what Anthropometry is
- Know the types of measurements that can be made
- Understand how anthropometry is used for ergonomics and workplace design

Anthropometry

- From the Greek
  - Anthro- : man
  - pometry: measurements
  - Literal meaning: “measurement of humans”
- A branch of anthropology

Anthropometric Data

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

Expected value

The expected value is calculated by multiplying each of the possible outcomes by the likelihood each outcome will occur and then summing all of those values.

$$E(X) = \sum_{i=1}^{n} x_i \,.\, p(x_i)$$

For example, suppose Sarah is 1600 mm tall and the mean height of females in the population is 1650 mm.

What can we say about Sarah?

We can say that Sarah is 50 mm shorter than average.

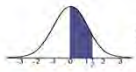
Now, suppose that the standard deviation of the distribution of female height is 100 mm.

What can we say about Sarah?

We can say that Sarah is one half of a standard deviation below the average height.

Using a statistic called the standard normal deviate, Z, we can calculate how tall Sarah is compared to all other females in the population.

$$z = \frac{(x - \bar{x})}{sd}$$



Standard Normal Table (z)

Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for $z = 1.25$ the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2969	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3513	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
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2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

The Standard Normal Deviate: Z

Sarah is 1600 mm tall and the mean stature was 1650 mm and standard deviation 100 mm. Therefore, for Sarah, her z score is (1600–1650)/100 or −0.5.

We can see that for z = −0.5, the area under the normal curve to the left of z is 0.5 - 0.1915 = 0.3085.

This is the proportion of the normal distribution that lies to the left of z = −0.5. In other words, approximately 31% of females are shorter than Sarah—Sarah is of 31st percentile stature.

Percentiles to Real Measurements and Back Again

To find the measured value of a given percentile, use

$$x = \bar{x} + (z \times sd)$$

If Karen were 25th percentile stature and the mean and standard deviation female stature were 1650 and 100 mm, respectively, how tall would she be?

Percentiles to Real Measurements and Back Again

The value of z corresponding to the 25th percentile is z = −0.68 (the actual area in the table is 0.2517, rounded down to 0.25).

This means that Karen is 0.68 of a standard deviation shorter than the mean.

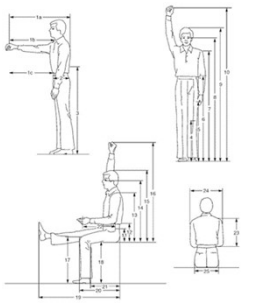
Percentiles to Real Measurements and Back Again

Therefore, Karen's stature, x, is

$$x = 1650 + (-0.68 \times 100) = 1650 - 68 = 1582\ mm$$

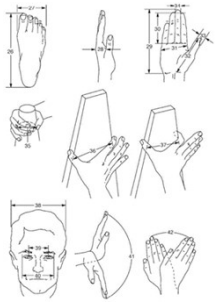
Anthropometric Dimensions

- Designing to maximize the fit between the person and the equipment is an art



Anthropometric Dimensions

- Few small people are in the 5th percentile for all measurements
- Few large people are in the 95th percentile for most of their measurements
- As more measures are added, the number of people accommodated will be reduced because of the variability.



FPST 3213 16

Distribution of Overhead Reach

- What body characteristics need to be considering while designing the process presented in the picture?

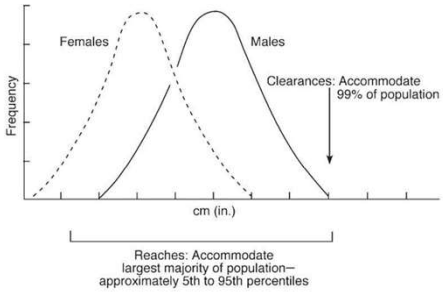
FPST 3213 17

Distribution of Overhead Reach

- Heights for valves or controls
- Strength for opening the valves

FPST 3213 18

Reaches



Distribution of Overhead Reach

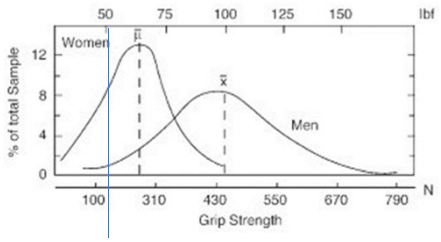
- Maximum heights for valves or controls
  - The 5th percentile overhead reach is about 74 in

Distribution of Overhead Reach

- Strength for opening the valves

Distribution of Grip Strength

- Determine force requirements for performing a repetitive task



Distribution of Overhead Reach

- The control should be located below the 5th percentile shoulder height, or 49 in.
- Also be no lower than the 95th percentile knuckle height, or 32 in.

Selected Strength Data for Males and Females

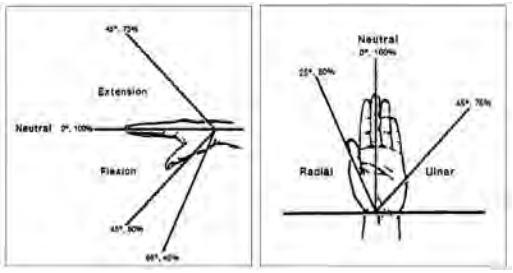
Pushing (N)[a]		Mean	Standard Deviation
Handle Height (m)			
1.7	Males	300	50
	Females	181	75
1.3	Males	337	83
	Females	221	103
0.7	Males	393	134
	Females	185	57
Pulling (N)[b]			
Handle height (m)			
1.7	Males	263	60
	Females	196	56
1.3	Males	347	55
	Females	223	80
0.7	Males	541	81
	Females	292	97
Wrist twisting Strength (Nm)[a] Males only			
Knob diameter (mm)			
9.5		52.75	12.8
12.7		65.21	12.54
19.1		111.65	26.2

[a] Daams, B.J. 1993. Ergonomics, 36: 397–406.
[b] Swain, A.D., Shelton, G.C., and Rigby, L.V. 1970. Ergonomics, 13: 201–208.

Distribution of Overhead Reach

- Was this process well designed?

Affect of Posture on Grip Strength



Hold your pencil in your hand……

Distribution of Grip Strength

- For example, using a wire crimper requires an exertion of about 176N when the wrist and hand are relatively straight
- But increasing the grip span reduces grip strength by about 40 percent.
- If the crimpers require more force than above, you can justify an automatic crimper for the task

Maximum Grip Strength

Condition	% of Max grip strength, bare-handed, 5-cm (2-in.) span, neutral wrist angles
45 degrees of wrist flexion	60
65 degrees of wrist flexion	45
45 degrees of wrist extension	75
25 degrees of radial deviation of wrist	80
40 degrees of ulnar deviation of wrist	75
Grip span of 2.5 cm (1 in.)	40
Grip span of 11 cm (4.5 in.)	45
Wearing rubber household gloves	81
Wearing gardening gloves	74
Wearing heavy heat-treated gloves	62
Wearing pressurized (3.5 psig) flight gloves	64

Power Grip

Cylindrical Grip

Spherical Grip

Hook Grip

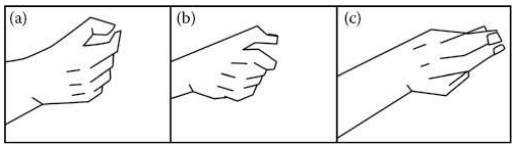
Pinch Grip

- Characterized by opposition of the thumb and the distal joints of the fingers

Tip pinch

Lateral pinch

Chuck pinch



(a) Tip pinch, (b) key pinch, and (c) palm pinch.

Additional Types of Pinch Grips

Pulp - 2

Pulp - 3

TABLE 2.2
Hand Function Strengths for Men and Women (Chao et al., 1989)

Type of function	n	Functional Strength (kg) Male	Female
Grasp	60	40 ± 9	23 ± 7
Tip pinch	124	6 ± 1	5 ± 1
Chuck pinch	60	6 ± 1	5 ± 1
Key pinch	84	11 ± 2	8 ± 1
Radial deviation of index finger	60	4 ± 1	3 ± 1
Radial deviation of middle finger	60	4 ± 2	3 ± 1
Radial deviation of ring finger	60	3 ± 1	2 ± 1
Radial deviation of little finger	60	2 ± 1	2 ± 1
Ulnar deviation of index finger	60	4 ± 1	3 ± 1
Ulnar deviation of middle finger	60	4 ± 2	3 ± 1
Ulnar deviation of ring finger	60	3 ± 2	2 ± 1
Ulnar deviation of little finger	60	3 ± 1	2 ± 1
Thumb abduction	47	4 ± 1	3 ± 1
Thumb adduction	47	7 ± 3	5 ± 2

Selected Grip and Pinch Strength Data for U.S. Adults 25–75 Years

	Males		Females	
	Mean	Standard Deviation	Mean	Standard Deviation
Grip strength				
Right hand	46.2	12.6	27.9	7.6
Left hand	41.4	12.3	24.6	7.0
Tip pinch				
Right hand	7.6	1.8	5.0	1.2
Left hand	7.3	1.8	4.8	1.1
Key pinch				
Right hand	10.9	2.0	7.2	1.3
Left hand	10.5	2.0	6.8	1.4
Palmar pinch				
Right hand	10.4	2.2	7.2	1.3
Left hand	10.2	2.4	7.0	1.6

Source: From Mathiowetz, V. et al. 1985. *Archives of Physical Medicine and Rehabilitation*, 66: 69.
Note: The strength is denoted in kilograms (kg).

Distribution of Overhead Reach

- What body characteristics need to be considering while designing the process presented in the picture?
  - Height
  - Strength
  - Grip
  - ??

Range of Motion

The most efficient work is done within the first 1/3 of the range of motion for a movement

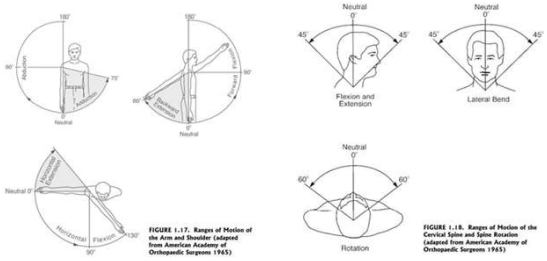
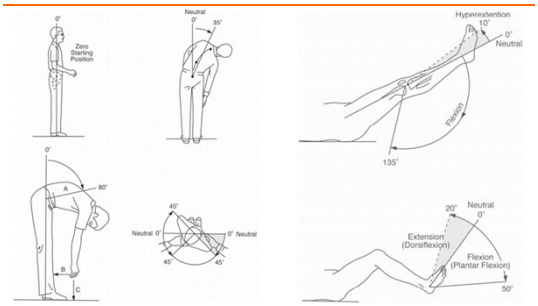
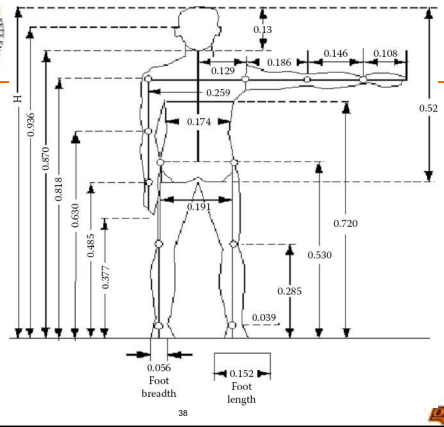


FIGURE 1.17. Ranges of Motion of the Arm and Shoulder (adapted from American Academy of Orthopaedic Surgeons 1965)

FIGURE 1.18. Ranges of Motion of the Cervical Spine and Spine Rotation (adapted from American Academy of Orthopaedic Surgeons 1965)

Range of Motion





Suggested Values of Anthropometric Data for Specific Design Needs

Measurement	Design Usage	Suggested Range, cm (in.)
Stature	Clearance for standing access	203 (80); add 13 cm (5 in.) for motion and clothing to the 99th-percentile male value
Eye height, standing	Visibility of signs, displays	140 to 164 (58 to 64)
Shoulder height, standing	Upper limit for lifting or working	114 to 126 (45 to 50)
Elbow height, standing	Height of hands in assembly tasks	95 to 100 (37 to 40)
	Height of hands in packing tasks	90 to 95 (35 to 37)
Hip height, standing	Height over which a person can bend for short durations	73 to 78 (29 to 31)
Knuckle height, standing	Lowest height for work close to the body	54 to 70 (22 to 28)
Sitting height, above seat height	Clearance for seated work—overhead	100 (39)
Sitting shoulder height, above seat height	Upper limit for lifting or working	48 to 52 (19 to 21)

Suggested Values of Anthropometric Data for Specific Design Needs

Measurement	Design Usage	Suggested Range, cm (in.)
Sitting elbow height, above seat height	Height of hands in assembly or typing task, armrest height	17 to 20 (8 to 9)
Thigh thickness, seated	Minimum clearance under table or workbench	21 (8)
Buttocks-to-knee length	Forward minimum leg clearance, seated	67 (26)
Buttocks-to-popliteal length	Maximum length of seat to accommodate short thighs	44 (17)
	Minimum length of seat for people with long legs so 70% of thigh is supported	38 (15)
Knee height, seated	Lowest height for a seated work surface, from bottom	61 (24)
Popliteal height, seated	Lowest height of seat adjustability for small people	36 (14)
	Lowest height of seat adjustability for tall people	52 (20)

Anthropometric Data

If a piece of equipment was designed to fit 90% of the male US. population, it would fit roughly 90% of Germans, 80% of Frenchmen, 65% of Italians, 45% of Japanese, 25% of Thais and 10% of Vietnamese.

Anthropometric Data

- Most of U.S. data have been taken from military populations
- Will they have similar characteristics that an industrial population?

Anthropometric Data

- Military population is skewed heavily toward those under age 40
- Military personnel tend to be more fit than the industrial population
- Using military data will have a negative effect on industrial plant design

Anthropometric Data

- Example: access points and hatchways
  - Industrial workers are larger around the middle than military service personnel, requiring designers need to accommodate 99% of the population

Anthropometric Data

- NASA (1978-1981)
  - https://msis.jsc.nasa.gov/sections/section03.htm
- 1988 US Army Anthropometry Survey (ANSUR)
- Table 1.9 (Kodak)
  - Suggests values of data for specific design needs
- Is there a “best source” for Anthropometric Data?
  - UMTRI (Transportation Research Institute)
  - http://mreed.umtri.umich.edu/mreed/downloads.html

Distribution of a Body Size Characteristic

- Airplane seating
- Auditorium seating
- Desk heights

- Knee Room
- Thigh support to prevent sliding forward
- But not too much for short people or their feet will not touch the floor

In summary

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

Aerobic Work Capacities

Aerobic Capacity

- The measure of the ability of the heart and lungs to get oxygen to the muscles
- Aerobic capacity refers to the maximum amount of oxygen consumed by the body during intense exercises, in a given time frame.

Aerobic Capacities

- More oxygen
- Work harder work for longer periods of time

Aerobic Capacities

- There is not much data on aerobic capacities of industrial workers.

Aerobic Capacities

- Working long shifts is significantly different than exercising.
- For an eight hour shift the average workload should be about 27% of aerobic capacity for low lifting

Aerobic Effort Levels of Occupational Tasks

Task – Whole Body	Task - Upper Body	Usual Time	Effort Level	Equ. Exercise
Sitting in a car or Truck	Inspection Work	>2 hr	Light	fishing
Machining parts	Sewing	>2 hr	Moderate	Walking 2 mph
Digging Trench	Punch Press Standing	<1 hr	Heavy	Running 12 min mi
Chopping Wood	Power Tools Overhead	1-2 hr	Very Heavy	Jumping rope
Firefighting	Lifting cases 15/min	1-2 hrs	Extremely Heavy	Stair Treadmill

Team project - Feedback

- Sources
- One activity/task within the sector, per student
- READ FEEDBACK!

HW2 - Feedback

- 1. Insufficient cost analysis
- 2. Memo formatting

To do list

- HW 4 will be posted
- Team project

Biomechanics

Objectives

- Know how different forces are applied on the human body
- Use equations for solve biomechanics problems

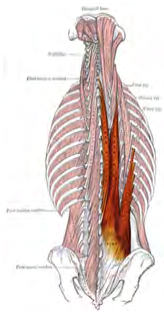
Definitions

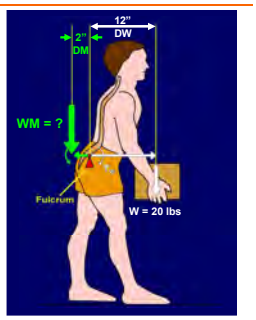
- Ergonomics – How work affects people
- Human factors – Human machine interface
- Anthropometry - Measurement of humans
- Biomechanics – Science of Human Movement

MSD's and human error prevention

FPST 3213 4

How much force is developed by erector spinae?





FPST 3213 5

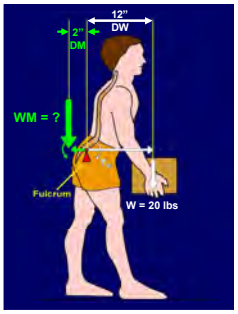
How much force is developed by erector spinae?

WM = ?

Moment 2 = Moment 1

(W) X (DW) = Moment 1

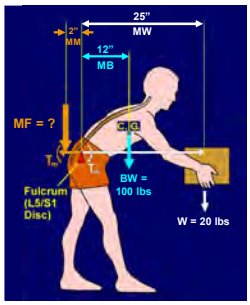
(WM) X (DM) = Moment 2



FPST 3213 6

Add Reaching

How much force is developed by erector spinae?

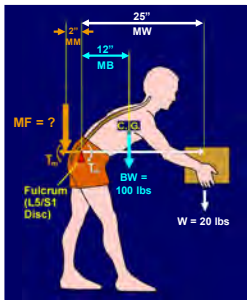


FPST 3213 7

Add Reaching

MF = ?

Moment 2 = Moment 1 + Moment 3



FPST 3213 8

Conclusion

With a 20 lb box the erector spinae supports 120 lb.

With reaching and a body weight of 100 lb in CG, the erector spinae supports 850 lb

Biomechanics

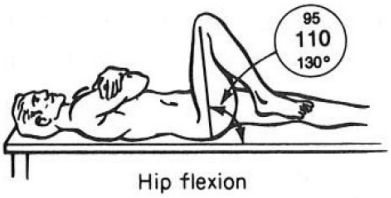
FPST 3213 9

Types of Body Movements

Flexion

- A movement of a segment of the body causing a decrease in the angle at the joint.

Types of Body Movements

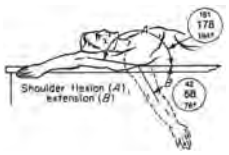


Types of Body Movements

Extension

- A movement in the opposite direction of flexion which causes an increase in the angle of the joint

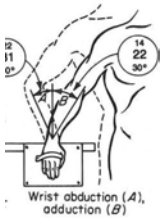
Types of Body Movements

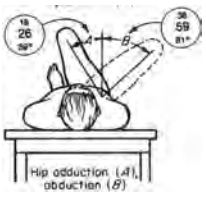


Types of Body Movements

- Abduction
  - A movement of a body segment in a lateral plane away from the midline of the body such as raising the arm sideways
- Adduction
  - A movement of a body segment toward the midline as when moving the arm from the outward horizontal position downward to the vertical position

Types of Body Movements



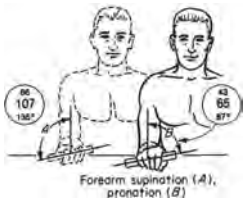


Types of Body Movements

Rotation

- The movement of a segment around its own longitudinal axis
- Medial rotation
  - toward the midline of the body
- Lateral rotation
  - away from the midline of the body

Types of Body Movements

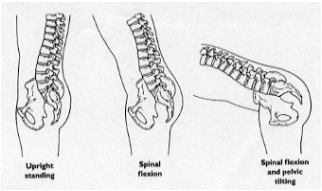


Rotation

- Pronation
  - Palms down
- Supination
  - Palms up

Biomechanics of Spine & Hip

- Movements of spine
  - Flexion, rotation, extension
- Hip Movements
  - Elevation, flexion, extension

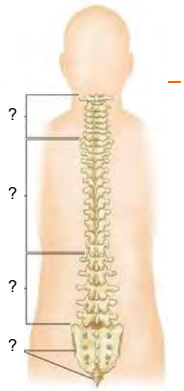


Body Segment

- Center of mass

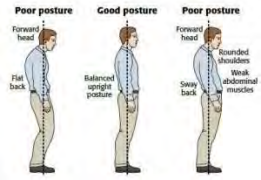
The Spine

- Low back pain
- Soft tissue injuries
- Acute fractures
- Stress fractures
- Disc herniation
- Whiplash injuries
- Other ailments



Posture

- What exactly is “good posture”



Improving your general posture

Classes of Movement

- Discrete movements
  - A singular reaching movement to a stationary target
- Repetitive movements
  - Repetition of a single movement to a stationary target

Classes of Movement

- Sequential movements
  - Discrete movements to a number of stationary targets regularly or a regularly spaced
- Continuous movements
  - Require muscular control adjustments to some degree during the movement
- Static posturing
  - Maintaining a specific position of a body member for a period of time

Classes of Movement

Discrete movements	Holding a part in one hand while soldering it
Repetitive movements	Reaching for a switch
Sequential movements	Operating the steering wheel of a car
Continuous movements	Hammering a nail
Static posturing	Typing on a keyboard

Body Segment

Body Segment Density

Body Segment	Year = 1860	Year = 1955
Head and Neck	1.11 g/cm^3	1.11 g/cm^3
Trunk	--	1.03
Upper Arm	1.08	1.07
Forearm	1.10	1.13
Hand	1.11	1.16
Thigh	1.07	1.05
Lower Leg	1.10	1.09
Foot	1.09	1.10

Density = Mass / Volume *Human Segment Density ~ 1 g/cm^3*

Pressure

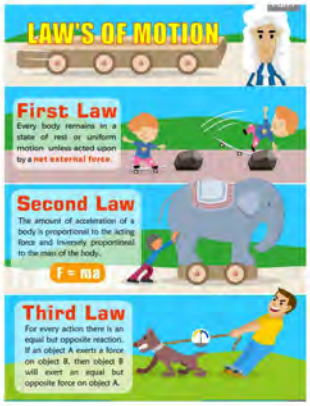
Equal and opposite reaction force

$$P = \frac{F}{A}$$

P = pressure
F = force
A = area

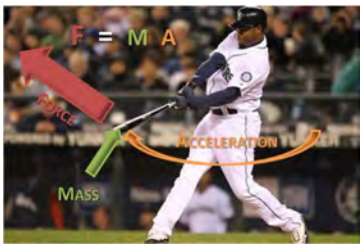
Sir Isaac Newton

- Formulated 3 physical “laws”
  - Movement produced by a system of levers.
    - Movement (dynamic)
    - Stabilization (static)



Newton's 1th Law of Inertia

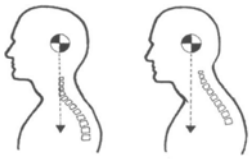
Newton's 2nd Law of Motion



Newton's 2nd Law of Motion

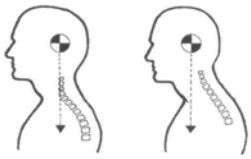
- Muscles contract and create force on the body's levers (connective tissue, bones)
- With any human movement, F=ma can be used to create a simplified calculation of force including static positions

Newton's 2nd Law of Motion



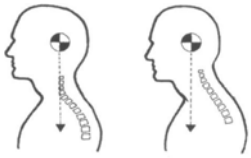
What is preventing your head from snapping off?

