Acknowledgements

I wish thank the hundreds of students I have had the pleasure to teach over the last two decades as you inspired me to develop resources to enhance your learning experience.

This manual was created with significant input from my graduate students, Fatina Gammoh, Susan Gaines, Larry Lowe, my research assistant Ms. Deborah LaClair and Professional Ergonomist, Ms. Johnine Mowatt. Thank you all for the support and the inspiration you give as it continues to fuel my love for research, teaching and working in the critically important field Ergonomics.
Objective

This manual was created to provide a hands-on resources to support teaching and learning goals for an ergonomics course. I have provided exercises that have been used for several years and they have been designed to be performed individually or in a group. Additionally, select exercises may also be performed by students working remotely or taking the course via distance learning technology.
Lab Report Guidelines

Goal:
The goal of the laboratory assignments is provide an environment to enhance the learning experience by teaching through the use of ergonomic tools, equipment and analysis tools. The students will work in teams in the lab to gain experience in ergonomic team dynamics, data collection, analysis, interpretation and presentation. The labs are designed to prepare the students to use ergonomic equipment in both research and application environments.

Ergonomic Labs:
- Labs will be conducted in class during regularly scheduled attendance according to the syllabus or at alternative times that are compatible with lab team member schedules.
- Remote students will be given a similar assignment that can be done by one person; Remote students are always welcome to join the class in person for the labs.
- Labs may be done in groups of 2 to 4 depending on class size.
- One lab report is submitted per group and a single grade is given to all names on the lab report.
- Lab reports will be due the following class, unless otherwise stated.
- Although you will be answering specific questions in the lab, format the responses in a report when feasible.
- At the end of the semester each member of the lab team is required to submit a peer evaluation form for the other lab members participation

Lab Reports

All lab reports are to be submitted as formal written reports by the lab group. Your lab should have as a minimum the following headings:
- Cover Page
- Introduction
- Purpose of Lab
- Methodology for lab
  - Subject information
  - Equipment utilized
  - Laboratory environment
  - Process of data collection
- Analysis
- Results
- Discussion/Conclusions
- *How these lab results pertains to society, your work, your life etc…, or how this information may be useful.*
- References, if any
Lab Report Grade Sheet

Lab Group Members:________________________________________________

Lab title:___________________________________________________________

(10 points) Introduction/Overview of Lab _________________

(10 points) Discussion of Methodology _________________
(i.e. equipment, subjects, processes)

(30 points) Effective use of tools and techniques _________________
(Ergonomic Approach and analysis)

(10 points) Presentation of Results _________________

(25 points) Interpretation/Discussion of Results _________________

(5 points) Application of knowledge _________________

(10 points) Conclusion and Significance of Lab _________________
(implications, where results can be useful, etc.)

Comments: __________________________________________________________________

(Attach a Copy of this Form to all Lab Report Submissions)
Laboratory Assignments

I. Classroom Labs

1. Equipment Evaluation Lab
2. Human Senses Lab
3. Anthropometric Lab
4. MMH & Lifting Lab
5. Information Processing Lab
6. Cumulative Trauma Disorder (Work related musculoskeletal disorder) Lab
7. Work Place Evaluation Lab
8. Human Senses & Human Systems
9. Anthropometric & Segment Weight Lab
10. Lifting Lab
11. Locations of Centers of Gravity on Human Segments
12. Biomechanical Modeling Lab
13. Two-Joint Angle Influence on Adjacent Joint Mobility
14. Seated Work Assessment Lab
15. Warning Label Lab
16. Muscle Contraction Lab
II. Ergonomic Application Labs – Prepared by Ms. Johnine Mowatt, M.S.

1. Anthropometry
2. Manual Material Handling (MMH)
3. Ergonomics by Design
4. Design an Operator Job
5. Manufacturing Key Measures (Cost Justification)
6. Rotation
7. Cumulative Trauma Disorders
8. Administrative and Engineering Controls

III. Additional Hand Outs
I. Classroom Labs
1. **Equipment Evaluation Lab**

**On-site students:**

As a lab group, identify a piece of equipment to study in the ergonomics laboratory.

Make sure you do not use a piece of equipment that another team is evaluating.

For the piece of equipment that your team selects do the following:

1) Review any manual or material that describes the tool

2) Practice using the tool

3) Identify applications or research environments where this piece of equipment or software would be useful in an ergonomic setting

4) Go to the internet and identify an application where this tool or a similar tool was used in a research or application environment.

5) Prepare a presentation to teach the class how to use the equipment
   a. PowerPoint presentation should be approximately 5 minutes long
   b. Summarize how to use this equipment in a 1-2 page summary.
   c. Email both documents to Instructor so that it can be placed on the course site for classmates.