Newton's 2nd Law of Motion



- levator scapulae
- upper trapezius
- posterior cervical muscles

Newton's 2nd Law of Motion



$$F = m * a$$

mass of the head

9.8m/s^2

calculate the muscle forces necessary to prevent movement

Newton's 3rd Law Action and Reaction

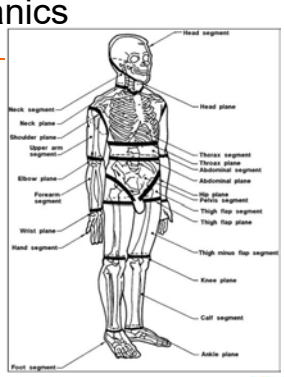
- An important consideration here is the concept that gravity is ALWAYS touching every object

Newton's 3rd Law Action and Reaction

- Example
  - Ground reaction forces
  - Running on soft ground will result in much less impact forces than running on hard concrete

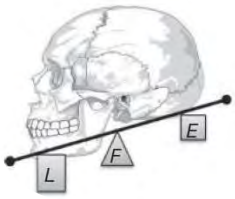
Biomechanics

- Human body is a system of links



Lever System

First class lever



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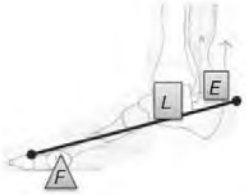
Lever System

Second class lever



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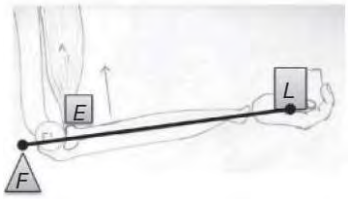
Lever System

Third class lever



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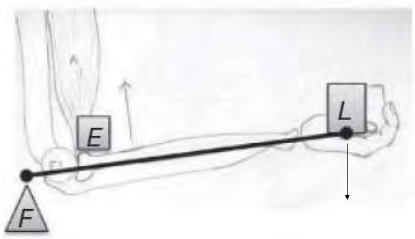
Lever System



Newton's 2nd Law of Motion

$$F = m * a$$

Where: F is the net force applied
m is the mass of the body
a is the body's acceleration

Torque or Moment

- When the force of gravity does not act exactly through the center of a joint, there is a tendency for rotation about the joint axis

$$M = F * d$$

Where:
M is the moment
F is the net force
d is the perpendicular distance from the axis of rotation

Units

$$F = m * a$$

kg m/s^2

N (Newton)

$$M = F * d$$

N * m

Note:
Some books mention that Moments can also be expressed as inch-pounds or foot-pounds

$$M = W * d$$

lb * in

Weight is the force generated by the gravitational attraction of the earth on the mass of an object. Weight is expresses in pound-force (lb) an opposed to pound-mass (lbm)

Newtonian Principle

- The sum of the moments in any one direction equals the moment of inertia of the object times its angular acceleration in that direction

$$\sum M = I\alpha$$ Dynamic Condition

Where: M is the moment
I is the moment of inertia
α is the angular acceleration
I depends on its mass and the distribution of that mass within the segment (constant)

Governing Equation

- Moments that tend to cause rotation about the joint in one direction (e.g., clockwise) must be exactly counterbalanced by moments that tend to cause rotation about the joint in the opposite direction (counterclockwise)

$$\sum M = 0$$ Static Condition

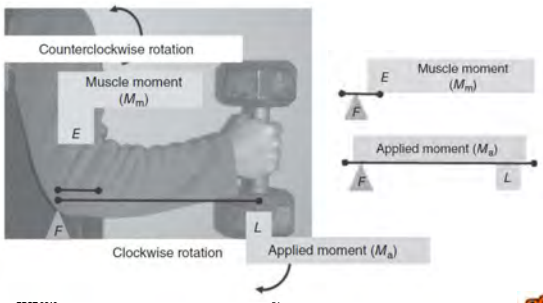
EXAMPLE OF

TORQUE CALCULATIONS

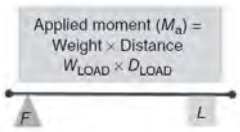
Example 1

How much is the clockwise rotation force, the moment, at the elbow while holding a 40 lb dumbbell?

Example 1



Example 1



$M_a = W_{LOAD} \times D_{LOAD}$
Weight = 40 lb
Distance = 12 in.

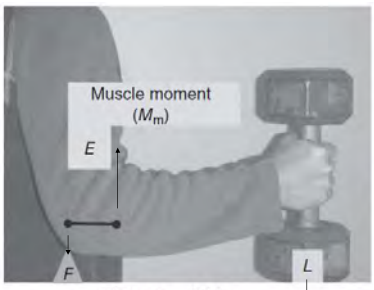
M_a = 40 lb × 12 in.
M_a = 480 in. lb

Example 1

The moment at the elbow is 480 in. lb.

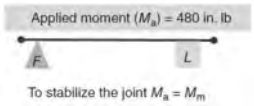
What is the force that the muscles need to generate to stabilize the joint?

Example 1



Distance = 0.5 in.

Example 1



To stabilize the joint $M_a = M_m$

Muscle moment (Mm) = Weight × Distance
$W_{muscle} \times D_{muscle}$

Example 1

$M_m = W_{effort} \times D_{effort}$
Weight = ? lb
Distance = 0.5 in.

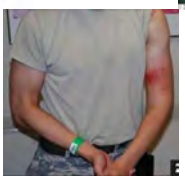
$M_m = M_a$ and M_a = 480 in. lb
480 in. lb = $W_{effort} \times$ 0.5 in.

480 in. lb/0.5 in. = W_{effort}
960 lb = W_{effort}

Example 1

This means the muscles must respond with 960lb of force to generate the 480 in. lb moment that is needed to stabilize the joint.

Example 2



Example 2

How much torque is produced at the elbow by the biceps brachii inserting at an angle of 60° on the radius when the tension in the muscle is 400 N?

(Assume that the muscle attachment to the radius is 3 cm from the center of rotation at the elbow point.)

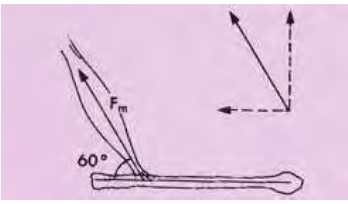
Example 2

Known:

$F_m = 400$ N

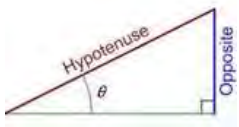
$\alpha = 60°$

$d_\perp = 0{,}03$ m



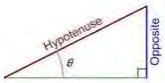
Example 2

Only the component of muscle force perpendicular to the bone generates torque at the joint.



$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

Example 2



$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

Therefore $F_P = F_m \sin\theta$

$F_p = (400\ \text{N})(\sin 60)$

$F_p = 346{,}4\ \text{N}$

Example 2

The force is $F_p = 346{,}4\ \text{N}$.

However, the questions is about the torque at the elbow.

Example 2

$$M = F * d$$

Because $T_{orque(M)} = F_p d_\perp$

Thus $T_{orque(M)} = (346.4\ N)(0.03\ m)$

$T_{orque(M)} = 10{,}4\ N{-}m$

Example 2

The torque produced at the elbow is 10,4 N-m

Example 3

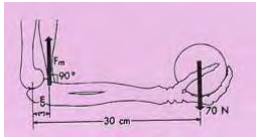
How much force must be produced by the biceps brachii, attaching at 90˚ to the radius at 3 cm from the center of rotation at the elbow joint, to support a weight of 70 N held in the hand at a distance of 30 cm from the elbow joint? (Neglect the weight of the forearm and hand and neglect any action of other muscles.)

Known

$d_m = 3\ cm$

$wt = 70\ N$

$d_{wt} = 30\ cm$



Example 3

Since the situation described is static, the sum of the torques acting at the elbow must be equal to 0.

$$\sum T_e = 0$$
$$\sum T_e = (F_m)(d_m) - (wt)(d_{wt})$$
$$0 = (F_m)(0.03\ m) - (70\ N)(0.30\ m)$$
$$F_m = \frac{(70\ N)(0.30\ m)}{0.03\ m}$$
$$F_m = 700\ N$$

Example 3

To support a weight of 70 N held in the hand the biceps brachii needs to produce a force of 700 N

Influence of the distance

If rotational force or **moment = weight × distance**, how much rotational force or moment is generated on the L5/S1 spinal unit when the 40 lb weight is lifted?

It Depends on the Distance!

- Holding 40 lb, 20 in. from the L5/S1 results in XXXX in. lb of rotational force.
- Holding 40 lb, 15 in. from the L5/S1 results in XXXX in. lb of rotational force.
- Holding 40 lb, 10 in. from the L5/S1 results in XXXX in. lb of rotational force.

Influence of the distance

- Holding 40 lb, 20 in. from the L5/S1 results in 800 in. lb of rotational force.
- Holding 40 lb, 15 in. from the L5/S1 results in 600 in. lb of rotational force.
- Holding 40 lb, 10 in. from the L5/S1 results in 400 in. lb of rotational force.

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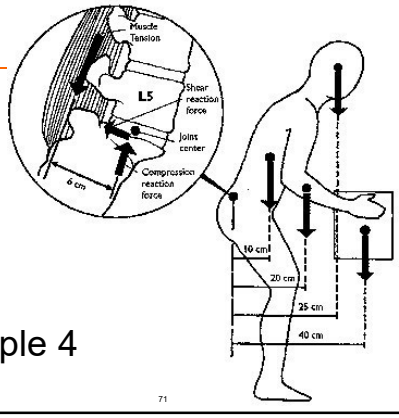

Example 4

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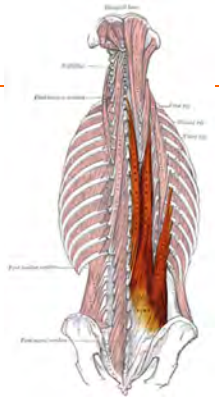
Example 4

- How much force is developed by erector spinae?



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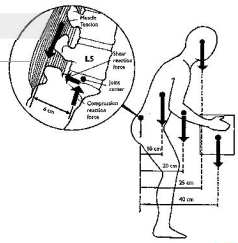
Example 4

Segment	Weight	Moment Arm From Spine
Head	13 lbs.(58N)	25 cm
Trunk	73.75 lbs.(328N)	10 cm
Arms	18.2 lbs. (81N)	20 cm
Box	24.95 lbs.(111N)	40 cm



1 lb = 4.448 Newtons

Example 4

Torque =

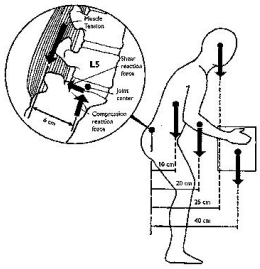
(328N)(10cm) + (81N)(20cm) + (58N)(25cm) + (111N)(40cm) = 10,790 Ncm

Example 4

Force in Erector Spinae = ?

Static position

$\sum M = 0$

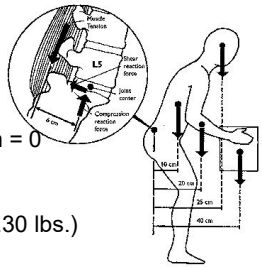


Example 4

$\sum M = 0$

(F)(6cm) - 10,790 Ncm = 0

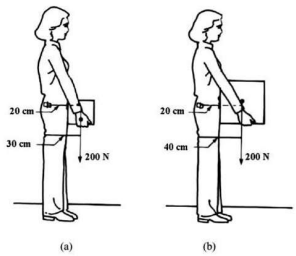
F = 1798.33 N (or 404.30 lbs.)



Holding

- Factors
  - Posture
  - Size and shape of an object

Influence of Box Size



Twice Wide

- Ma = 60 Nm
- Mb = 80 Nm

Example 5

For the situation presented bellow, how much is the muscle moment, if the muscle is located 1 in from the fulcrum?

Muscle moment (M_m) = applied moment (M_a)

Example 5

Muscle moment (M_m) = applied moment (M_a)

$$M_m = M_a$$

$$M_a = 800\,\text{in.lb (which is } 40\,\text{lb} \times 20\,\text{in.)}$$

$$M_m - 800\,\text{in.lb}$$

$$M_m = \text{distance} \times \text{force } (W_{muscle})$$

$$800\,\text{in.lb} = 1\,\text{in.} \times W_{muscle}$$

$$800\,\text{lb} = W_{muscle} \text{ or muscle force}$$

Example 5

800 lb of muscle force

Do you think the result is going to chance if we include the weight of the human that is moving the box?

Example 5

- The torso contains approximately 60% of your body weight.

- A 200 – lb person
- 6 in from the center of mass to the fulcrum

Muscle moment (M_m) = Total applied moment (M_{total})

Example 5

$$M_m = M_{total}$$

where

$$M_{total} = 800 \text{ in.-lb (Ma)} + 720 \text{ in.-lb } (M_{body})$$

$$M_{total} = 1520 \text{ in.-lb}$$

$$Mm = M_{total}$$

$$M_{effort} = \text{distance} \times \text{force } (W_{muscle})$$

$$1520 \text{ in.-lb} = 1 \text{ in.} \times W_{muscle}$$

$$1520 \text{ lb} = \text{Muscle Force}$$

Example 5

If we include the weight of the human that is moving the box, the muscle force increases from 800 lb to 1520 lb

Overhead Drilling

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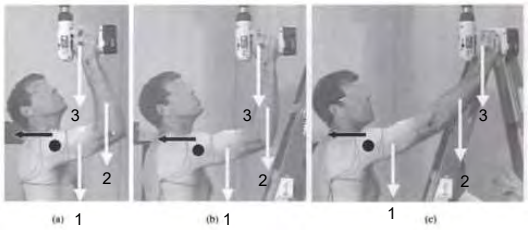
Overhead Drilling



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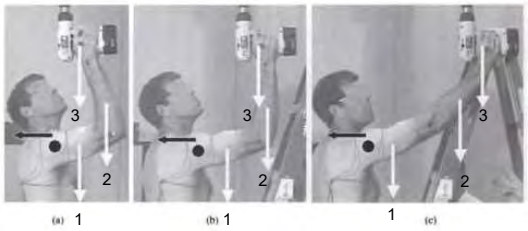
Overhead Drilling



13 Nm 21 Nm 29 Nm

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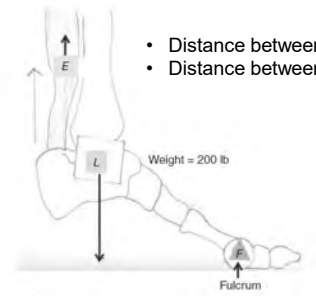
Example 6

How much is the muscle moment?

- Distance between load and fulcrum 6.5 in
- Distance between muscle and fulcrum 8 in



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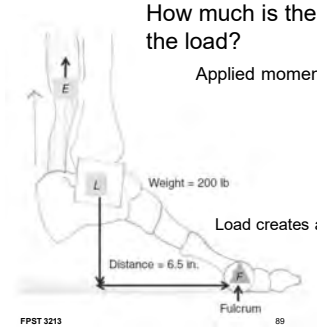
Example 6

How much is the applied moment by the load?

Applied moment (M_a) = distance × weight

M_a = 6.5 in. × 200 lb

M_a = 1300 in. lb



Load creates an applied moment = 1300 in. lb

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Example 6

How much is the muscle moment?

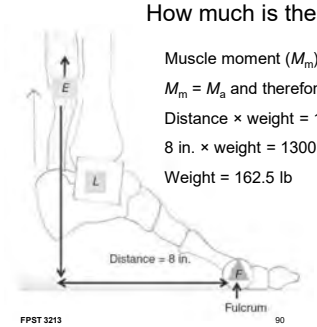
Muscle moment (M_m) = Applied moment (M_a)

$M_m = M_a$ and therefore M_m = 1300 in. lb

Distance × weight = 1300 in. lb

8 in. × weight = 1300 in. lb

Weight = 162.5 lb



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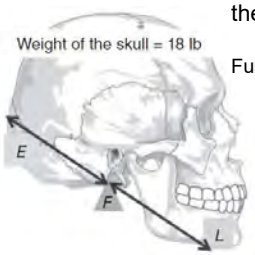
Example 6

Muscle moment or the effort = 162.5 lb

Example 7

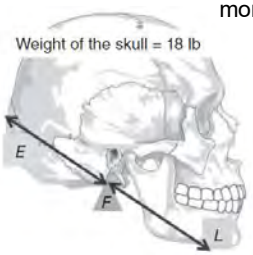
How much is muscle moment if the muscle is centered on the spine?



Fulcrum is 4 in from both (E and L)

Example 7

How much is the applied moment by the load?



Applied moment (M_a) = distance × weight

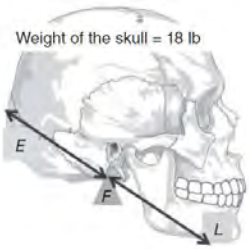
M_a = 4 in. × 18 lb

M_a = 72 in. lb

The skull, if centered on the neck, results in a 72 in. lb rotational force

Example 7

How much is muscle force?



Muscle moment (c) = Applied moment (M_a)

$M_a = M_a$, where Ma is 72 in. lb, therefore

M_a = 72 in. lb

Distance × weight = 72 in. lb

4 in. × weight = 72 in. lb

Weight or muscle force = 18 lb

Example 7

It takes 18 lb of force to hold up the 18 lb skull if the skull is centered on the spine

1

Workplace Design

2

Objectives

- Be able to set up a workstation for an individual
- Understand the field of vision
- Know how to select the appropriate way to deal with a change in elevation
- Conveyors

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3

Workplace & Workstation

- Workplace is a location where a person or people perform tasks for a relatively long period
- Workstation is one of a series of workplaces that may be occupied or used by the same person sequentially when performing his or her job

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4

Workplace Design

- Purpose
  - Reduce job stress
  - Reduce MSDs
  - Increase Safety
  - Increase Productivity
  - Accommodate individual differences in size and strength.

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5

General Workplace Layout and Dimensions

- Criteria
  - Reaches
  - Size
  - Muscle strength ...

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6

General Workplace Layout and Dimensions

- Well-designed
  - Audience
  - Anthropometric measurements
  - Mock-up for trial

7

General Workplace Layout and Dimensions

- When a special design should be considered?
  - Repetitive actions

8

Original design

9

Prototype

10

General Workplace Layout and Dimensions

- Avoided Static loads – Biomechanics
- Change posture
  - Sitting
  - Standing
  - Sit/stand
  - Reclined
  - Leaning

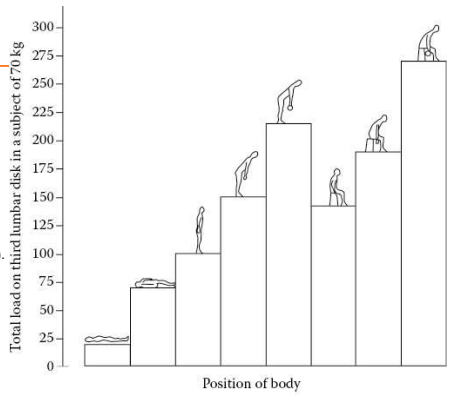
11

TABLE 3.1
Choice of Workplace by Task Variables (developed from information in Ely, Thomson, and Orlansky 1963b; Murrell 1965; Rehnlund 1973; Woodson 1981).

Parameters	Heavy Load or Forces	Intermittent Work	Extended Work Envelope	Variable Tasks	Variable Surface Height	Repetitive Movements	Visual Attention	Fine Manipulation	Duration > 4 hrs.
Heavy Load or Forces		ST	ST	ST	ST	ST	ST	ST	ST/C
Intermittent Work			ST	ST	ST	S or ST	S or ST	S or ST	S or ST
Extended Work Envelope				St	ST	ST	ST	ST	ST/C
Variable Tasks					ST	ST	ST	ST	ST/C
Variable Surface Height						S	S	S	S
Repetitive Movements							S	S	S
Visual Attention								S	S
Fine Manipulation									S
Duration > 4 hrs									

Note: S = sitting; ST = standing; ST/C = standing, with chair available.
Job and workplace characteristics are looked at, one at a time, in relation to the preferred workplace choice: sitting, standing, or standing with a chair provided. More than one type of workplace may be acceptable for these task combinations; the most appropriate choice is italicized.

12



Bridger, R. S. (2018). Introduction to human factors and ergonomics. Boca Raton, FL: CRC Press, Taylor & Francis Group.

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13

SITTING WORKPLACES

FPST 3213 14

14

Sitting

- Items easily located
- Less than 6 in above work surface
- Objects weight less than 10 lb
- Precision work or visual inspection
- Well-designed chairs

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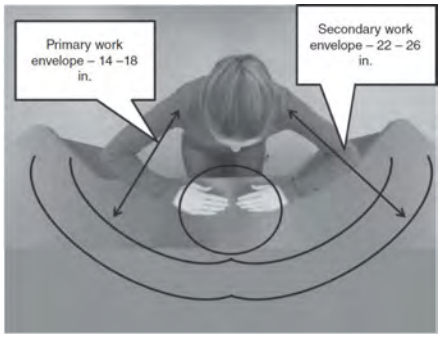
Working envelope



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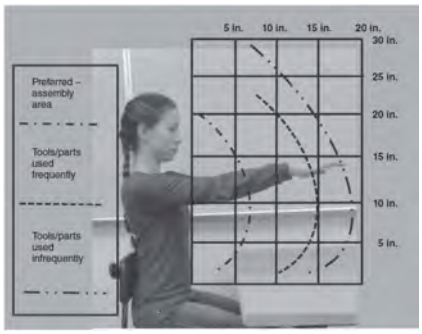
17

Working envelope



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FPST 3213 19

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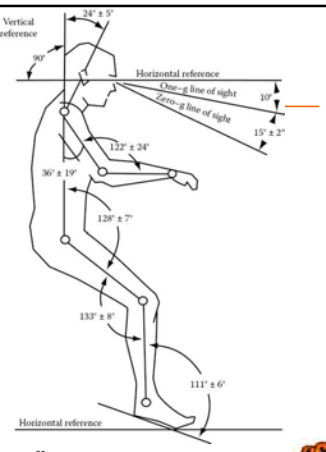

Bridger, R. S. (2018). Introduction to human factors and ergonomics. Boca Raton, FL: CRC Press, Taylor & Francis Group.

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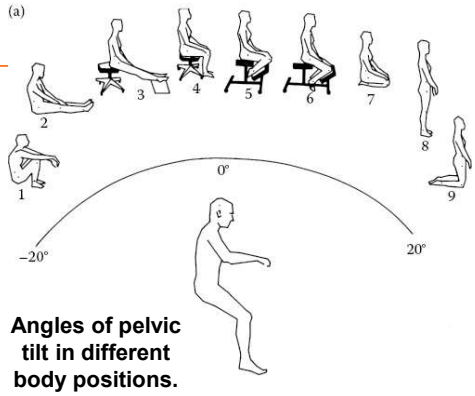

Bridger, R. S. (2018). Introduction to human factors and ergonomics. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Angles of pelvic tilt in different body positions.

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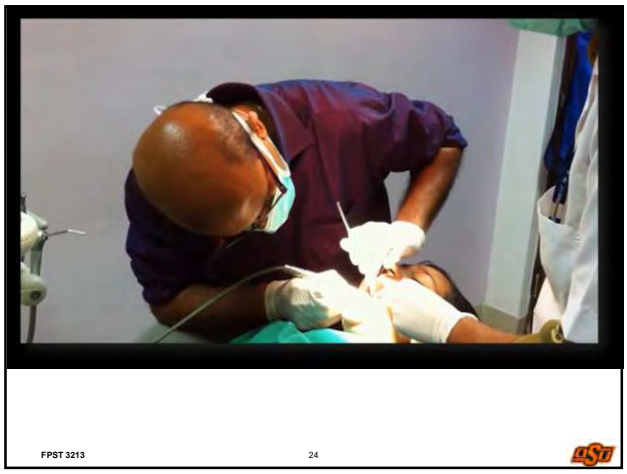

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26

Sitting is the New Smoking

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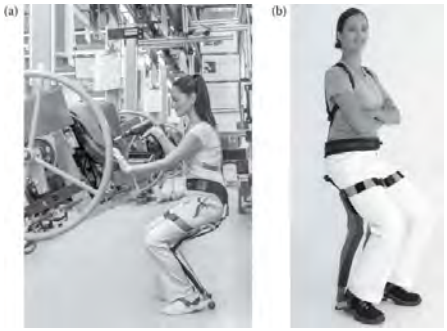
27



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RECLINED WORKPLACES

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Reclined

- Working overhead
- Reduce static load

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FPST 3213 34

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STANDING WORKPLACES

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Standing

- High, low, or extended reaches
- Frequent movement between workstations
- Downward forces must be exerted on the work
- Wrapping and packing operations
- Should include use of floor mats

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People Are Different

Age Differences

Height Differences

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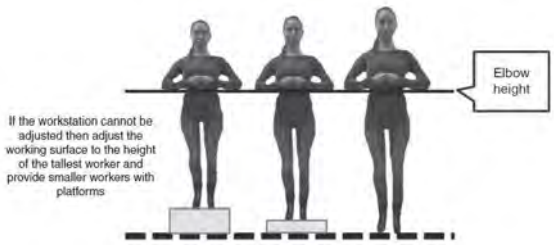
Height-adjustable platform



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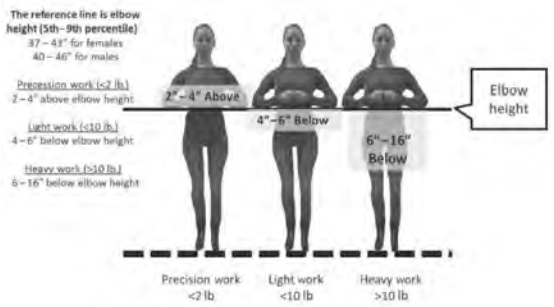
Standing work height guidelines



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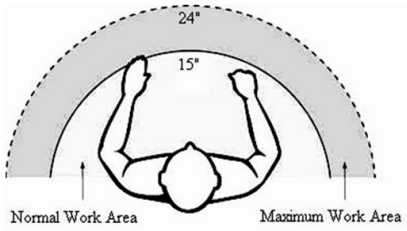
Standing Workplace Design

- Adjusting the workplace shape



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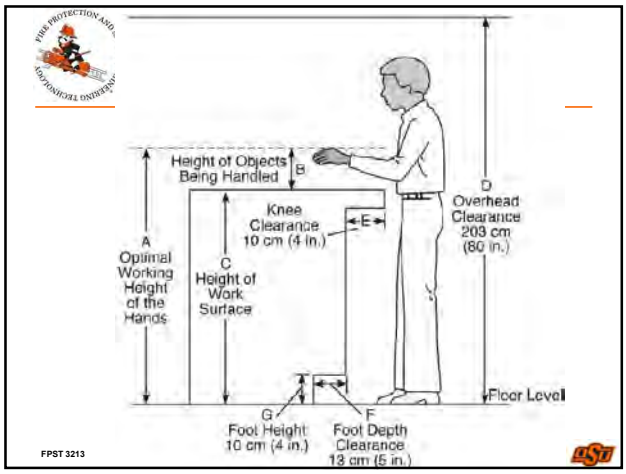
42



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Standing Workplace Design

- Drafting board
- What's missing?

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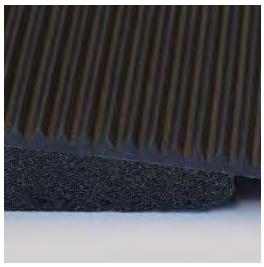
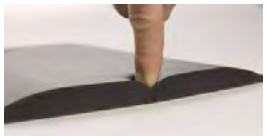
Anti-fatigue mats

- Anti-fatigue mats





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Safe Cells

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- $300

FPST 3213 47

47

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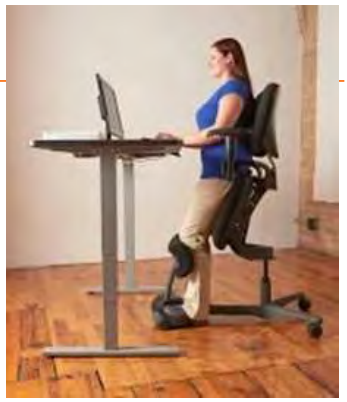
- $2,000



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Footwear

-

- Floor surface
- Standing requirements
- Nature of the work
- Environmental hazards

50

51

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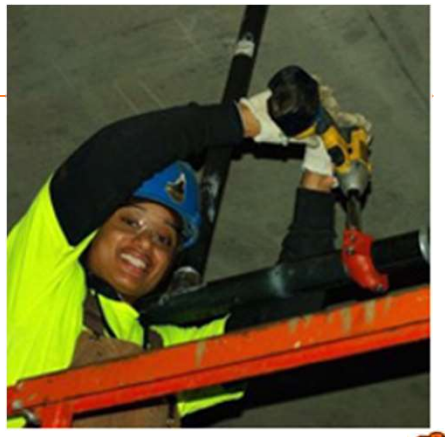

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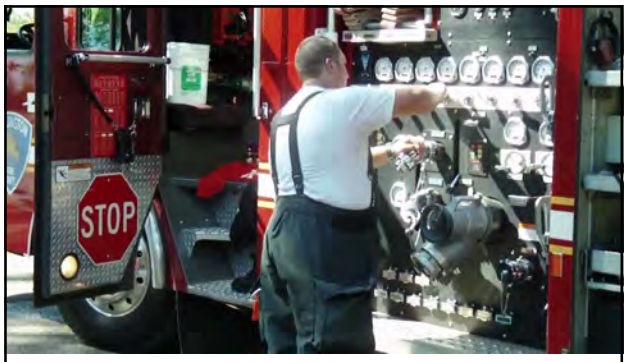

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https://www.bing.com/videos/search?q=sitting+work+&&view=detail&mid=D9450A5E81E66B4D6CC5D9450A5E81E66B4D6CC5&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dsitting%2Bwork%2B%26FORM%3DHDRSC4

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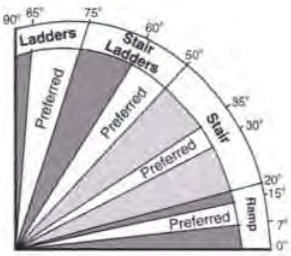
RAMPS, STAIRS, AND AISLES

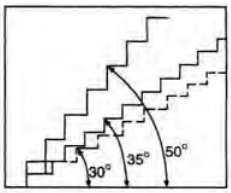
FPST 3213 65

65

Ramps, and stairs



(a) Slope and Type of Structure



(b) Fixed Stair Slope

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66

Stair-ladder

- "Alternating tread-type stair"

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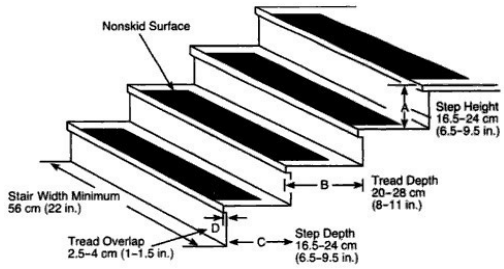
Stairs and ladders

- OSHA 1910.23 and 1910.25



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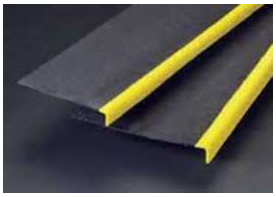
Fixed Stairway Design



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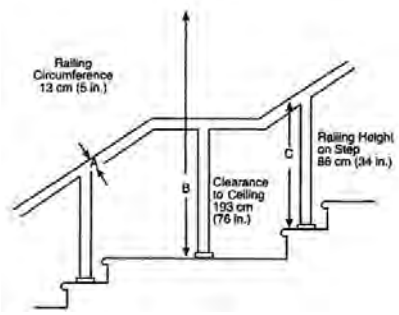
Handrail Design Guidelines
- 29 CFR 1910.29



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Aisles

- Avoid blind corners
- Mark them
- Avoid having doors open into corridors
- Keep aisles clear

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Aisles

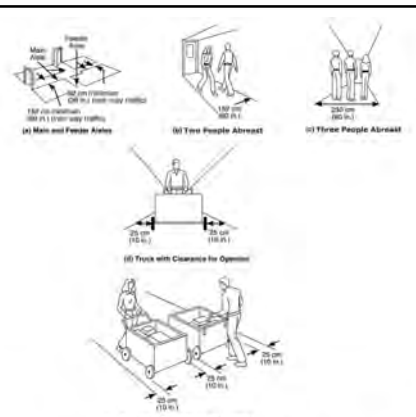

FIGURE 3.23 Minimum Clearances for Aisles and Corridors (adapted from Thomson et al. 1963; Woodson, Tillman and Tillman 1992; Access Board 1998)

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CONVEYORS

73

CONVEYORS

- Should be accessible from both sides
- Provide crossovers
- Assembly task rate should be average of most and least skilled operator
- Provide space to temporarily place parts or trays after sliding them from the conveyor

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CONVEYORS

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CONVEYORS

https://www.youtube.com/watch?v=Dzek1XniYiQ

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Visual Work Dimensions

- Visual field
- Viewing angle
- Viewing distance
- Size of the visual target

FPST 3213 83

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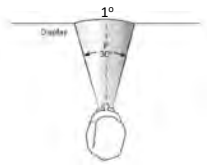
Visual field



Visual Cone

- Center of the fovea
  - a small depression in the retina of the eye where visual acuity is highest. Viewing distance

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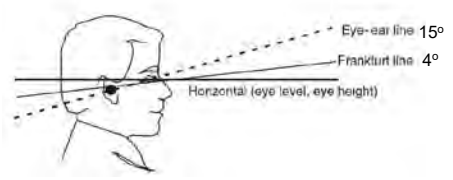
84

Viewing Angle



- Standing eye height ranges 52.2-75.3 in
- Seated eye height ranges 25.2-35.6 in
- Shoe height (1.2 in) added to standing eye height
- Slump factor (1.5 in) subtracted from the seated eye height

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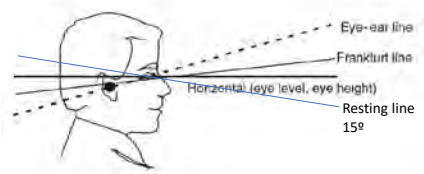
85

Resting line



This is the best location for important information

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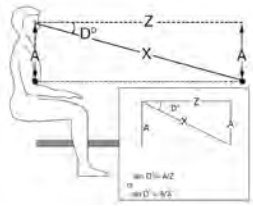
Viewing Distance & Angle



- If an object is 10 in below eye level and the horizontal distance from the eye to the object is 27 in, then what is viewing angle?
- Is this a good angle?
- What can we do?

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87

Size of Visual Targets

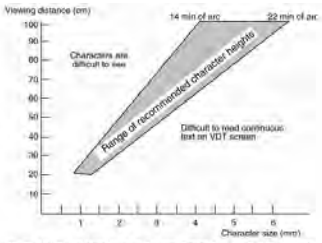

FIGURE 3.2 Size of Visual Targets at Different Viewing Distances (based on material developed by Inger M. Williams, 1989)

- If the visual angle of an object is less than 3 minutes of arc, magnifiers should used

θ = tan–1 (size of visual object / viewing distance to object)
To obtain minutes of arc, multiply θ by 60

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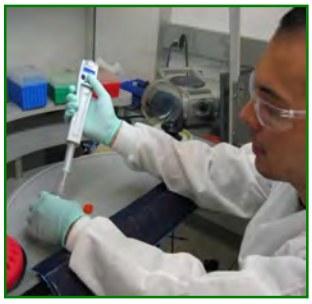
Lab Workstation Ergonomics



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Lab Workstation Ergonomics - Problems

- Extremely flexed neck
- Body leaning forward
- Hunched upper body
- Arms held up without support
- Bent wrists to use controls
- Insufficient leg clarence

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Lab Workstation Ergonomics - recommendations

- Stand when working on high surfaces or with high objects; sit when working on low surfaces
- Plan work area layout to avoid long reaches
- Keep under-counter area clear
- Use low containers and waste bins
- Adjust chair, work bench or microscope to avoid bending your head forward

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Lab and Bench Padding Options

Keep your elbows off the table!!

Tabletop padded wedges

Adjustable clamp-on pads

Padded 'sleeves' worn under lab coat

Gel arm and elbow pads

Closed-cell foam edge protector

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Reverse tweezers

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Magnification systems

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94

Adjustable Workstations

- No one design can be optimal for all people

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95

Administrative Controls

- Training – working in neutral position
- Breaks/Microbreaks – at least once per hour
  - Reduce injuries, won't decrease productivity
  - Can be as short as 30 to 60 seconds
  - Focus on an object 20 feet away
  - Not required to stop work, can change task
- Stretching – at least once per hour

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The Future of Workstation Design

https://www.youtube.com/watch?v=eHdShyF9x7U

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Ergonomic Assessments

- Conduct Workspace Inspections Quarterly
- What are the current conditions?
- How do we achieve desired conditions?
- Can be performed by:
  - Industrial Hygiene Office
  - Individual
  - Co-worker

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Tasks for Managers/Employers

- Conduct On Job Training (OJT) and maintain documentation of it
- Provide:
  - Adjustable, adjustable, adjustable

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How do we Prevent Injuries?

- Change behaviors
- Change the environment
- Change the person???
- Non-work Activities

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100

Ergonomics Programs

- Chapter 6 in your textbook!

FPST 3213 101

101

Resources

- Computer Workstation Ergonomics, NASA pamphlet
- Cornell University Ergonomics Web. http://ergo.human.cornell.edu/
- National Institute for Occupational Safety and Health: Ergonomics and Musculoskeletal Disorders. http://www.cdc.gov/niosh/topics/ergonomics/
- Healthy Computing
  - http://www.healthycomputing.com/health/

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To do list

- HW 6

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The Future of Workstation Design

If we're not careful….

https://www.youtube.com/watch?v=s-kdRdzxdZQ

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Equipment Design

Workstation / Equipment Design

https://www.youtube.com/watch?v=-UpxsrlLbpU

Objectives

- Understand display design
- Understand different control design parameters
- Know how people will use different interfaces
- Be able to select the right tool

General Design Guidelines

- The goal of the ergonomist is designing equipment to be within the strength, endurance, reach, sensory, and information-processing capabilities of a large number of people

General Design Guidelines

- Machines are designed to improve the performance of the human system
- Machine sizing (“right-sizing”) should consider

Maintenance

- Horizontal clearance of at least 46” each side
- Vertical clearance of 80” if it requires overhead maintenance
- Access to components should accommodate both hands
- 1.8” clearance around each side of a component to be grasped

Maintenance

- Need to see equipment
- Lock-out/Tag-out
- Replaceable units

Displays

This one…

…or this one?

Displays

- Need to know
- Nice to know
- Historical

Displays

- Tactile/haptic
- Auditory
- Visual

Visual Versus Auditory Presentation of Communication in a Production Environment (adapted from Deatherage 1972; Ivergard 1999)

Use visual presentation if:

- The person's job allows him or her to remain in one position
- The message does not call for immediate action
- The message is complex
- The message is long
- The message will be referred to later
- The auditory system of the person is overburdened
- The message deals with location in space
- The receiving location is too noisy

Use auditory presentation if:

- The person's job requires him or her to move about continually
- The message calls for immediate action, as auditory alarms can be detected from any direction
- The message is simple
- The message is short
- The message will not be referred to later
- The visual system of the person is overburdened
- The message deals with events in time
- The receiving location is too bright or if preservation of dark adaptation is necessary
- The signal is originally acoustic
- The operator lacks training and experience of coded messages
- The situation is stressful and additional attention-getting is needed

Use tonal presentation rather than speech if:

- The operator is trained to understand coded messages
- In situations where it is difficult to hear speech (tones can be heard in situations where speech is inaudible)
- Where it is undesirable or unnecessary for others to understand the message
- If the operator's job involves constant talking
- In cases where speech could interfere with other speech messages

Visual Displays

- Static

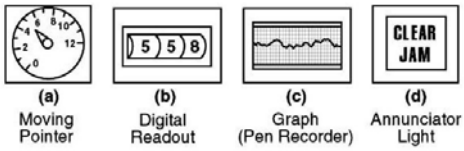
- Dynamic
  - Light
  - Instrument
  - Electronic

Light Displays

- A basic lamp display is usually color-coded and size-coded
  - Red
    - Danger, warning, fire
    - Small red – malfunction
    - Large RED – emergency condition
  - Yellow
    - Caution, slow, power on
  - Green
    - Go, ready, functioning correctly

Examples of Visual Displays

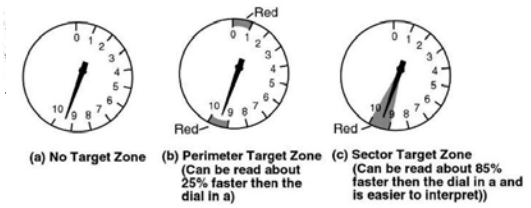
- An annunciator light typically has written instructions on it



(a) Moving Pointer (b) Digital Readout (c) Graph (Pen Recorder) (d) Annunciator Light

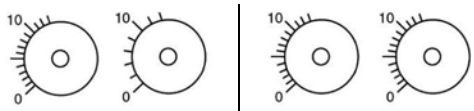
Instrument Displays

- Circular or semicircular dials are preferable to rectangular gauges
- Should only have two, four, or five marked intervals in between to avoid confusion
- Place zero at the 9 o'clock or 12 o'clock position
- Make the direction of increasing value

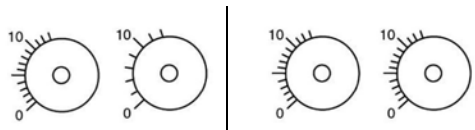


(a) No Target Zone (b) Perimeter Target Zone (Can be read about 25% faster then the dial in a) (c) Sector Target Zone (Can be read about 85% faster then the dial in a and is easier to interpret))

Why?