6) Be prepared to present this information in class in two weeks and demonstrate how the equipment is used.
Remote or Off-site students:

Identify a piece of ergonomic equipment in your office, on the internet or that you may have previously used. You may use a piece of equipment or software that is not fully available to you. Write a 1-2 page overview of this piece of ergonomic equipment and include the following:

1) Identify applications or research environments where this piece of equipment or software would be useful in an ergonomic setting

2) Go to the internet and identify at least two applications where this tool or a similar tool was used in a research or application environment.

3) Provide costs associated with the purchase of the equipment or software

4) Include all references and sources
2. Human Senses & Human Systems Lab

This lab is designed to teach about the descriptions, functions and operation of the following human senses and human systems:

- Visual Sense
- Auditory Sense
- Cardiovascular System
- Skeletal System

1. Methodology

This lab consists of a series of questions having to do with describing the various senses and systems of the human body. The method of research involves using the internet and the class textbook as research tools for general information.

Part A – Visual Sense: Describe the operations of the eye from the time that an object is perceived by the eye until the image is received in the brain.

a) Describe the various elements of the eye
Figure 1 is a pictorial showing the major elements of the eye.

![Figure 1. Human Eye](image)

Source: Encyclopedia Britannica, Inc.

b) Describe the process that the eye is going through to perform the receipt of the image

1) Light coming into the eye first interacts with the cornea. The cornea is the clear, transparent outer portion on the front of the eye and is responsible for 2/3 of the focusing power of the eye.

2) The light now passes through the iris. The iris is the colored part of the eye and regulates the amount of light that passes through the eye. It does this by moving the dilator and sphincter muscles of the pupil.
3) The light now passes through the lens. The lens focuses the light on the back of the eye. For distant objects, the lens is kept thin and flat by the eye muscles, while for closer objects the lens is thicker and rounder.

   After passing through the lens, the light passes through a vitreous body of fluid, which is the consistency of a gel, having the refractory properties, similar to water.

4) The light now shines upon the retina. The retina consists of light sensitive nerve tissue that converts images into electrical impulses. The retina has two different types of light sensors.

   A) Approximately 120 million rods respond to low-intensity light for black and white vision.

   B) Approximately 20 million cones respond to colored light. Pigments in the cones respond to the wavelength of the light, differently for blue, green or red.

   A corresponding electrical signal is produced which is then sent to the brain by way of the optic nerve.

   Because the optic nerve is offset approximately 15° from the center, and there are no light sensors, this creates a blind spot in the eye. The blind spots of both eyes do not overlap, so you are not aware of the blind spots, as they do not appear in your field of vision.
Part B – Auditory Sense: Describe the operation of the ear.

a) Describe the various elements of the ear by three segments
Figure 3 is a pictorial showing the major elements of the ear.

b) Describe the process of receiving sound

1) The *outer ear* consists of the **pinna** and **outer ear canal**. The pinna funnels sound into the outer ear canal, which sends the sound to the eardrum.

2) The *middle ear* consists of the **eardrum, hammer, anvil and stirrup**. The middle ear amplifies the sound. The eardrum area is 25x larger than the surface going into the inner ear and the ear bones (including the hammer, anvil and stirrup) mechanically increase the intensity of the sound. Both of these together increase the effective sound pressure by $22x^2$.

3) The vibration from the *middle ear* is transferred to the **cochlea** (snail shaped). The cochlea is lined with **sensitive hair**, which generates nerve signals to the brain via the auditory nerve.
Part C – Cardiovascular System:

a) Describe the cardiovascular process

Figure 3 shows the chambers and valves of the heart

![Heart Diagram]

Source: www.HowStuffWorks.com

1) Each chamber (right atrium, left atrium, right ventricle, left ventricle) contains a one-way valve (tricuspid valve, pulmonary valve, mitral valve, aortic valve) at the exit of the chamber to prevent blood from flowing back into the chamber.

The heart muscle contracts (beating of the heart) and pumps blood from the heart to the body. Each contraction happens in two stages. In the first stage both the right and left atria contract simultaneously, pumping the blood into the right and left ventricles. Then simultaneously, the ventricles contract, pumping the blood out of the heart. Between contractions, the heart relaxes allowing blood to fill the heart again.

1) The heart has separate functions on its left and right sides. The right side of the heart is responsible to pump blood from the body, which is lacking in oxygen and
pump it to the lungs where carbon dioxide is released and the blood becomes oxygenated.

2) The left side of the heart pumps the oxygenated blood from the lungs to the rest of the body where the body absorbs the oxygen and allows the blood to collect carbon dioxide.

The increase in heart rate will then send more blood to the lungs (respiratory system), which then causes the body to breath heavier in response to the demand for more oxygen.