(a) Poor (b) Good



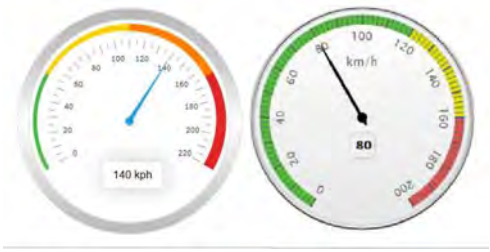
(a) Poor (b) Good

Conformity

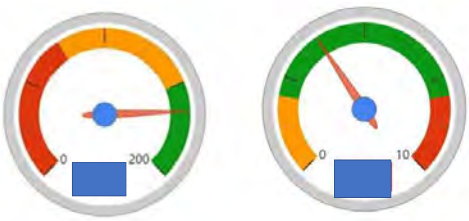
www.shutterstock.com • 85259

Maximums should be to the right

Use whole numbers oriented upright not radially



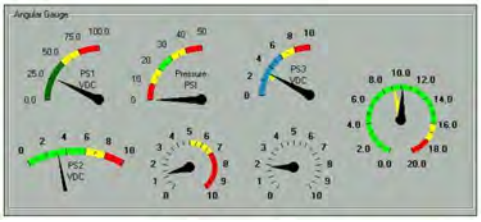
Avoid the need for interpolation for quantitative readings



Avoid the need for interpolation for quantitative readings

Instrument Displays

- Rapid reading = faster response time
- Use white markings on a black background
- Digital vs analog



Minimum Diameter of Inner Ring Inside the Scale Markings of a Dial at Various Viewing Distances (adapted from Woodson, Tillman, and Tillman 1992)

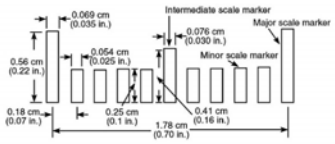
No. of Scale Marks	Viewing Distance				
	50 cm (20 in.)	91 cm (3 ft.)	1.8 m (6 ft.)	3.6 m (12 ft.)	6 m (20 ft.)
50		3.3 cm (1.3 in.)	6.6 cm (2.6 in.)	13 cm (5.0 in.)	23 cm (9.0 in.)
100	3.5 cm (1.4 in.)	6.6 (2.6)	12.7 (5.0)	25.4 (10.0)	43.2 (17.0)
150	5.1 (2.0)	9.9 (3.9)	20.3 (8.0)	38.0 (15.0)	66.0 (26.0)
200	7.4 (2.9)	12.7 (5.0)	25.4 (10.0)	53.3 (21.0)	86.4 (34.0)
250	8.9 (3.5)	16.3 (6.4)	33.0 (13.0)	66.0 (26.0)	109.2 (43.0)
300	10.2 (4.0)	19.5 (7.7)	38.0 (15.0)	78.7 (31.0)	129.5 (51.0)
350	12.7 (5.0)	22.9 (9.0)	45.7 (18.0)	91.4 (36.0)	152.4 (60.0)

Instrument Displays

- Installation
  - Avoid shadows and optical distortion
  - Align groups of dials uniformly
  - Provide adequate illumination
  - Clearly labeled
  - Remove or cover unused displays

Instrument Displays

- Ensure the markings are of sufficient thickness to be discernable from the viewing distance



- Recommended scale mark dimensions for 28” viewing distance

Instrument Displays

- Installation
  - Standing work: between 42” and 62” from the floor
  - Seated work: no higher than 20” above the work service

Electronic Displays

- Organization of information
- Design of graphical objects
- Coding techniques
- LED most common method

LED stands for **Light Emitting Diode**
CRT stands for **Cathode-Ray Tube**

Electronic Displays

- CRT versus LED
  - LEDs have superior contrast
  - Do not flicker
  - Lighter weight and smaller footprint
  - CRTs have wider viewing angles

CRT stands for **Cathode-Ray Tube**
LED stands for **Light Emitting Diode**

Guideline for LED Displays

- Minimize the use of segmented alphanumeric

1234567890

Good example?

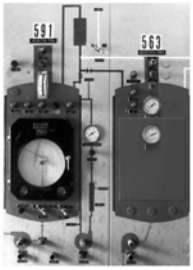
Guideline for LED Displays

- Vertical numbers

1 2 3 4 5 6 7 8 9 0

Controls

Design of Controls



- A control is anything used by a person to affect performance of a system such as ……

Control Design, Selection and Location

- Minimum
- Frequent posture adjustment
- Use hand control for precision operation
- Use feet controls for large forces
- Distinguish between normal and emergency operations

Prevent accidental activation of controls

Spacing

Control	Type of Use	Measurements of Separation	Recommended Separation: Minimum mm	Minimum in.	Desirable mm	Desirable in.
Push Button	One Finger (Randomly)		12	½	51	2
	One Finger (Sequentially)		6	¼	25	1
	Different Fingers (Randomly or Sequentially)		12	½	12	½
Toggle Switch	One Finger (Randomly)		20	¾	51	2
	One Finger (Sequentially)		12	½	25	1
	Different Fingers (Randomly or Sequentially)		16	⅝	20	¾
Crank and Lever	One Hand (Randomly)		51	2	100	4
	Two Hands (Simultaneously)		76	3	127	5
Knob	One Hand (Randomly)		25	1	51	2
	Two Hands (Simultaneously)		76	3	127	5
Pedal	One Foot (Randomly)		d = 100 D = 203	4 8	152 254	6 10
	One Foot (Sequentially)		d = 51 D = 152	2 6	100 203	4 8

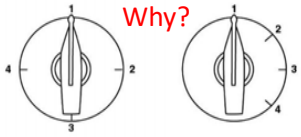
Shape coding

- Varying the shape, size and color on complex panels

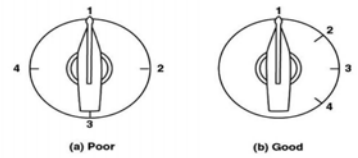
Control Resistance

- Design controls so that they
  - Are large enough to grasp
    - Less than 22 psi grip pressure

Why?



Control Resistance



Have the shortest amount of movement

Control Resistance

- Provide a positive indication of activation so malfunction is obvious
- Provide feedback to the operator
- Integrate use of arms or foot support to avoid static loading
- Provide a backrest for seated operator if push force greater than 22 N

Control Types

- Toggle switches
  - Used when operation has only two options
    - On/off

Control Types

- Push buttons
  - Frequently used to enter information into a piece of equipment for each button represents a separate response
    - Vending machine

Control Types

- Rotary selector switches
  - 3 to 24 values

Control Types

- Knobs
  - Extend the range of rotary selector switches
  - Can be rotated more than 360°

Control Types

- Valves
  - Denote direction of operation
  - Label as
    - normally open (NO)
    - normally closed (NC)

Control Types

- Crank
  - Provide either fine or course adjustment over a wide range

Control Types

- Levers
  - Useful in providing accurate adjustment over a small range

Control Types

- Hand wheels
  - Used for two handed operation when high force is required

Behavioral stereotypes

- Very loud sounds or blinking visual displays imply _____
- Large or dark objects denote _____
- Small or light-colored objects denote _____
- In addition to red, yellow, and green, blue indicates _____
- Coolness associated with _____ and warmth is associated with _____

Control movement stereotypes

TABLE 4.6
General Movement Expectations of Controls (adapted from Alexander 1976; Woodson, Tillman, and Tillman 1992)

Function	Direction of Control Movement
*On/start/engage	*Up, right, forward, press†
*Off/stop/disengage	*Down, left, rearward, pull†
Right	right, clockwise
Left	left, counterclockwise
Up	Up,rearward
Down	Down, forward
Retract (raising)	Up, rearward, counterclockwise, pull
Extend (lowering)	Down, forward, clockwise, push
Increase	Up,right, forward, clockwise‡
Decrease	Down, left, rearward, counterclockwise‡
Open (liquids, gases, doors)	Down,left, counterclockwise
Close (liquids, gases, doors)	Up, right, clockwise

This one…

…or this one?

Tools

Tools

https://www.youtube.com/watch?v=tDvV0pYOISQ

The best tool is one that…

- Fits the job you are doing
- Fits the work space available
- Fits your hand and force
- Can be used in a comfortable work position
- It is safe in all aspects

Key concepts

- Understanding the User
- Computer Interface
- Matching Expectations

Understanding the User

- Limits of human memory and attention
- Early in the design stage, gather user characteristics such as _____

Matching Expectations

- System should tell operator
  - Where they are
  - What they have done
  - Whether it was successful

Matching Expectations

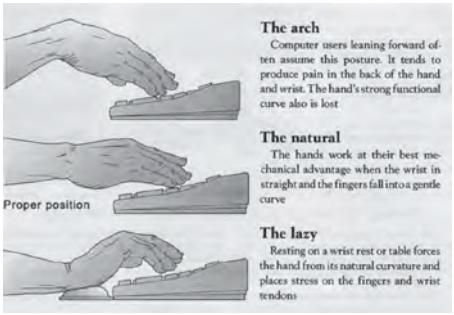
- Don't describe the symptoms of a problem, tell the operator the cause
- Keep false alarm rate low
- Make controls self-explanatory

Computer Devices

Computer Input Device

SmartFish ergonomic keyboard and tilting mouse

http://www.youtube.com/watch?v=c3Cwfz25Jeg



The arch
Computer users leaning forward often assume this posture. It tends to produce pain in the back of the hand and wrist. The hand's strong functional curve also is lost

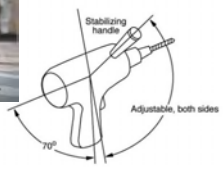
The natural
The hands work at their best mechanical advantage when the wrist in straight and the fingers fall into a gentle curve

The lazy
Resting on a wrist rest or table forces the hand from its natural curvature and places stress on the fingers and wrist tendons

Working with a Soldering Iron

Extended and bent tip, elbows closer to his side
Reduce muscle fatigue

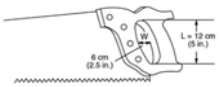
Electric Drill with Stabilizing Handle



Give the operator the opportunity to use the other hand to stabilize it

Saw Handle Dimensions

- Keeps the wrist closer to neutral
- Length of the hole no less than 5”
- Width should be at least 2.5”



Double-handle Tools

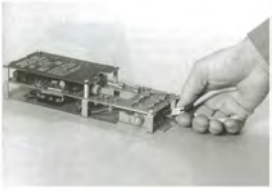
Closed grip span

Open grip span

- Tool with a grip span at least 2.5” when fully closed and no more than 3.5” inches when fully open
- Use tools that spring open

Safety Aspects

Safety Aspects



- Ensure handles are long enough

Safety Aspects

- Holding tool for a chisel

- Martor safety knife

Safety Aspects

- Martor safety knife
- Safety knife MARTOR SECUPRO 625 product video GB - Bing video

Tool Designs

https://www.youtube.com/watch?v=E9DVp7YvQVU

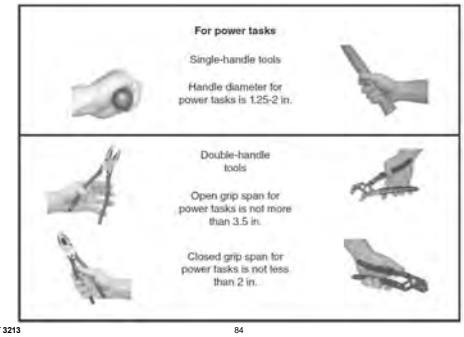
Tool Designs

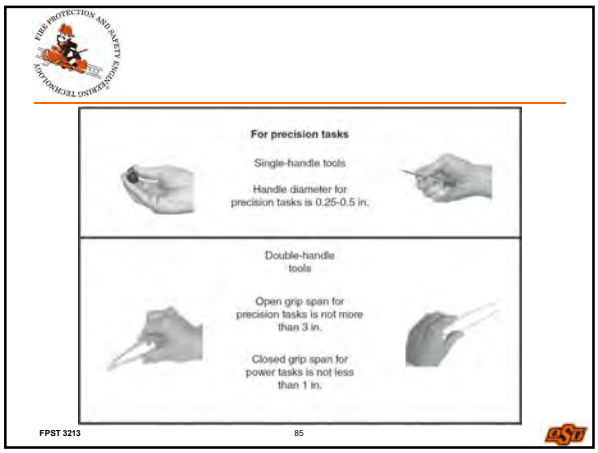
Tool Designs

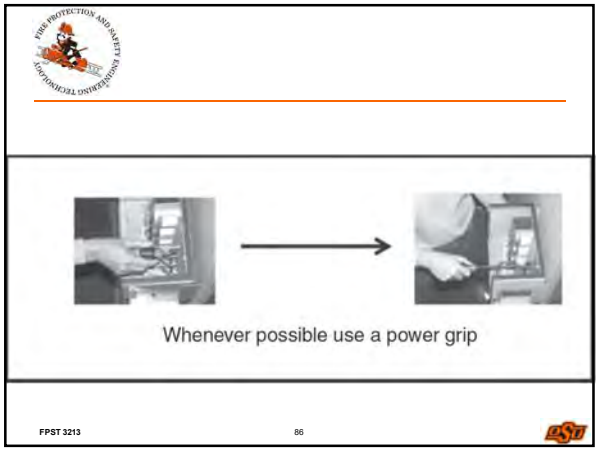
Tools

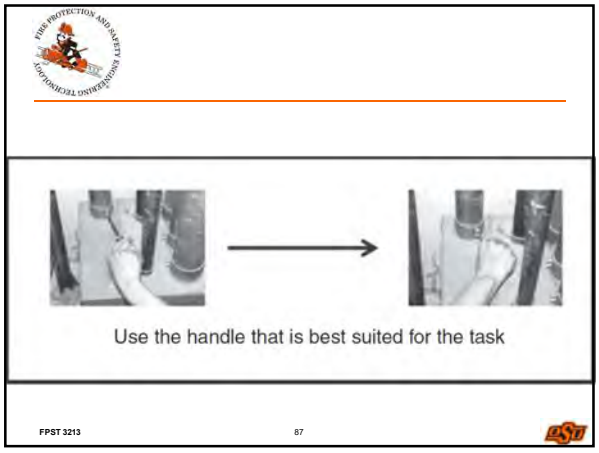
Tools

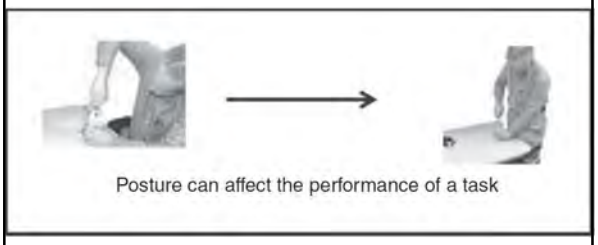
https://www.youtube.com/watch?v=i6WMPSnFoQY




For precision tasks
Single-handle tools
Handle diameter for precision tasks is 0.25-0.5 in.
Double-handle tools
Open grip span for precision tasks is not more than 3 in.
Closed grip span for power tasks is not less than 1 in.
FPST 3213
85


Whenever possible use a power grip
FPST 3213
86


Use the handle that is best suited for the task
FPST 3213
87



Posture can affect the performance of a task

Additional Tool Selection Guidelines

- Handle Length at least 5”
- Proper handle thickness
  - Vibration absorbing material if needed
- Strip trigger instead of single finger
  - Avoid thumb triggers
- Weight less than 5 pounds
  - If more, then use a balancer
- Precision tool weight less than 1 pound

Power tools

- Force to active it!

Ergonomic Balancer

https://www.youtube.com/watch?v=wjb3zo06bOI

Tools

Tools

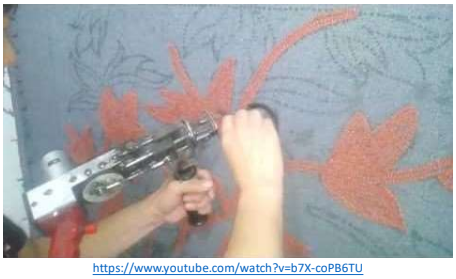
To do list

- HW 6
- HW 7

Work Design

Objectives

- Work design definition
- Consequences of poor work design
- Workplace analysis
- The occupational athlete.



https://www.youtube.com/watch?v=b7X-coPB6TU

Work design

- Organization of job demands in a job

Organizational factors influencing job demands

Management policies + Psychosocial factors = stress

Work Design

- Human centered
  - Macroergonomics

Organizational designs

- Measurements of overall effectiveness
  - Productivity
  - Efficiency
  - Profitability
  - Quality
  - Health and safety
  - Absenteeism
  - Turnover

Occupational stress from the workers' perspectives

- Job requirements
- Job control
- Communications

Shiftwork

- 1985: Expiration of the Walsh-Healy Act
  - Set limitation of hours that an employee could work in a 24-hour period before being paid overtime differential
  - Companies began to explore opportunities to work longer shifts and compressed work weeks

Shiftwork

- Shift work and employee health and safety
  - Work-related patterns such as smoking and unhealthy nutrition habits

Shiftwork

- Eight-hour shifts versus 12-hour shifts

Guidelines for selecting alternative work systems

- Specific night shifts
- Consecutive nights not less than four in a row
- Rest periods of at least 24 hours after each night shift
  - https://www.sleepfoundation.org/shift-work-disorder/tips/workplace

Design to minimize fatigue

- Physical fatigue
  - Cardiovascular measurement
- Physiological fatigue
  - Introduce a secondary task
  - Measure production rates

Sign of serious fatigue is simple exhaustion

Static muscle fatigue

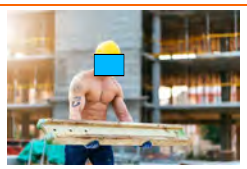
- The longer the muscle remains under contraction the more time the lactic acid has built up

Dynamic work fatigue

- Workers will typically report being very tired and needing more sleep

Physical fitness of the workforce

- Job rotation
- Stretching
- Work simulation
- Work conditioning
  - The industrial athlete



Job Simulation

Repetitive work

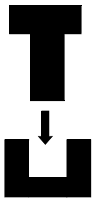
- If the cycle is repeated continuously for two or more hours of work it is considered repetitive

The design of repetitive work

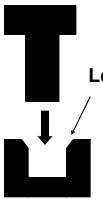
- Change positions
- Limit use of vibrating tools
- Poorly designed, machine or molded parts require excessive force on hands and arms during assembly

Chamfers & Lead-ins

Poor

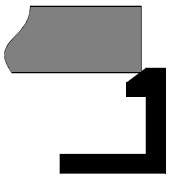


Good

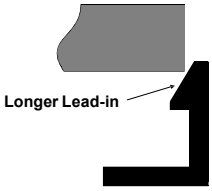


Reduce Snap-fit Force

Undesirable

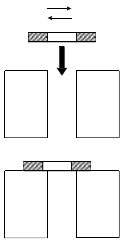


Improved

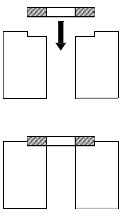


Minimize Holding Down & Alignment

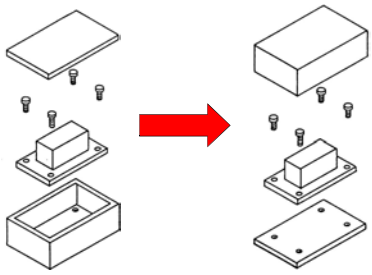
Poor



Good



Design To Improve Access



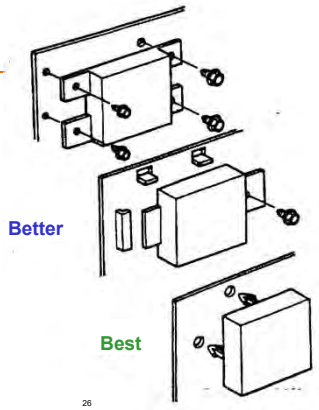
Before After

Poor

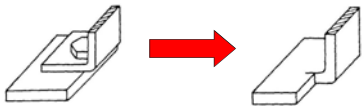
Better

Minimize Number of Fasteners

Best



Reduce Part Count



Before After

MSDs and work design

- Train workers to recognize early symptoms and report them immediately
- Job rotation
- Identify best techniques
- Employees returning to work

General guidelines to improve organizational factors and job design

- Design in enhanced communications
- Minimize manual handling of materials
- Provide easy-to-use processes
- Provide any mechanism where the workers are involved in the design process
- Develop an ergonomics team
- Formulate guidelines for handling emergency events

What is Work Design?

https://youtu.be/uR3dJJjSDdM

- Workplace Analysis

Workplace Analysis

- Qualitative
- Semi-quantitative
- Quantitative

Workplace Analysis

- Qualitative
  - A walk-through survey
  - Use of Job Safety Analysis (JSA) to consider risk factors of a job based on professional judgment and experience

Workplace Analysis

- Qualitative
  - Should be familiar with injury history
  - Interviews with one or more experienced operators is **critical**

Workplace Analysis

- Semi-quantitative
  - Consider duration and intensity
  - Rodgers muscle fatigue assessment
    - Assesses the amount of fatigue and muscles during various work patterns within a five minute work period
  - Liberty mutual tables for manual materials handling Include information for lifting and lowering carrying pushing and pulling (covered later)

Workplace Analysis

Semi-quantitative

- ACGIH TLV for hand activity level
  - Evaluation is based on assessment of hand activity and the level of effort for a typical posture while performing a short cycle task
    - Step 1 – Identify the level of hand activity on the scale of 0 to 10
    - Step 2 – Characterize the effort level by noting the effort associated with a typically high force and rate on a scale of 0-10
    - Step 3 – Compute the ratio
    - If the ratio is below the action level, no further analysis. If it's above, job redesign is required

American Conference of Governmental Industrial Hygienists (ACGIH)
Threshold Limit Value (TLV)

Workplace Analysis

- Quantitative
  - Thresholds established
  - Strength and biomechanics

Quantitative Analysis

- Static Work
  - Strength and biomechanics has no time consideration
  - For static work the concern is fatigue of the muscle group
- Dynamic Work
  - Considers the relative demand of the work on the least fit individual based on population data
    - Typically the 10% female

Quantitative Analysis

- Dynamic Work
  - The percent maximum aerobic capacity is the percent ratio of the oxygen demand of the work and the criterion aerobic capacity

Metabolic demands Maximum limit	Shift lengths (hours)
33%	8
30%	10
25%	12

Quantitative Analysis

- Dynamic Work
  - If more than 33% of the heart rate range for whole body work is required during a shift, worker is likely to become fatigued

Quantitative Analysis

- Dynamic Work
  - Another good measure is the rate of oxygen consumption and the rate of energy expenditure
    - Rate of oxygen consumption is a fraction of the individual's maximum aerobic capacity

Quantitative Analysis

- NIOSH lifting equation (covered later)
  - First proposed in 1981 - Updated in 1991
  - Provides a recommended weight limit (RWL)

Avoiding Whole-body Fatigue

- The main goal is avoiding whole-body fatigue which
  - Reduces productivity
  - Results in lower psychomotor skills (which may lead to accidents and overexertion injuries)
  - Reduces comfort and acceptability

The Occupational Athlete

a.k.a. The Industrial Athlete

The Industrial Athlete

Athlete v Employee

Three Athletic Principles

Athletic Principles	At Work
Biomechanics	Occupational Role Profiling Onsite Coaching
Pre Screening	Pre-Employment
Strength & Conditioning	Job Hardening

The Industrial Athlete

- Anyone who makes a living using mental and physical talents to perform jobs that require skill, strength, flexibility, coordination and endurance—just like an athlete.

The Industrial Athlete

- Athletes and workers use their musculoskeletal system to perform their sport or job

…therefore, the employee deserves the same commitment and attention from the rehabilitation team as the athlete

The Industrial Athlete

- Treat industrial athletes as comprehensively and intensely as a competitive athlete

The Industrial Athlete

- So why does recovery from similar injuries take three to four times as long in the industrial arena than in the sports arena?
- How much rest does a football player get between games?

The Industrial Athlete

- PT's recognize the need to:
  - Design tasks and jobs so that they have rest breaks and sensible shift patterns
  - Design equipment and work to improve posture and ease the load on the body
  - Information design, to make the interpretation and use of handbooks, signs, and displays easier and less error-prone
  - Design training to cover all significant job aspects human learning requirements

The Industrial Athlete

- "If ergonomics says the job is within standards for the majority of individuals, the question that needs to be examined is could many of these injuries be avoided if we conditioned the industrial worker and modeled an exercise program based on their respective jobs?
- What is that called?

The Industrial Athlete

- Work hardening and work conditioning

The Industrial Athlete

- "Injury prevention should include strength and endurance training to build better work fitness, learning how to safely perform work tasks with good body mechanics, and adapting the work environment to promote ergonomically correct work sites"

https://www.ptonthenet.com/articles/The-Industrial-Athlete-%E2%80%93-Part-1-2101

The Industrial Athlete

- Use of protective equipment while working or performing the event. The least expensive injury is the one you never have to treat.
- Training that strengthens potential areas of weakness and enhances performance at work. Better adaptation to handle the demands of the job or activity.
- Diagnose the injury as quickly as possible and initiate measures to decrease the severity of disability.
- Rehabilitation that improves flexibility, muscular balance, and other factors that may have contributed to the injury and may prevent future injury

The Industrial Athlete

"Bringing the sports medicine model to the industrial setting can reduce the medical and non-medical expenditures related to repetitive stress injuries. The goal of returning competitive athletes to their functional status before their injuries should be just as aggressively pursued for industrial athletes. In a competitive business environment, it is crucial to have a healthy, strong, highly motivated team to get the job done."

https://oem.bmj.com/content/57/4/285.1

Industrial Athlete at Boeing Since 2004

- The Industrial Athlete program is an innovative, voluntary workplace program designed to improve the health and productivity of employees and address the need to keep employees strong and healthy.

Industrial Athlete at Boeing

- By using sports medicine techniques, the program has been found to reduce discomfort after employee participation

By Sabyasachi Basu, Laurence S. Wechsler, Deborah R. Smith, Corinne D. Towler, Catherine M. Curley, Karen Rogers and Tina L. Hermans
https://www.boeing.com/features/innovation-quarterly/dec2016/feature-technology-ind-athlete.page

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The Industrial Athlete

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Work Hardening/Conditioning

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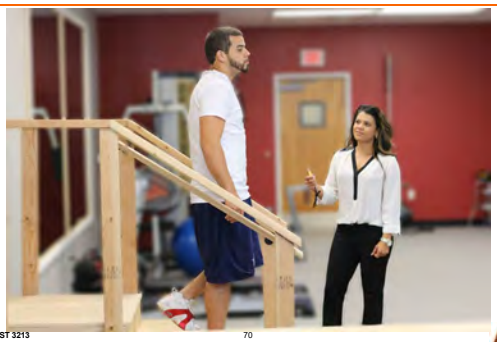
Work Hardening/Conditioning



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Work Hardening/Conditioning

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Work Hardening/Conditioning

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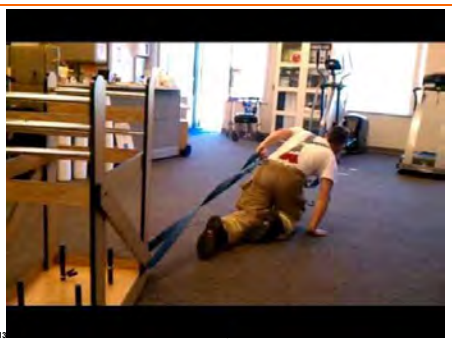
Work Hardening/Conditioning

Work Hardening/Conditioning

Work Hardening/Conditioning

Work Hardening/Conditioning



Human Reliability and Information transfer

How to make a PB&J Sandwich

https://www.youtube.com/watch?v=XWe4iohhmIw

Questions?

1

Human Reliability and Information Transfer

2

Objectives

- Understand different ways to assess the potential for human error (human reliability)
- Learn methods to minimize a common source of error (information transfer)

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3

Reduction of Error

- Human centered
  - Use Macroergonomics
  - Reduce fatigue, stress, MSD
  - Increase safety, productivity, quality

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4

Definitions

- **Reliability:** the probability that any item will perform a specified function for a given time under specific conditions
- **Human reliability:** the probability of successful human performance on a task in any stage of system operation(s) under a given time parameter
- **Human performance reliability:** the probability that the human will fulfill a given job under specified conditions

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Reduction of Error

- Reliability analyses in 1950s only focused on equipment
- Humans are not perfect
  - Must account for failings of human operators
  - Information transfer common source of error

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Human Reliability Analysis

- Evolved because of catastrophic disasters
  - Causes of major catastrophic accidents were compilation of

?

7

Human Reliability Analysis (HRA)

- Human reliability…as an activity…
  - The analysis, prediction and evaluation of work-oriented human performance
  - Attempts to quantify
    - Error likelihood
    - Probability of task accomplishment
    - Response time

8

Goals of HRA

- Predict human performance outcomes related to specific tasks
- Identify the effects on the system and undesired outcomes
- Isolate factors most likely to cause human error
- Identify potential areas of risk
- Quantify the overall risk
- Indicate systemic improvements

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HRA Techniques

- Human Error Probability
  - The number of actual errors / number of opportunities for error to occur

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HRA Techniques

- THERP - Technique for Human Error Rate Prediction
  - Analyzes success or failure of an operator actions as they were part of the system
  - Steps
    - Identify system functions that may be affected by human error
    - Analyze jobs performed by human operators
    - Estimate probability of human error and undetected error on each task
    - Evaluate and estimate consequences of the error

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HRA Techniques

- HEART - Human Error Assessment and Reduction Technique
  - Identify a specific task
  - Assign a nominal human error probability
  - Result is quantified risk

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HRA Techniques

- SLIM - Success Likelihood Index Method
  - Link human error probabilities of a specific situation to performance-shaping factors
  - Involves a weighting and rating scale to quantify risk

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HRA Techniques

TESEO - T*ecnica empirica stima errori operatori*

- Evaluates the probability of a human error occurring throughout the completion of a specific task
  - The time available to the operator to complete the task
  - The operator's level of experience/characteristics
  - The operator's state of mind
  - The environmental and ergonomic conditions prevalent

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Limitations of HRAs

- Estimations are based on subjective (biased) judgements of the analysts
- Do not account for all human interactions throughout all aspects of system operations (installation, management maintenance, etc.)
- Relies on probability estimations where no data exists
- Estimations may not be transferable from on event to another

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Error Tolerance

- The best way to protect the system is to make it more error-tolerant
  - 30 minute rule
    - Allow the human operator time to think after initiating an action before an automated system takes over
  - Safety Factors
    - Backup systems or redundancies

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Human error is unpredictable and thus, inevitable

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Examples

- King's Cross Fire
- Avenida Suba Tragedy
- Explosions
- Three Mile Island

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King's Cross Fire

The King's Cross fire.

On 18 November 1987, the worst fire in the history of the London Underground began when a match was dropped on the escalators.

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King's Cross Fire

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Avenida Suba Tragedy - Colombia

On 24 April 2004, Bogota Colombia experience the worst "traffic" accident when an asphalt recycler land over a school bus.

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Avenida Suba Tragedy - Colombia

EL TIEMPO

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Avenida Suba Tragedy

Newspaper EL TIEMPO

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Avenida Suba Tragedy

EL TIEMPO

REUTERS

EFE

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Avenida Suba Tragedy

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Avenida Suba Tragedy

Memorial

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Beirut explosion

On 4 August 2020, a **large amount of ammonium nitrate stored at the port of the city of Beirut**, the capital of Lebanon, exploded, causing at least 200 deaths, 3 reported missing, 6,500 injuries, US$ 10–15 billion in property damage, and leaving an estimated 300,000 people homeless.

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Beirut explosion

Source: Google Earth
Graphic: Nadaie Croker, CNN

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Beirut explosion

TONY VRALAS VIA EPA

El barco Rhosus llevaba un historial de inspecciones técnicas deficientes antes de ser retenido en el puerto de Beirut.

CORTESÍA DE @OMARADIK

Durante seis años, el peligroso material estuvo almacenado sin las medidas de seguridad pertinentes.

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Beirut explosion

GETTY IMAGES BBC

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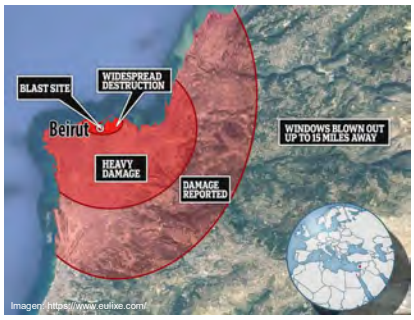
Beirut explosion



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Beirut explosion

Satellite images show damage at Beirut blast site

Source: Cnes 2020, Distribution Airbus DS

BBC

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Beirut explosion

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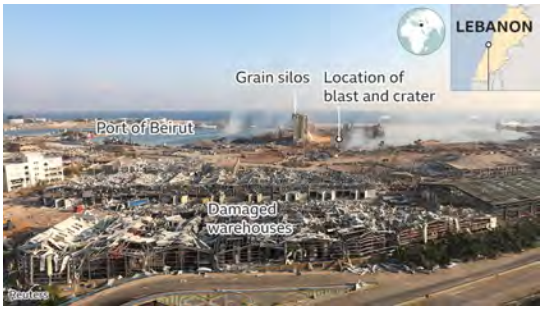
Beirut explosion



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Beirut explosion

HASSAN AMMAR / AP

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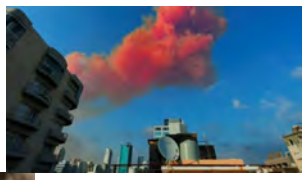
Beirut explosion

REUTERS



GETTY IMAGES

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Mexico Explosion

On 18 January 2019, a pipeline transporting gasoline exploded in the town of Tlahuelilpan, in the Mexican state of Hidalgo. The blast killed at least 137 people and injured dozens more. Mexican authorities blamed fuel thieves, who had illegally tapped the pipeline.

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Mexico Explosion

Foto: Coordinación Social del Gobierno de México

Imagen: TV Azteca

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Mexico Explosion

Imagen: CNN en español

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Mexico Explosion

Imágenes: CNN en español

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Three Mile Island

https://www.youtube.com/watch?v=eGI7VymjSho

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Information Transfer

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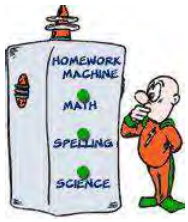
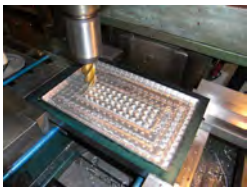
Information Transfer





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Information Transfer

- Common Information Transfer Errors
  - Not complying with a warning
  - Misinterpretation of instructions
  - Information overload from too many codes
  - Entering information in the wrong location on a form
  - Transposing numbers
  - Correct signal might not be sent
  - Label and function not synchronized
  - Behavioral stereotypes
  - ???

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Warnings

To provide individuals with information regarding _____

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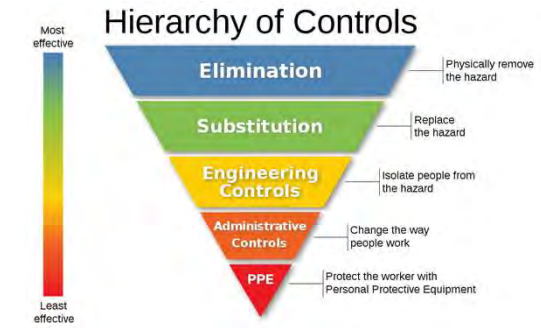
What happened to Warnings?



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What Makes an Effective Warning?

- Easily Identifiable
- Distinguishable from the background noise
- Interpretable
- Understood by the user population

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Audible Alarms

- Incidental
  - Warn after problem has started
- Intentional
  - Engineering sounds specifically designed to warn
- Different types
  - Speech
  - Non- speech
  - Auditory icons

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Speech Signals

- Recognition
  - Preceded by signal
  - Change in voice
  - Distinct from ambient
  - Repetition
- Urgency
  - Female voice
  - Short word duration
  - Emotional voice
- Process 3 messages in emergencies
  - 7 under normal conditions
- Preferred
  - Best response
  - Easy to learn / remember

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Speech Signals

- High workload conditions
- The perceived urgency depends
  - Pitch, intensity, duration
- Use the words
  - Danger, caution, warning
- Example: _____
- Evacuation/Emergency: Voice Sample from Matthew Kelly (Highcroft.com) - Bing video

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Speech Signals

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Non-speech Signals

- 10 dB above ambient
- Standardized within facility
- Use stereotypes
  - Urgency
    - Speed: faster
    - Pulse level: high
    - Interval: short
- Example: _____Evacuate alarm sound - Bing video

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Audibility vs. Intelligibility

- Audibility
- Intelligibility

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Requirements

- In areas greater than 85 dB, meeting intelligibility requirements may not be possible and other means of communication might be required

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Requirements

- According to NFPA 72:
  - Male voice provides for better intelligibility outdoors
    - Lower frequency travels better
  - Female voice better for indoor messages
    - More distinct from typical ambient noises

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Visual Signals

- Signal word
- Hazard
- Consequences
- Instructions

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Visual Signals

- Signal word

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Visual Signals

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Legibility of Color Combinations

Very Good		O		O		
Good	O		O		O	O
Fair		O		O		
Poor	O		O		O	O
Very Poor		O		O		

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Coding

- Color Coding
- Shape Coding
- Alpha Coding
- Symbol Coding

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Coding

- Detectable
- Meaningful
- Stereotypes
- Standardized

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Labels and Signs

- Comprehensibility
- Legibility
- Readability

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Too many signs….

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Too many signs….

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Too many signs….

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Written Instructions

- Not paragraphs
- Diagrams and text (inexperienced)
- Diagrams only (experienced)
- Warnings in instructions
  - Reading level 7 or 8 (average population)

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1. Calculate the average sentence length:

   L = Number of words + Number of sentence

2. Calculate the average number of syllables per word:

   N = Number of syllables + Number of words

3. Determine grade level:

   Reading level = (L x 0.39) + (N x 11.8) – 15.59

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Example

Prior to entry, the entry supervisor must ensure that the authorized entrants are fully informed of hazardous materials or conditions they are likely to encounter by conducting a safety preparation briefing.

- 31 words
- 1 sentence
- 58 syllables

- Reading level = (31/1*0.39) + (58/31*11.8) – 15.59
- Reading Level = 18.6

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Wacky Warning Labels

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Wacky Warning Labels

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Wacky Warning Labels

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Wacky Warning Labels

Warning:
Does not suply oxygen.

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Communication

https://youtu.be/gCfzeONu3Mo

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Written Instruction

- Passive vs. Active voice

Five hamburgers must have been eaten by the man.

Hamburgers (subject) *are being* ***eaten*** (verb).

The letter was mailed by Marilyn.

The ***letter*** (subject) *was being* ***mailed*** (verb).

The man must have eaten five hamburgers.

The ***man*** *(subject)* is doing the ***eating*** (verb).

Marilyn mailed the letter.

Marilyn (subject) is doing the ***mailing*** (verb).

Colorful parrots live in the rainforests.

Parrots (subject) are doing the ***living*** (verb).

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Written Instruction

- Safe
- Adequate
- Appropriate
- Sufficient
- Correct
- Suitable
- Applicable
- Acceptable
- "Be Careful"

What's wrong with these words?

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Written Instruction

- What's wrong with this sentence?
- Ensure the permit is complete
  - It's active voice
  - It does not who must ensure

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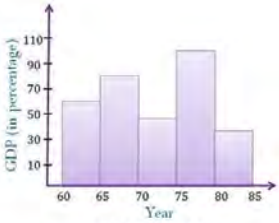
Data Presentation

Bar Graph



Histogram

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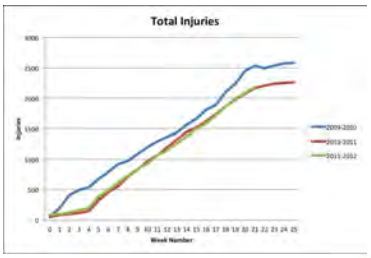
Data Presentation

- Keep things simple
- Consider how data will be viewed
  - Style
  - Color
  - Shape



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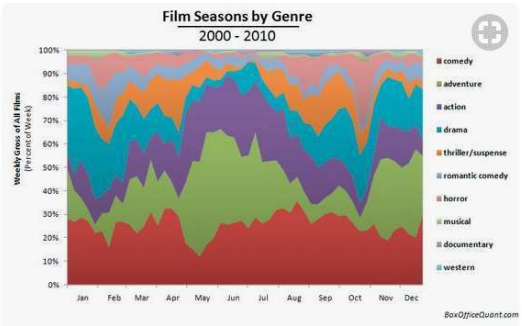
Data Presentation



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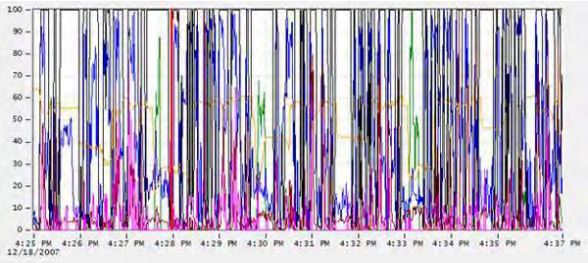
81

Data Presentation



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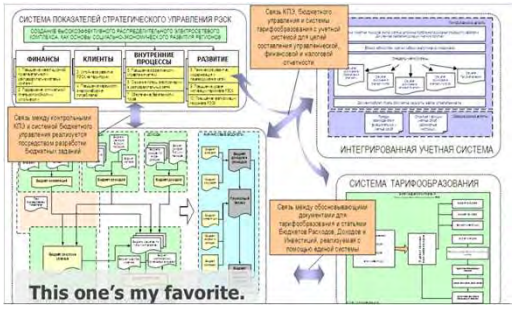
Data Presentation



"Death by Power Point" Alexi Kapterev

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Human Error

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To Err is Human…

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How Can Human Error Prevention Help Safety?

https://www.youtube.com/watch?v=lLmJ1Mm13lQ

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Is 99.9% Good Enough?