**major risk factors that can't be changed?**

1) Increasing age
2) Male sex (gender)
3) Heredity (including Race)

**major risk factors you can modify, treat or control by changing your lifestyle or taking medicine?**

1) Tobacco smoke.
2) High blood cholesterol
3) High blood pressure
4) Physical inactivity
5) Obesity and overweight
What other factors contribute to heart disease risk?

1) Stress

2) Drinking too much alcohol

a) Part D – Skeletal System:

Figure 7 is a pictorial showing the spinal column, the types of vertebrae.

<table>
<thead>
<tr>
<th>Term</th>
<th># of Vertebrae</th>
<th>Body Area</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>7</td>
<td>Neck</td>
<td>C1 – C7</td>
</tr>
<tr>
<td>Thoracic</td>
<td>12</td>
<td>Chest</td>
<td>T1 – T12</td>
</tr>
<tr>
<td>Lumbar</td>
<td>5 or 6</td>
<td>Low Back</td>
<td>L1 – L5</td>
</tr>
<tr>
<td>Sacrum</td>
<td>5 (fused)</td>
<td>Pelvis</td>
<td>S1 – S5</td>
</tr>
<tr>
<td>Coccyx</td>
<td>3</td>
<td>Tailbone</td>
<td>None</td>
</tr>
</tbody>
</table>

Figure 4
**The spine provides mobility and strength.**

The disc material is called fibrocartilage. Fibrocartilage is a cartilage, which consists of a dense matrix of collagen fibers.  

*The purpose of the disc is to absorb and distribute the force from movement.*  

such as walking, and also *prevent the vertebrae from grinding* against each other.

![Figure 5](image-url)
3. **Anthropometric Lab**

**Remote or Off-site Students:**
Remote or off-site students, please use a tape measure, measuring stick and standard scale to collect your measurements. Collect the information for two people. Contact the TA for a supplemental data set to support your calculations in Part 4 of the assignment.

**On Campus Students**

**Laboratory Instructions:** The data for this lab is to be collected in the Ergonomic Lab during your scheduled lab time. Use the anthropometric tools for linear and angular measurement and the lab scale for body weight. You will also use the hand dynamometer to measure grip strength. The lab is to be performed in your designated lab groups.

**Part A:** Obtain the following measurements for a sample group of three to four lab members.

1. Ankle to knee distance
2. Elbow to wrist length
3. Wrist to end of finger tip length
4. Shoulder to top of head length
5. Sitting eye level
6. Horizontal range of motion for the wrist
7. Breadth of index finger
8. Grip strength with dominant hand (*REMOTE OR OFF-SITE students use Grip*

*Strength tables to obtain an estimate for a population norm compatible with your two subjects*)

9. Persons overall height

10. Persons total body weight (you may estimate this value)

1) Record the data in an excel spreadsheet with the following headings:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age</th>
<th>Ankle to knee</th>
<th>Elbow to wrist length</th>
<th>Wrist to end of middle finger length</th>
<th>Shoulder to top of head length</th>
<th>Sitting Eye Level</th>
<th>Horizontal range of motion for wrist</th>
<th>Breadth of index finger</th>
<th>Grip Strength</th>
<th>Height (inches)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>3</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Briefly state how each of these anthropometrics can be useful in engineering design

3) State the tools, equipment and procedure used to collect each measurement

**Part B:**

1) Post your data on WebCourses so that the entire class can create one data set with all input.

2) Using the comprehensive data set do the following:

   a) Calculate summary statistics for the data (measures of central tendency, measures of variation; determine if there are any outliers in the data set)

   b) Construct a 95% confidence interval for each of the measurements
Part C: Take 4 *additional* anthropometric measurements that would be important in automobile design. Explain how or where they would be useful in automobile design.

Part D: Using the proportional relationship (see chart) between body segment length and height (h) calculate the estimated height for measurements 1 – 7 *for the subjects in your lab group.*

Determine the difference in the estimated length of segments 1 – 7 and the actual measurements obtained for each of the items.

a) Prepare a table that shows the estimates compared to the actual measurements

b) Briefly discuss the differences in the estimates and the actual measurements

Part E: Using the “Percentage Distribution of Total Body Weight” and the subjects’ body weight, calculate the estimated weight of the following body segments and state a work place, product development, etc. environment where it would be useful to have this information.