- 870 unsafe landings per day in US
- 105 dropped babies per day
- 56 lost pieces of mail per second
- 123,287 incorrect drug prescriptions per day

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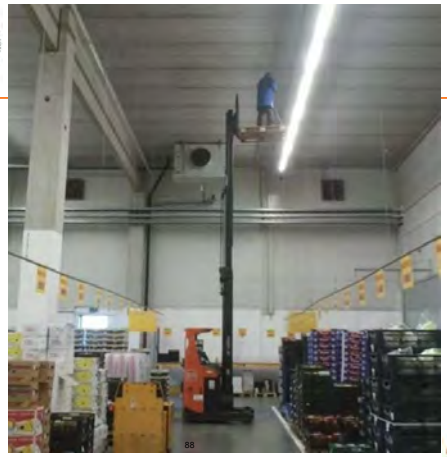

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90

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Stats

- About 80% of all workplace incidents are attributed to human error
  - Closer to 90% in some industries

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Stats

- When broken down further…
  - Majority of errors stem from latent organizational weaknesses
  - About 30% are caused by the individual worker touching the equipment and systems

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Human Error

- Not all of errors lead to a disaster or loss:
- What are these events called?
- Errors of **omission**
- Errors of **commission**
- **There are only two reasons why someone does something unsafe.**

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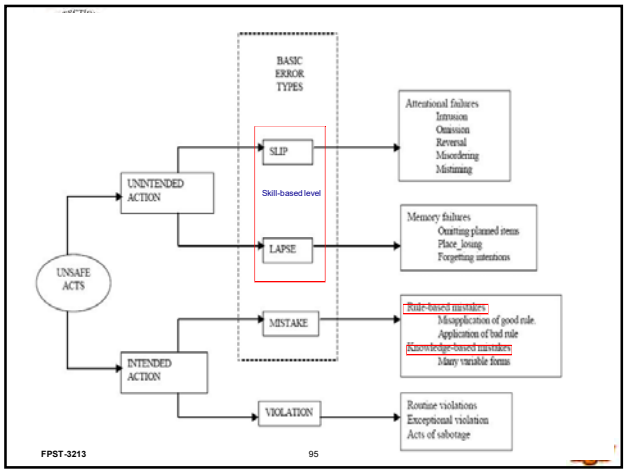

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Human Factors

- Population
- Environment
- Situation

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Views of Human Error

- Old view
  - System is fine except for the people
  - Human error causes potential for failure
- Human error is a conclusion of incident investigations

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Views of Human Error

- New view
  - Human error…a symptom of deeper trouble
  - …the starting point to determining failure
- System is not inherently safe…people create safety, efficiency, productivity

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Why Error Occurs

- Old view
  - Says what people failed to do
  - States what people should have do to prevent the incident
  - Single out poor performers
  - Find evidence of bad behavior
  - Unreliable people weaken a safe system
- Corrective actions
  - Replace people
    - …with new people or technology
  - More procedures…more training

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Why Error Occurs

- New view
  - Not the cause of incidents
  - Not random
  - Understand <u>why</u> people did what they did
    - Why did their decision make sense to them at the time of the incident?
    - What conditions produced the behavior?
  - Nobody comes to work to do a bad job
  - Corrective Actions?

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Reactions to Failure

- Looking back on the event sequence knowing the outcome
- Focused on what people should have done knowing the outcome

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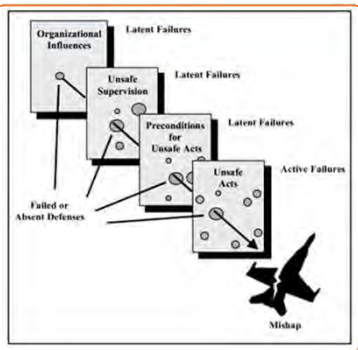
Two Kinds of Error: Active and Latent



Model of Human Error causation (Reason, 1990). Adapted from Shappel (2000)

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Latent Organizational Weaknesses (sources)

- Processes (structure)
  - Work controls
  - Accountability policies
  - Reviews & approval processes
  - Equipment design
  - Procedure development
  - Human resources
  - Training
- Values (relationships)
  - Measures & controls
  - Critical incidents
  - Coaching & teamwork
  - Rewards & sanctions
  - Reinforcement
  - Promotions & terminations

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Risk Perception/Tolerance

Factors that affect Risk Tolerance
- Pride
- Heroism
- Fatalistic
- Invulnerability
- Pollyanna
- Bald Tire

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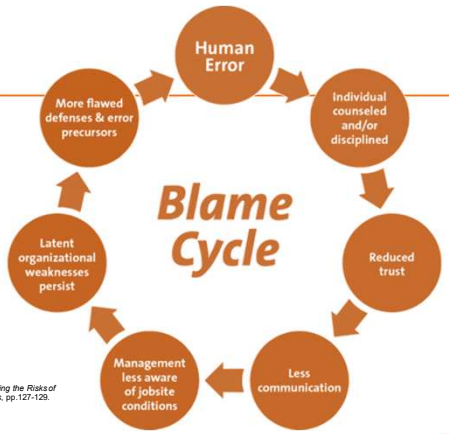

Source: Reason, *Managing the Risks of Organizational Accidents*, pp.127-129.

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Human Error

- People are fallible, and even the best people make mistakes.
- Error-likely situations are predictable, manageable, and preventable.
- Individual behavior is influenced by organizational processes and values.
- People achieve high levels of performance due largely on the encouragement and reinforcement received from leaders, peers, and subordinates.
- Events can be avoided by understanding the reasons mistakes occur and applying the lessons learned from past events (or errors).

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Do you believe a facility can be operated indefinitely without events?

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Human Error

https://youtu.be/Fw3SwEXc3PU

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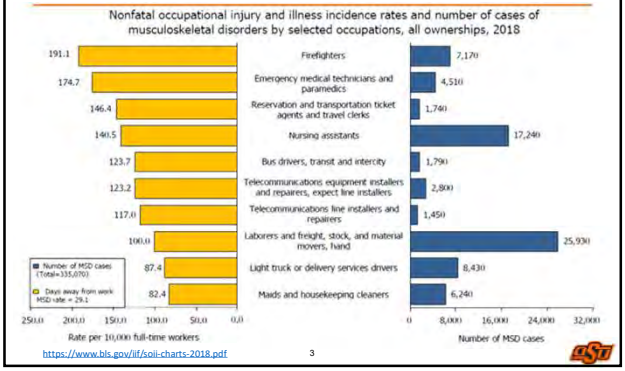
1

Manual Materials Handling (MH)

2

MSD Summary



https://www.bls.gov/iif/soii-charts-2018.pdf

3

3

Types of Musculoskeletal Injuries - MH

- Muscle Overexertion Injuries
- Muscle Overuse Injuries
- Work-Related Musculoskeletal Disorders

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MSD Summary

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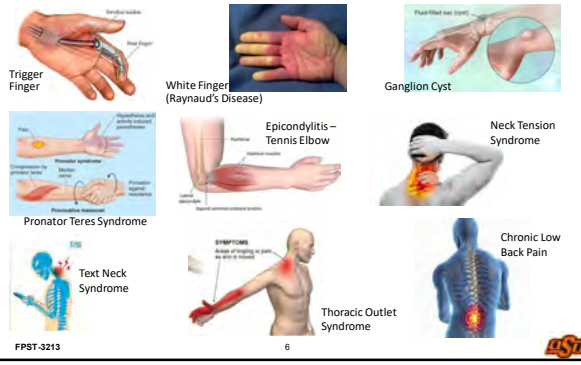
MSD Summary



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Reduce Manual Handling

- Remove non-value-added operations
- Design a system that minimizes the amount of manual handling

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Reduce Manual Handling

- Materials Flow Analysis
  - Unit load
  - Mechanization
  - Standardization
  - Adaptability
  - Dead Weight
  - Gravity
  - Automation

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Education of Handlers

- Guidelines for lifting training
  - Two-person handling
  - One-on-one lifting and force exertion
  - Use of handling assist devices
  - Use of back belts

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Selection

- Select only people capable of lifting
- Disadvantages
  - Limited flexibility
  - Abilities decrease with age

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Redesigning Jobs and Workplaces

- Majority of the workforce
- Manual handling tasks into the safe lifting zone "Ergonomic strike zone"

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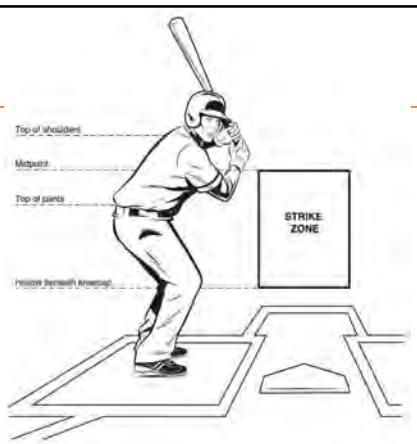

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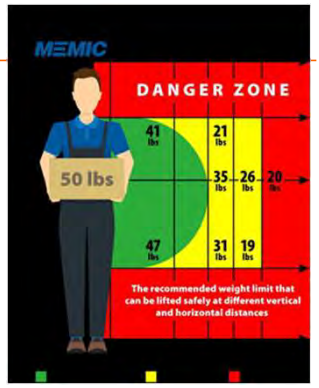
- Lifting injury factors



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"lift with your legs, and not your back"

"keep your back straight"

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Manual Handling 8 basic steps to correct lifting technique

https://www.youtube.com/watch?v=Lq2dJKw6-Uk

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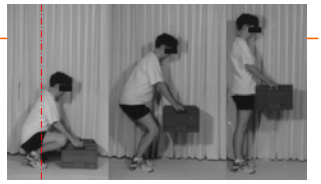
Proper Lifting. Which one is correct?



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Safe Lifting

3:10 – 9:00 https://www.youtube.com/watch?v=901uQgfiuVk

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NIOSH

- Work Practices Guide for Manual Lifting-Determining Acceptable Weights of Lift

The National Institute for Occupational Safety and Health (NIOSH)

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Factors That Contribute to Acceptable Weights for Lifting

- Configuration of the load
- Size of the load
- Tray design

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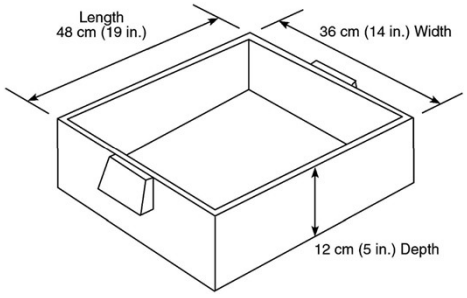
Recommended Maximum Dimensions of a Tray



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Factors That Contribute to Acceptable Weights for Lifting

- Tray design
  - Width determines the horizontal distance of the center of mass of the load from the handler's lumbar spine
  - Length affects which muscle groups take the load when it is handled manually
  - Depth is often determined by the volume of parts, product, or supplies desired in a production process or over a given time period

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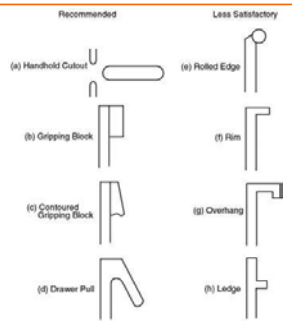
Examples of tray handholds



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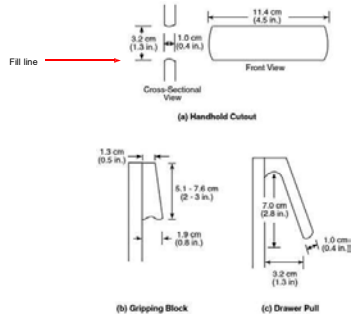
Recommended dimensions for handholds on trays



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Cases

- What if there are no handholds?
- Adding handholds
  - Increase recommended weight by 10%
  - Metabolic work load is 1% less
  - Fatigue in low back and forearms is reduced

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Guidelines for the Design of Occasional Lifts

- The 1994 NIOSH Guidelines for the Design of Manual Lifting Tasks
  - Maximum weight to be handled manually is 51 lb.

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Guidelines for the Design of Frequent Lifting Tasks

- Acceptable weights for workers determined by:
  - Biomechanical stresses
  - Strength requirements
  - Local muscle fatigue
  - Metabolic demands of lifting

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Frequent Lifting

- Possible accumulation of fatigue over time
- Muscle fatigue accumulates quickly at frequencies of 15 per minute

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Example

Loading a tractor trailer, where the handler moves a pallet-load of 40 cases into the trailer, unloads it, moves the pallet out, and gets another full pallet.

- The pallet unloading takes 2 minutes at a lifting rate of 20/min
- 3 minutes of recovery time before the next pallet is ready to unload
- Muscle fatigue?

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Example

- How many lifts per each pallet unloading cycle?
- What is the total time of the pallet unloading cycle?

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Example

- Average rate per minute is 40/5 = 8/min
- 8 per minute < 15 per minute
- No muscle fatigue

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Lifting Risk Factors

- Weight
- Location/site
- Frequency/duration/pace
- Stability
- Coupling
- Workplace geometry
- Environment

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The NIOSH Lifting Equation

- In 1981, NIOSH published the Work Practices Guide for Manual Lifting.
- The equation was then reformed in 1991 and was called the revised NIOSH lifting equation.
  - Added asymmetry and coupling

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The NIOSH Lifting Equation

- Answers the question… "Is this weight too heavy for the task?"

Recommended Weight Limit (RWL)

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The NIOSH Lifting Equation

- Answers the question… "How significant is the risk?"

Lifting Index (LI)

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NIOSH Lifting Equation

RWL = LC x HM x VM x DM x AM x FM x CM

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Load Constant (LC)

- 51 pounds / 23 Kg

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NIOSH Lifting Equation

RWL = 51 x HM x VM x DM x AM x FM x CM

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Task Variables and Multipliers

		US	Metric
Load Constant	LC	51 lb	23 kg
Horizontal Multiplier	HM	10 / *H*	25 / *H*
Vertical Multiplier	VM	1 – (0.0075|*V* – 30|)	1 – (0.003|*V* – 75|)
Distance Multiplier	DM	0.82 + (1.8 / *D*)	0.82 + (4.5 / *D*)
Asymmetric Multiplier	AM	1 – (0.0032*A*)	1 – (0.0032*A*)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 6	From Table 6

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Task Variables

- Weight of object
- H = Horizontal location of the object relative to the body
- V = Vertical location of the object relative to the floor
- D = Distance the object is moved vertically
- A = Asymmetry angle or twisting requirement
- F = Frequency and duration of lifting activity
- C = Coupling or quality of the workers grip on the object

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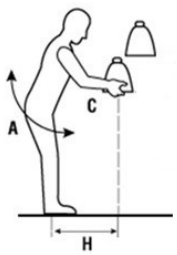
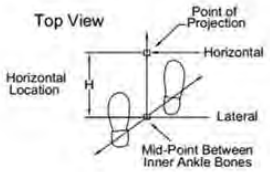
(H) Horizontal Location of the Object





10 in < (H) < 25 in

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Table 1
Horizontal Multiplier

H	HM	H	HM
in		cm	
≤10	1.00	≤25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45
>25	.00	58	.43
		60	.42
		63	.40
		>63	.00

$$HM = {}^{10}/_{H} \text{ inches}$$

$$HM = {}^{25}/_{H} \text{ cm}$$

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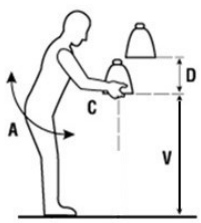
(V) Vertical Location of the Object

- The vertical location is measured from the floor (or standing surface) to the vertical mid-point between the hands as they grasp the object.



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(V) Vertical Location of the Object

- Measure taken at the 3rd MCP joint

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(V) Vertical Location of the Object

- Parallel hands
- Offset hands

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Table 2
Vertical Multiplier

V in	VM	V cm	VM
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

$$VM = \left(1 - (0.0075|V - 30|)\right)$$

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(D) Vertical Travel Distance

Origin - beginning or starting point

- the point at which the weight of the object is loaded onto the hands and moved vertically.

Destination - ending point

- the point at which the weight of the object is unloaded from the hands and stops moving vertically.

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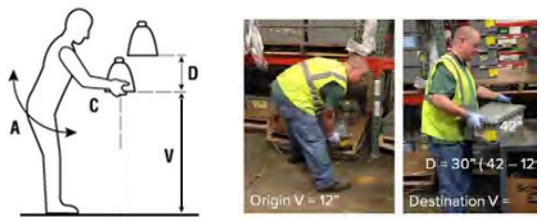
(D) Vertical Travel Distance



10 in < (D) < 70 in

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Table 3
Distance Multiplier

D	DM	D	DM
in		cm	
≤10	1.00	≤25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

$$DM = \left(0.82 + \left(\frac{1.8}{D}\right)\right)$$

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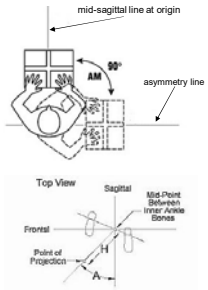
(A) Asymmetric Angle



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(A) Asymmetric Angle

- The best time to measure for (A) is when you are measuring the Horizontal (H) position of the hands by projecting on the floor directly below the hand grasps.
- You will use a goniometer to determine the angle between the asymmetric line and the mid sagittal line, this measurement can easily be done at the floor level
- Assume that workers will not pivot
- If no twisting is <u>required</u>, then A is 0º

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(A) Asymmetric Angle

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Table 4
Asymmetric Multiplier

A	AM
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

$$AM = 1 - (0.0032A)$$

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(F) Frequency

- Frequency is defined by
  - Number of lifts per minute
  - Amount of time engaged in the lifting activity
  - The vertical height of the lift from the floor
- Use the average number of lifts per minute during an average 15 minute sampling period.
  - For example, count the total number of lifts in a typical 15 minute period of time and divide that total number by 15.

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Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F) ‡	Work Duration					
	≤ 1 Hour		>1 but ≤ 2 Hours		>2 but ≤ 8 Hours	
	V < 30†	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V are in inches. ‡For lifting less frequently than once per 5 minutes, set F = .2 lifts/minute.

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Work Duration

- **1 = Short** - lifting 1 hour with recovery time of 1.2 X work time
- **2 = Moderate** - lifting between 1 and 2 hours with recovery time of 0.3 X work time
- **3 = Long** - lifting between 2 and 8 hours with standard industrial rest allowances for lunch and rest breaks.

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- If the recovery time requirement is not met, and another lifting session is immediately required, then the total work time must be added together. If the total work time exceeds 1 hour, then the job must be classified as a moderate-duration lifting task.
- If a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes (120 minx .3 = 36 min) would be required before initiating a subsequent lifting session.
- If the recovery time requirement is not met, and another lifting session is subsequently required, then the total work time must be added together. If the total work time exceeds 2 hours, then the job must be classified as a long-duration lifting task.

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Example

A worker performs lifting task continuously for 25 minutes, then performs light work tasks for 15 minutes, and then lifts for an additional 45-minute period.

1. In this case, the recovery time between lifting sessions (15 minutes) is less than 1.2 times the initial 25-minute work time (25 minx 1.2 = 30 min).
2. Therefore, the two work times (25 minutes and 45 minutes) must be added together to determine the duration.
3. Since the total work time (70 minutes) exceeds 1 hour, the job is classified as moderate-duration.

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In class exercise

A worker performs lifting tasks continuously 90 minutes, then performs light work for 15 minutes, and then subsequently performs the lifting tasks for another 90 minutes.

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Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F) ‡	Work Duration					
	≤1 Hour		>1 but ≤2 Hours		>2 but ≤8 Hours	
	V < 30†	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V are in inches. ‡For lifting less frequently than once per 5 minutes, set F = .2 lifts/minute.

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(C) Coupling

- Hand to object coupling can affect the max force a worker must exert during the lift
- Good coupling = low grasp forces
- Poor coupling = high grasp forces.

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Good Coupling

Optimal Container Design

≤ 16 inches (40 cm) frontal length

≤ 12 inches (30 cm) height a smooth non-slip surface

Optimal Handle Design

- 0.75 - 1.5 inches (1.9 to 3.8 cm) diameter
- greater than or equal to 4.5 inches (11.5 cm) length
- 2 inches (5 cm) clearance
- cylindrical shape
- smooth, non-slip surface

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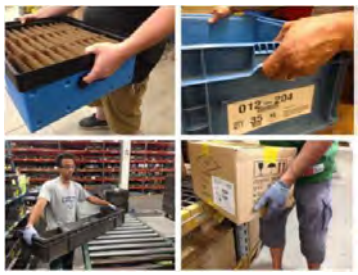
Fair Coupling



- Handles or hand-hold cut-outs of less than optimal design
- No handles, or cut outs or irregular object where the hand can be flexed about 90 degrees

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Poor Coupling

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Coupling Modifier

Table 6 Coupling Multiplier

Coupling Type	Coupling Multiplier (CM)	
	V< 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

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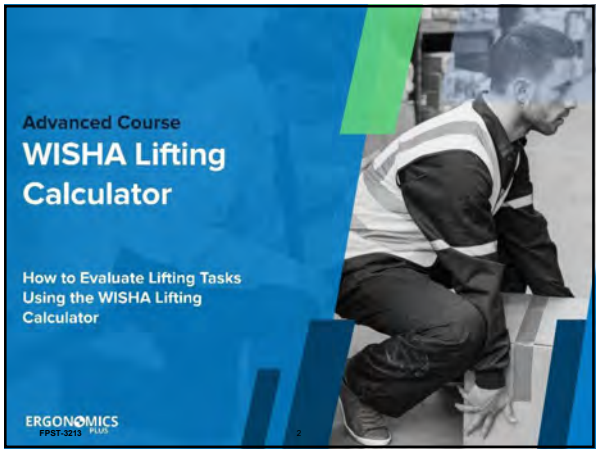

WISHA

- Weight Limit
  - Answers, "Is this weight too heavy for the task?"
- Lifting Index
  - Answers, "How significant is the risk?"

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1.1 WISHA Lifting Calculator Outputs

- Lifting Index
  - Answers, "How significant is the risk?"
  - lifting Index= Weight of Object/Weight Limit
  - 1.0 - 1.5 = Potential Risk
  - > 1.5 Significant Risk
  - The goal is to design a job task with a lifting Index of < 1.0

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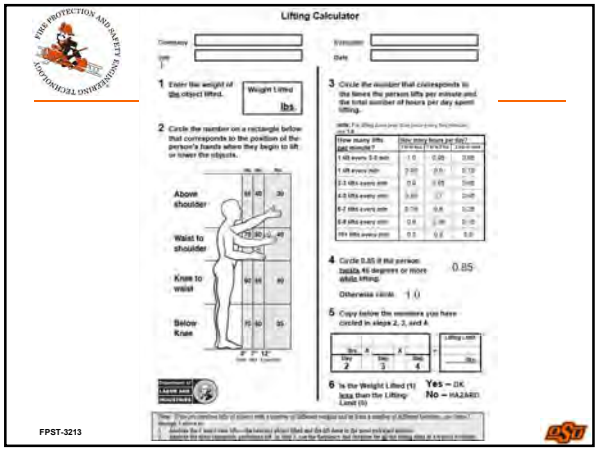

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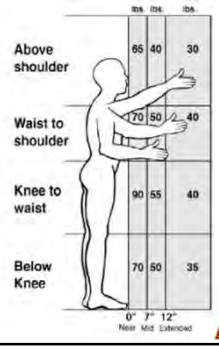
3.2 Determine Unadjusted Weight Limit

Unadjusted Weight Limit

1. Horizontal Location
2. Vertical Location



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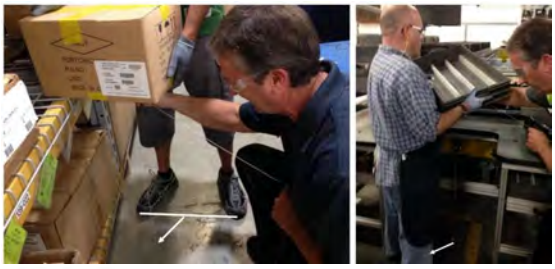
3.3 Horizontal Location



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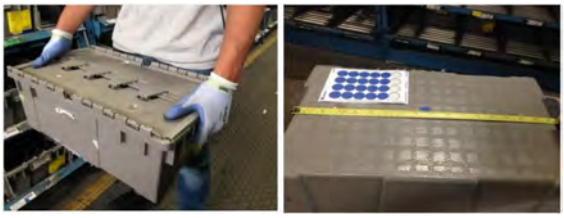
3.3 Horizontal Location

Mid-point of hands grasping the object (load center):



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3.3 Horizontal Location

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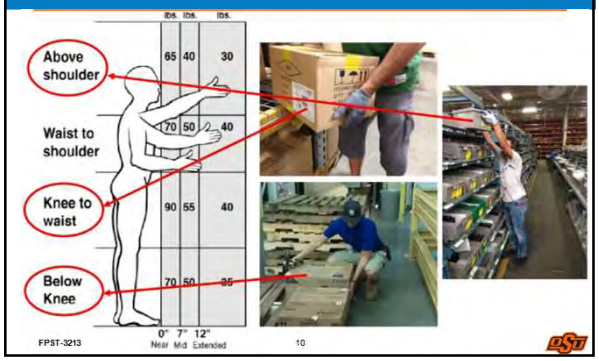
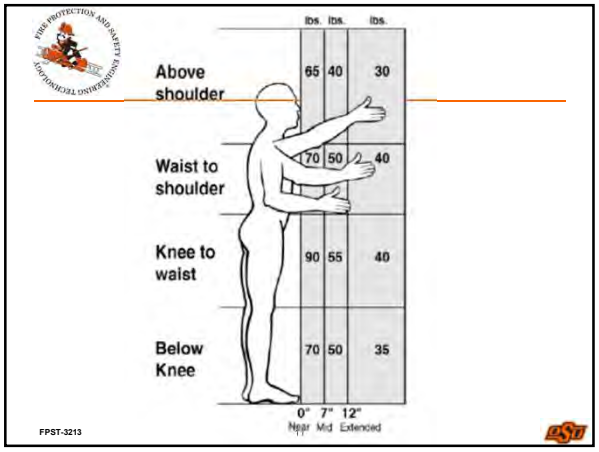
3.4 Vertical Location





3.6 Limit Reduction Modifier

Lifts / Minute	Hours / Day		
	1 hr or less	1 to 2 hrs	2 hrs or more
1 lift every 2-5 mins	1	0.95	0.85
1 lift every min	0.95	0.9	0.75
2-3 lifts every min	0.9	0.85	0.65
4-5 lifts every min	0.85	0.7	0.45
6-7 lifts every min	0.75	0.5	0.25
8-9 lifts every min	0.6	0.35	0.15
10+ lifts every min	0.3	0.2	0

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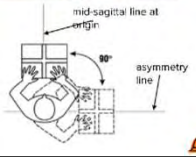
3.7 Twisting Adjustment

Twisting - Measure the degree to which the body is required to twist or turn during the lifting task. The asymmetric angle is the amount (in degrees) of trunk and shoulder rotation required by the lifting task



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Example 1 Warehouse Picking

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Example 1 Warehouse Picking

- Determine & Record Task measurements:
  - The Horizontal Location (H) of the hands is 12.5" at the origin.
  - The Vertical Location (V) of the hands is 12-30"at the origin, but we will use the lowest level to assess the worst case.
  - Vertical Location (V) is 42" at the destination, therefore the Travel Distance (D) is 30".
  - The Asymmetric Angle (A) is 50 degrees at the origin.
  - The container is of optimal design with handholds; therefore coupling is defined as "good".
  - Average frequency of lifting in this manner is 1 lift every 2 minutes (.5 lifts per minute) over a duration of an 8-hour period.

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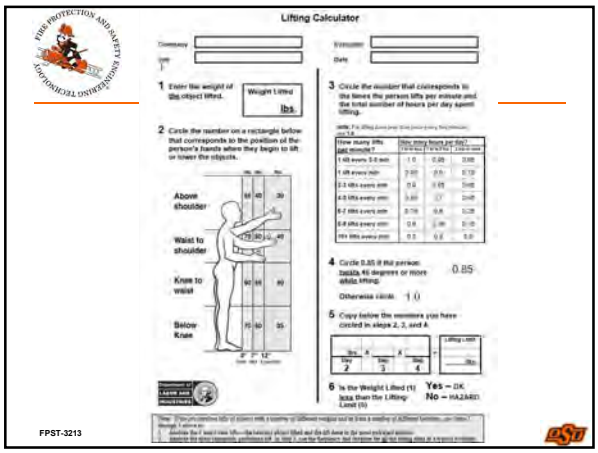

WISHA

"Is this weight too heavy for the task?"

"How significant is the risk?"

What can we do?

WISHA vs. NIOSH

WISHA Task variables

- Weight of Object
- H=Horizontal Location (Horizontal Hand Position)
- V=Vertical Location (Vertical Hand Position)
- A = Asymmetry angle or twisting requirement
- F= Frequency and duration of Lifting

NIOSH Task Variables

- Weight of Object
- H = Horizontal location of the object relative to the body
- V = Vertical location of the object relative to the floor
- A = Asymmetry angle or twisting requirement
- F = Frequency and duration of lifting activity
- D = Distance the object is moved vertically
- C = Coupling or quality of the workers grip on the object

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WISHA vs. NIOSH

- The results of 2015 study highlighted a fair correlation between these two assessment methods
- The WISHA index is a simpler and easier method, but the assessment model of NIOSH equation is more comprehensive and probably produces more reliable and valid results

Naeimeh Asadi, Alireza Choobineh, Sareh Keshavarzi, Hadi Daneshmandi (2015). A Comparative Assessment of Manual Load Lifting Using NIOSH Equation and WISHA Index Methods in Industrial Workers of Shiraz City. J Health Sci Surveillance Sys January 2015; Vol 3; No 1

Conclusion

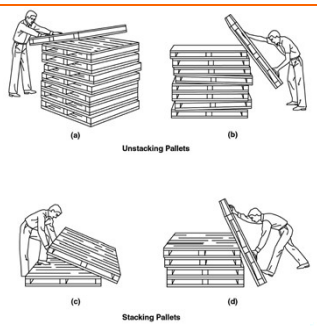
- The greater the LI, the smaller the fraction of workers capable of safely sustaining the level of activity. Thus, two or more job designs could be compared.
- The LI can also help prioritize ergonomic redesign. The equation does have limitations, however. It only addresses two-handed lifts, for instance.

Conclusion

- Material handling tasks should be designed to minimize the weight, range of motion and frequency of the activity, and using the equation allows you to get closer to optimal from the beginning

Special Considerations

Manual handling of pallets



Drum Handling

Drum dolly

https://www.youtube.com/watch?v=_0BBViyDbDk

Drum Handling

Drum dolly

https://www.youtube.com/watch?v=2jYBOUzOIyc

Drum Handling

Overhead hoist

https://www.youtube.com/watch?v=6VF-leJ8dCg

Drum Handling

Overhead hoist

https://www.youtube.com/watch?v=hTFUh9P1nlU

Drum Handling

Forklift drum grabber

https://www.youtube.com/watch?v=uNKVdoAyOWg

Pail and Drum Pouring

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Bag Handling

https://www.youtube.com/watch?v=ZOTE5zU_uzY

1:15-2:35

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Large-Size Sheet or Wallboard Handling

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Large-Size Sheet or Wallboard Handling

Custom Lifting Devices and Custom Lifting Tools

https://www.youtube.com/watch?v=fyK2Mw_ho10

NIOSH Lifting Equation

Practice Problems

Step 1. Gather Tools

- Data Collection Sheet, Pen, Clipboard
- Camera (video or photo)
- Tape Measure
- 70” string with 2 small washers
- Goniometer
- Scale
- PPE

Example 1 Warehouse Picking

Example 1 Warehouse Picking

- Determine & Record Task measurements:
  - The Horizontal Location (H) of the hands is 12.5" at the origin.
  - The Vertical Location (V) of the hands is 12-30"at the origin, but we will use the lowest level to assess the worst case.
  - Vertical Location (V) is 42" at the destination, therefore the Travel Distance (D) is 30".
  - The Asymmetric Angle (A) is 30 degrees at the origin.
  - The container is of optimal design with handholds; therefore coupling is defined as "good".
  - Average frequency of lifting in this manner is 1 lift every 2 minutes (.5 lifts per minute) over a duration of an 8-hour period.

Example 1 Warehouse Picking

- Determine & Record Task measurements:
  - H = 12.5" at the origin
  - V = 12" at the origin and 42" at the destination D=30"
  - A = 30° at the origin
  - C = good - container is of optimal design with handhold cutouts)
  - F = .5 lifts/minute (1 lift every 2 minutes)
  - L = 28 lb. average load and 28 lb. maximum load
  - Dur= Long (lifting between 2 and 8 hours with standard industrial rest allowances for lunch and rest breaks)

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Step 2. Determine Task Variables

RWL = *LC*(51) x *HM* x *VM* x *DM* x *AM* x *FM* x *CM*

H	V	D	A	F	C

HM	VM	DM	AM	FM	CM

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NIOSH Lifting Equation

"Is this weight too heavy for the task?"

"How significant is the risk?"

What can we do?

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Significant Control

- Significant control is a condition of the task that requires precision placement of the load at the destination of the lift.
- For example, when an object is fragile and careful placement is needed to protect the object from damage.
- Or, the worker needs to change grip or hold or guide the object at the lifting or lowering destination

Example 1 Machine Fixture Lifting

- The machine operator is required to lift a heavy tool fixture during the set-up process.
- Significant control of the object is required at the destination, so task variables will need to be determined at both the origin and destination.

Example 1 Machine Fixture Lifting

- Significant Control Lift"? - yes
- H = 10" at the origin, 19" at destination
- V = 38" at the origin and 50" at the destination D = 12"
- A= 0° at the origin and destination
- C = 3 (poor -an irregular object that requires a pinch grip and is hard to handle) F =<.2 lifts/minute (1 lift every 2 minutes)
- L = 26.5 lb. average load and 26.5 lb. maximum load
- Dur= Short (Frequency (F) is < 0.2 and duration is less than 1 hour)

Step 2. Determine Task Variables

RWL = *LC*(51) x *HM* x *VM* x *DM* x *AM* x *FM* x *CM*

	Load	H	V	D	A	F	C
origin							
destination							

		HM	VM	DM	AM	FM	CM
origin							
destination							

NIOSH Lifting Equation

"Is this weight too heavy for the task?"

"How significant is the risk?"

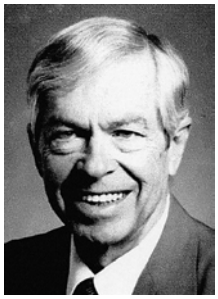
What can we do?

1

Snook Tables

2

Dr. Stover Snook



Dr. Snook earned a B.A. degree from Hartwick College, an M.A. from Fordham University, and a Ph.D. from Tufts University.

He is a Certified Professional Ergonomist (CPE), a Fellow of the Human Factors and Ergonomics Society, and a Fellow of the Ergonomics Society (UK).

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3

Career

- 1954 - Drafted into the Army in after graduating from college
- 1956 - Dunlap and Associates in Stamford, CT
  - Participated in the human factors design and evaluation of military missile systems, command and control systems, weather observing and forecasting systems, and aircraft cockpit design
- 1962 - joined the Liberty Mutual Research Center in Hopkinton, MA
  - Conducted occupational health research on low back pain, manual materials handling, cumulative trauma disorders, heat stress, fatigue, machine guarding, stairway design, and personal protective equipment.
- 1997 - retired as Assistant Vice President and Director of the Ergonomics Laboratories

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4

Career

- From 1974 to 2004, he was a Lecturer on Ergonomics at the Harvard School of Public Health, and a Visiting Scientist from 2004 to 2009.
- Pioneering Work:
  - The design of manual handling tasks (1991): revised tables of maximum acceptable weights and forces (2007)

    Stover H. Snook & Vincent M. Ciriello

    Ergonomics Journal

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Snook Tables

- The Liberty Mutual MMH Tables, commonly known as “Snook Tables”.
- Maximum acceptable weights and forces.

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Output

- "Is this weight or force too heavy or forceful for this task?"
- "How significant is the risk?"

7

- When a mixture of males and females are doing the task, the task should be designed so that it is acceptable to at least 75 per cent of the female population, which would make it acceptable to more than 90 percent of the male population.
- Any task that cannot be performed by at least 75 percent of the total population should be considered for MSD prevention controls and redesign.

8

Snook Tables

Above Shoulder
(above 54 in)

Frequency		Horizontal Distance (Front of Body to Hands) [in] 7 Distance of Lift [in] 10	20	30	10 Distance of Lift [in] 10	20	30	15 Distance of Lift [in] 10	20	30
1 / 8 h	1 / 8 h	35	31	29	29	26	24	26	24	22
1 / 30 min	2 / 1 h	31	26	24	24	22	20	22	20	18
1 / 5 min	12 / 1 h	26	24	22	22	20	18	20	20	18
1 / 2 min	30 / 1 h	26	24	22	22	20	18	20	20	18
1 / 1 min	1 / 1 min	26	24	20	20	20	18	20	18	15
1 / 14 s	4.3 / 1 min	20	20	18	18	18	13	18	18	13
1 / 9 s	6.7 / 1 min	18	18	15	15	15	13	15	15	13
1 / 5 s	12 / 1 min	18	18	13	13	13	11	13	13	11

Design goal = **18 pounds**

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9

- Select the tasks to be evaluated based on the most difficult and demanding lifting, lowering, carrying, pushing, or pulling tasks.
- When the task specific data does not match the values in the table, select the next highest table value that is closest to the actual task requirements.

10

Snook Tables

Floor to Knuckle
(below 29 in)

Frequency		Horizontal Distance (Front of Body to Hands) [in] 7 Distance of Lift [in] 10	20	30	10 Distance of Lift [in] 10	20	30	15 Distance of Lift [in] 10	20	30
1 / 8 h	1 / 8 h	51	48	42	42	40	35	40	37	31
1 / 30 min	2 / 1 h	37	35	31	31	31	26	29	29	24
1 / 5 min	12 / 1 h	33	33	29	29	26	22	26	24	22
1 / 2 min	30 / 1 h	33	33	29	26	26	22	26	24	22
1 / 1 min	1 / 1 min	31	31	26	26	24	22	24	22	20
1 / 14 s	4.3 / 1 min	29	26	24	24	20	20	24	20	20
1 / 9 s	6.7 / 1 min	26	24	22	22	20	18	22	20	18
1 / 5 s	12 / 1 min	22	20	18	18	15	15	18	15	15

Design goal = **22 pounds**

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Carrying at about waist height
(elbows bent)

Frequency		Distance of Carry [ft] 7	14	27
1 / 8 h	1 / 8 h	46	46	42
1 / 30 min	2 / 1 h	35	35	31
1 / 5 min	12 / 1 h	35	35	31
1 / 2 min	30 / 1 h	33	33	31
1 / 1 min	1 / 1 min	33	33	31
1 / 20 s	3 / 1 min	31	26	26
1 / 10 s	6 / 1 min	29	24	OR

Design goal = **31 pounds**

12

Snook Tables

Middle Pull Point (hands about 36 in)

Frequency		Pull Distance (ft) 7 Initial	7 Sustained	24 Initial	24 Sustained	48 Initial	48 Sustained	67 Initial	67 Sustained	145 Initial	145 Sustained	194 Initial	194 Sustained
1 / 8 h	1 / 8 h	59	42	55	37	46	31	46	26	46	26	42	20
1 / 30 min	2 / 1 h	57	35	51	31	44	26	[illegible]	[illegible]	42	20	37	15
1 / 5 min	12 / 1 h	55	33	48	26	42	24	40	20	40	20	35	15
1 / 2 min	30 / 1 h	49	26	44	26	37	22	[illegible]	[illegible]	35	18	33	13
1 / 1 min	1 / 1 min	46	26	42	24	37	22	33	18	31	15	OR	OR
1 / 30 s	2 / 1 min	46	26	42	24	31	18	OR	OR	OR	OR	OR	OR
1 / 15 s	4 / 1 min	44	26	37	20	OR	OR	OR	OR	OR	OR	OR	OR
1 / 12 s	5 / 1 min	42	26	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
1 / 6 s	10 / 1 min	35	18	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR

Design goal = **Initial 40 pounds, Sustained 20 pounds**

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Data Collection

Task variables needed to determine Snook Tables ***Design Goal***:

- Weight of Object
- Force Requirement
- Lift/Lower Distance
- Hand Distance (Horizontal Hand Position)
- Hand Height
- Push/Pull/Carry Distance
- Frequency
- Lifting/Lowering Zone

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Snook Tables Calculator

Snook Tables (Lift/Lower)

Floor to Knuckle (below 29 in.)

1 action/5 minutes (12 actions/hour)

15 inches

20 inches

42

CALCULATE

RESULTS

Risk Index	1.75
Design Goal	24.00 (lbs)
Lift/Lower Point	FloorToKnuckle
Frequency	1 action/5 minutes (12 actions/hour)
Horizontal Distance	15 inches
Distance of Lift	20 inches
Actual Weight	42

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Lifting / Lowering – Variables

- Lift Lower Point (Vertical Location)
  - Above shoulder (above 54")
  - Knuckle to shoulder (29 -54")
  - Floor to knuckle (below 29")
- Frequency
  - 1 action/8 hours
  - 1 action/30 minutes
  - 1 action/5 minutes
  - 1 action/2 minutes
  - 1 action/1 minute
  - 1 action/14 seconds
  - 1 action/9 seconds
  - 1 action/5 seconds
- Horizontal Distance
  - 7"
  - 10"
  - 15"
- Distance of Lift
  - 10"
  - 20"
  - 30"

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Lifting / Lowering – Example 1

Variables determined by the assessment:
- Lift Lower Point – Above Shoulder (above 54")
- Frequency – 1 action every 5 minutes (12 actions per hour)
- Horizontal Distance – 10" (front of body to mid-line of hands)
- Distance of Lift – 30" (lifts from height at 28" to 60" = 32")
- Weight of Object – 32 pounds

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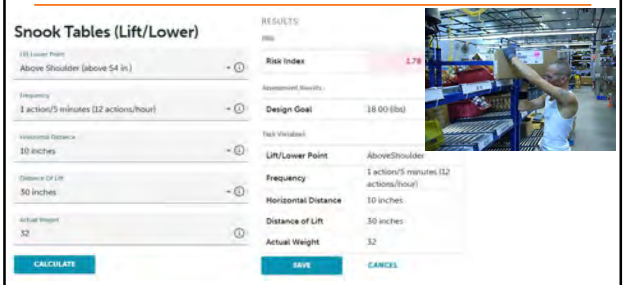
Lifting / Lowering – Example 1



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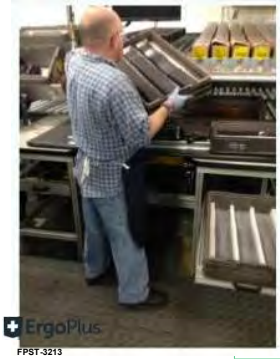
Lifting / Lowering – Example 2



Variables determined by the assessment:
- Lift Lower Point - Knuckle to shoulder (29 -54")
- Frequency – 1 action every 5 minutes (12 actions per hour)
- Horizontal Distance – 15"
- Distance of Lift – 20" (lowers from height of 49.5" to 31" = 18.5"
- Weight of Object – 25 pounds

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Lifting / Lowering – Example 2

Snook Tables (Lift/Lower)

Lift Lower Point: Knuckle to Shoulder (between 29 and 54 in.)

Frequency: 1 action/5 minutes (12 actions/hour)

Horizontal Distance: 15 inches

Distance Of Lift: 20 inches

Actual Weight: 25

CALCULATE

RESULTS

Risk

Risk Index	0.96

Assessment Results

Design Goal	26.00 (lbs)

Task Variables

Lift/Lower Point	KnuckleToShoulder
Frequency	1 action/5 minutes (12 actions/hour)
Horizontal Distance	15 inches
Distance of Lift	20 inches
Actual Weight	25

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Lifting / Lowering – Example 3

Variables determined by the assessment:
- Lift Lower Point – Floor to Knuckle (below 29")
- Frequency – 1 action every 2 minutes (30 actions per hour)
- Horizontal Distance – 10" (front of body to mid-line of hands)
- Distance of Lift – 30" (lifts from height of 4" to 32" = 28")
- Actual Weight – 35 pounds

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Lifting / Lowering – Example 3

Snook Tables (Lift/Lower)

Lift Lower Point: Floor to Knuckle (below 29 in.)
Frequency: 1 action/2 minutes (30 actions/hour)
Horizontal Distance: 10 inches
Distance Of Lift: 30 inches
Actual Weight: 35

CALCULATE

RESULTS

Risk Index: 1.94
Design Goal: 22.00 (lbs)

Lift/Lower Point	FloorToKnuckle
Frequency	1 action/2 minutes (30 actions/hour)
Horizontal Distance	10 inches
Distance of Lift	30 inches
Actual Weight	35

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Lifting / Lowering – Example 4

Variables determined by the assessment:

- Lift Lower Point –Knuckle to Shoulder (29 - 54")
- Frequency – 1 action every 30 minutes (2 actions per hour)
- Horizontal Distance – 7"
- Distance of Lift – 10"
- Weight of Object – 30 pounds

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Lifting / Lowering – Example 4

Snook Tables (Lift/Lower)

Lift Lower Point: Knuckle to Shoulder (between 29 and 54 in.)
Frequency: 1 action/30 minutes (2 actions/hour)
Horizontal Distance: 7 inches
Distance Of Lift: 10 inches
Actual Weight: 30

CALCULATE

RESULTS

Risk Index: 0.80
Design Goal: 35.00 (lbs)

Lift/Lower Point	KnuckleToShoulder
Frequency	1 action/30 minutes (2 actions/hour)
Horizontal Distance	7 inches
Distance of Lift	10 inches
Actual Weight	30

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Carrying – Variables

Carrying is defined as manually grasping an object of definable size and mass with two hands and transporting the object horizontally from one place to another without mechanical assistance

- Frequency
  - 1 action/8 hours
  - 1 action/30 minutes
  - 1 action/5 minutes
  - 1 action/2 minutes
  - 1 action/1 minute
  - 1 action/20 seconds
  - 1 action/10 seconds

Select the most conservative value

- Carry Point (Vertical Location)
  - Waist height (elbows bent)
  - Below Waist Height (elbows straight)

Only two options

- Carry Distance
  - 7'
  - 14'
  - 27'

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Carrying – Example 1

Variables determined by the assessment:
- Carry Point – Waist Height
- Frequency – 1 carry/2 minutes (30 carries per hour)
- Carry Distance – 27' (front of body to mid-line of hands)
- Actual Weight – 52 pounds

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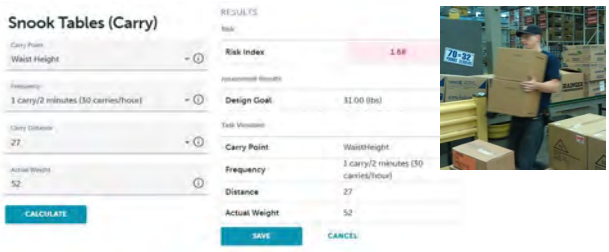
Carrying – Example 1



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Carrying – Example 2

Variables determined by the assessment:
- Carry Point – Waist Height
- Frequency – 1 carry every minute
- Carry Distance – 27'
- Actual Weight – 40 pounds

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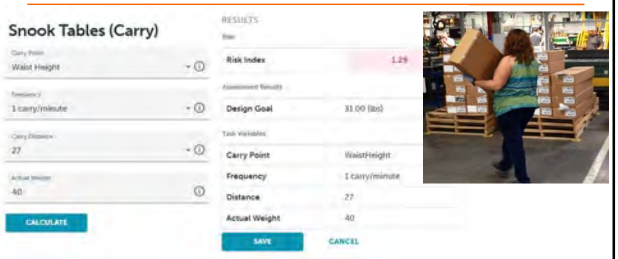
Carrying – Example 2



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Push / Pull – Variables

- Push/Pull Point (Vertical Location)
  - High (hands about 55")
  - Middle (hands about 36")
  - Low (hands about 24")
- Frequency
  - 1 action/8 hours
  - 1 action/30 minutes
  - 1 action/5 minutes
  - 1 action/2 minutes
  - 1 action/1 minute
  - 1 action/30 seconds
  - 1 action/15 seconds
  - 1 action/12 seconds
  - 1 action/6 seconds
- Push/Pull Distance
  - 7'
  - 24'
  - 48'
  - 97'
  - 145'
  - 194'
- Force Measurement
  - Initial Force
  - Sustained Force

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Push / Pull – Measurement

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Push / Pull – Measurement

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Push / Pull – Meter

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33

Push / Pull – Example 1

Variables determined by the assessment:
- Pull Point – Middle
- Frequency – 1 pull per 5 minutes
- Pull Distance – 97'
- Initial Force = 53 lbs.
- Sustained Force = 25 lbs.

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34

Push / Pull – Example 1

Snook Tables (Pull)

Middle (Hands about 36")

1 action/5 minutes (12 actions/hour)

97

53

25

CALCULATE

RESULTS

Risk Index	1.32	1.25
Design Goal	40.00 (lbs)	20.00 (lbs)

Pull Point	Middle (Hands about 36")
Frequency	1 action/5 minutes (12 actions/hour)
Pull Distance	97
Initial Force	53
Sustained Force	25

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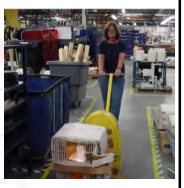

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Push / Pull – Example 2

Variables determined by the assessment:
- Pull Point – Low
- Frequency – 1 pull per 2 minutes
- Pull Distance – 24'
- Initial Force = 75 lbs.
- Sustained Force = 34 lbs.

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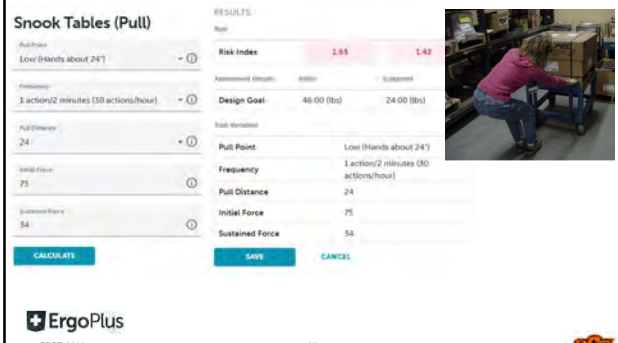
Push / Pull – Example 2



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Push / Pull – Example 3

Variables determined by the assessment:
- Pull Point – Middle
- Frequency – 1 pull per 30 minutes
- Pull Distance –145'
- Initial Force = 35 lbs.
- Sustained Force = 14 lbs.

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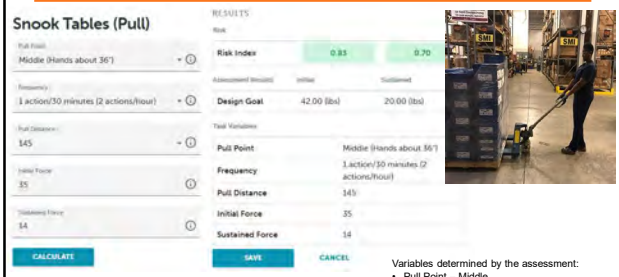
Push / Pull – Example 3



Variables determined by the assessment:
- Pull Point – Middle
- Frequency – 1 pull per 30 minutes
- Pull Distance –145'
- Initial Force = 35 lbs.
- Sustained Force = 14 lbs.

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Liberty Mutual Tables

Liberty Manual Research laboratory 25-year study

- Tests at least 80 hours for each subject
- All factors being under control (weight, distance…)

https://libertymmhtables.libertymutual.com/?action=initTaskSelection

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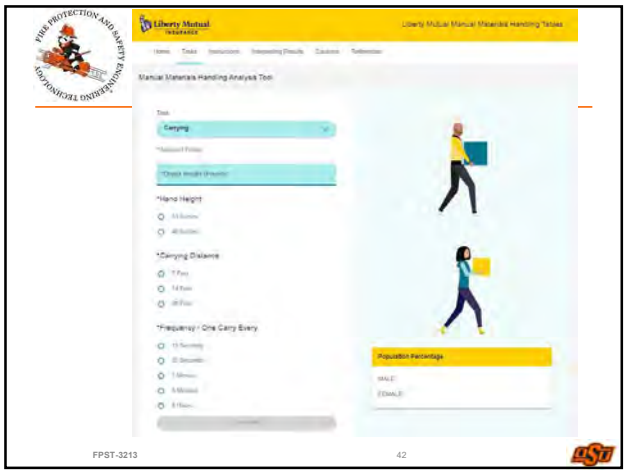

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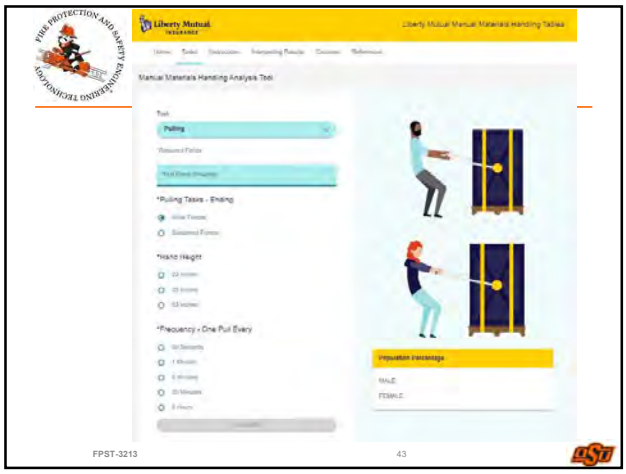

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REBA and RULA

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REBA

- Rapid Entire Body Assessment (REBA)
- Systematic process to evaluate <u>whole body</u> postural MSD risks associated with certain job tasks
- Developed by Dr. Sue Hignett and Dr. Lynn McAtamney
  - Ergonomists from University of Nottingham in England.

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REBA Objectives

- Simple postural analysis
- Divide the body into segments
- Provide a scoring system for muscle activity
- Consider coupling as an important variable

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REBA

- Considers critical tasks of a job
- Single page worksheet
  - Body postures
  - Forceful exertions
  - Type of movement or action
  - Repetition
  - Coupling

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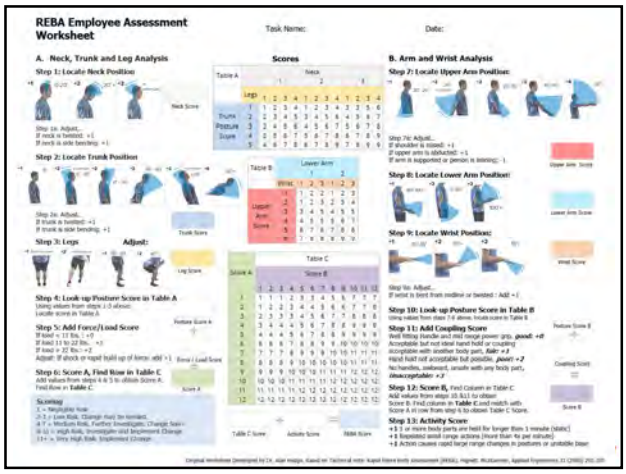

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REBA Output

Level of MSD risk for the work task being evaluated:

Score	Level of MSD Risk
1	negligible risk, no action required
2-3	low risk, change may be needed
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implement change
11+	very high risk, implement change

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REBA Limitations

- One posture at a single point in time
- Evaluator must decide what the worst part of the task is

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Assessment Preparation

Tools needed:

- Clip board and pen
- REBA worksheet or data collection worksheet
- Camera (video & picture)
- Goniometer
- Weight Measurement Gauge - if weight is not known and scale is not available
- REBA Excel calculator
- Personal Protective Equipment (PPE).

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Task Selection

Selection of the posture to be evaluated should be based on:

- The most difficult postures and demanding work tasks (based on worker interview and initial observation).
- The posture sustained for the longest period of time.
- The posture where the highest force loads occur.

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Determine & Record Task Variables

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Neck Position

FPST-3213 54 Source: Ergo-Plus.com

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Trunk Position
A
+1
B
+2 add +1 = +3
C
+2
0-20°
D
20-60°
+3
E
>60°
+4
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Source: Ergo-Plus.com

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Leg Position
Leg position adjustment:
Add +1 - if knees 30-60° flexed
Add +2 - if knees > 60° flexed
A
+1
B
+1
+2
D
+2
E
+1 add +1 = +2
30-60°
F
+2 add +2 = +4
>60°
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Source: Ergo-Plus.com

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Load / Force Score
A
< 11 lbs. = +0
B
< 11 lbs. = +0
If load < 11lbs. = +O
If load 11 to 22 lbs. = +1
If l o a d > 2 2 lbs.= + 2
C
11 – 22 lbs. = +1
D
> 22 lbs. = +2
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Source: Ergo-Plus.com

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Load / Force Score

If shock, rapid build up, or sudden exertion is required by the job task being evaluated:
Add +1

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Load / Force Score

Upper Arm adjustment:
If shoulders is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

FPST-3213 59 Source: Ergo-Plus.com

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Upper Arm Position

FPST-3213 60 Source: Ergo-Plus.com

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Lower Arm Position

FPST-3213 61 Source: Ergo-Plus.com

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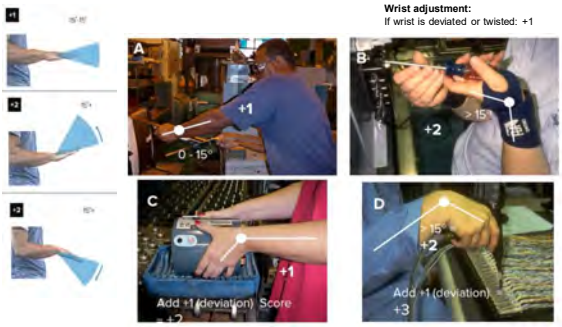
Wrist Position

Wrist adjustment:
If wrist is deviated or twisted: +1



FPST-3213 62 Source: Ergo-Plus.com

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Coupling

Add Coupling Score

Good - well fitting handle and mid-range power grip. Score= +O

Fair - Acceptable but not ideal hand hold or coupling acceptable with another body part. Score= +1

Poor - Hand hold not acceptable but possible. Score= +2

Unacceptable – Score= +3

FPST-3213 63 Source: Ergo-Plus.com

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Activity Score

+1 - One or more body parts are held for longer than 1 minute (static)

+1 - Repeated small range actions (more than 4x per minute)

+1 - Action causes rapid large range changes in postures or unstable base

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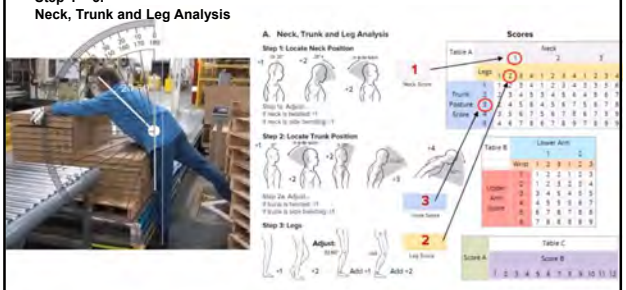
Example

Step 1 – 3:
Neck, Trunk and Leg Analysis



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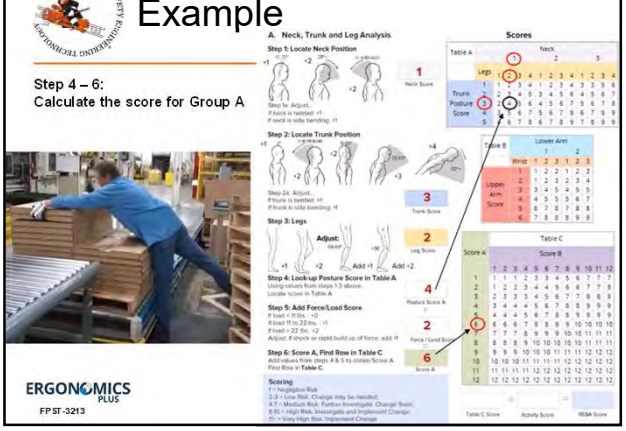
Example

Step 4 – 6:
Calculate the score for Group A



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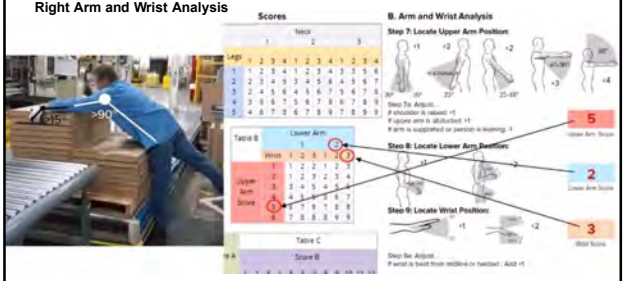
Example

Step 7 – 9:
Right Arm and Wrist Analysis



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Example

Steps 10-13:
Calculate Section B and REBA Score

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Example

RESULTS

= REBA Score

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Score	Level of MSD Risk
1	negligible risk, no action required
2-3	low risk, change may be needed
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implement change
11+	very high risk, implement change

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RULA

- Rapid Upper Limb Assessment
  - 1993 – UK
- Considers biomechanical and postural load requirements of job tasks/demands on the neck, trunk and upper extremities

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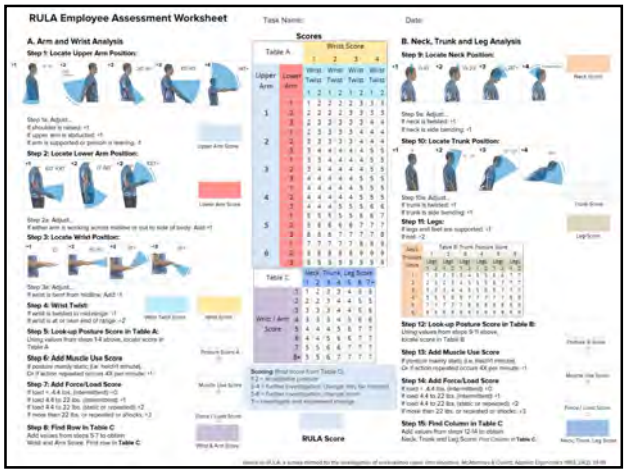

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RULA Output

Level of MSD risk for the work task being evaluated:

Score	Level of MSD Risk
1-2	negligible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

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Which Assessment do I use?

- Qualitative
  - RULA
  - REBA
  - Snook
- Quantitative
  - NIOSH
  - WISHA

- "How significant is the risk?"
- "Is this weight or force too heavy or forceful for this task?"

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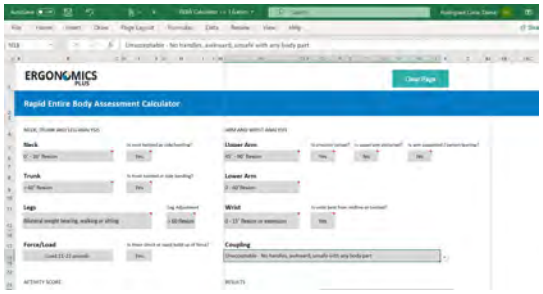

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Example 1

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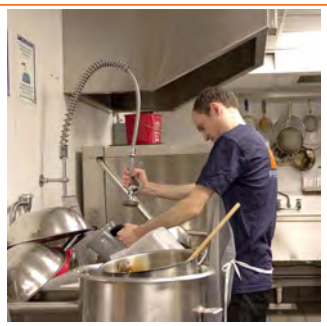
Example 2



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Conclusion

- Material handling tasks should be designed to minimize the weight, range of motion and frequency of the activity, and using the equation allows you to get closer to optimal from the beginning

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