1. Head and Neck
2. Torso
3. Hand
4. Thigh
Anthropometric Height Chart – Female

Source: Kroemer et al, 2003

This figure illustrates the major body segments for females. The equations to predict the length of arm and leg segments from height (H) for American females appears next to each segment. The height distribution for a mixed population of females is shown in the upper right corner. Measured values should be used in workplace design instead of estimates whenever possible. (Adapted from Kroemer et al, 2003)

Anthropometric Height Chart – Male

Source: Kroemer et al, 2003

This figure illustrates the major body segments for males. The equations to predict the length of arm and leg segments from height (H) for American males appears next to each segment. The height distribution for a mixed population of males is shown in the upper right corner. Measured values should be used in workplace design instead of estimates whenever possible. (Adapted from Kroemer et al, 2003)

### Prediction Equations to Estimate Segment Mass (in kg) from Total Body Weight

<table>
<thead>
<tr>
<th>Segment</th>
<th>Empirical equation</th>
<th>Standard error of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0.306W + 2.46</td>
<td>0.43</td>
</tr>
<tr>
<td>Head and neck</td>
<td>0.0534W + 2.33</td>
<td>0.60</td>
</tr>
<tr>
<td>Neck</td>
<td>0.0146W + 0.60</td>
<td>0.21</td>
</tr>
<tr>
<td>Head, neck and torso</td>
<td>0.5940W - 2.20</td>
<td>2.01</td>
</tr>
<tr>
<td>Neck and torso</td>
<td>0.5582W - 4.26</td>
<td>1.72</td>
</tr>
<tr>
<td>Total arm</td>
<td>0.0505W + 0.01</td>
<td>0.35</td>
</tr>
<tr>
<td>Upper arm</td>
<td>0.0274W - 0.01</td>
<td>0.19</td>
</tr>
<tr>
<td>Forearm and hand</td>
<td>0.0233W - 0.01</td>
<td>0.20</td>
</tr>
<tr>
<td>Forearm</td>
<td>0.0189W - 0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>Hand</td>
<td>0.0055W + 0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Total leg</td>
<td>0.1582W + 0.05</td>
<td>1.02</td>
</tr>
<tr>
<td>Thigh</td>
<td>0.1159W - 1.02</td>
<td>0.71</td>
</tr>
<tr>
<td>Shank and foot</td>
<td>0.0452W + 0.82</td>
<td>0.41</td>
</tr>
<tr>
<td>Shank</td>
<td>0.0375W + 0.38</td>
<td>0.33</td>
</tr>
<tr>
<td>Foot</td>
<td>0.0069W + 0.47</td>
<td>0.11</td>
</tr>
</tbody>
</table>


Part 1. MMH Evaluation

1. For the lifting task, ask a person to serve as the subject that is in reasonably good health. This task will evaluate the persons change in heart rate and consider their subjective rating of exertion using the Borg Scale while performing a physical activity.

2. The activity will be walking up and down the stairs with a box in the subjects’ hand.

Instructions: You will need one subject, one person to keep time and tell when the heart rate is to be taken and the rating of perceived exertion is to be collected. You will also need two people to record this information.

Process for lab

1. Take Resting Heart Rate

2. Ask questions about previous intake of caffeinated products.

3. Ask the person to begin performing the lifting or MMH

4. The heart rate (pulse) and Rating of Perceived Exertion(RPE) is to be taken every 60 seconds for 20 minutes using the Borg Scale.

5. At the cessation of the activity the H.R. will be taken for approximately 5 more minutes.
This information is to be analyzed by the group doing the following:

1. State experiment conditions

2. Subject information

3. How data was collected

4. Provide a graph of the heart rate information throughout task performance.

5. Using the numeric values for the RPE determine if there is a correlation between H.R. and the values obtained for the RPE.

6. Summarize your results.
BORG SCALE

Rating of Perceived Exertion Chart

1 MINIMAL EXERTION

2

3

4

5 MODERATE EXERTION

6

7 SOMEWHAT STRONG EXERTION

8

9

10 EXTREME EXERTION

Instructions: Subjects are to select the level of exertion that is being experienced when queried by the evaluator.
Part 2: NIOSH Lifting Guidelines

(Source of all figures, tables and equations is the Applications Manual for the Revised NIOSH Lifting Equation, DHHS (NIOSH) Publication Number 94-110.

A decade after the first NIOSH lifting guide, NIOSH revised the technique for assessing overexertion hazards of manual lifting. The new document no longer contains two separate weight limits (Action Limit (AL) and Maximum Permissible Limit (MPL)) but has only one Recommended Weight Limit (RWL). It represents the maximal weight of a load that may be lifted or lowered by about 90% of American industrial workers, male or female, physically fit and accustomed to physical labor.

This new equation resembles the 1981 formula for AL, but includes new multipliers to reflect asymmetry and the quality of hand-load coupling. The 1991 equation allows as maximum a “Load Constant” (LC) - permissible under the most favorable circumstances -- with a value of 23 kg (51 lb.)

\[ \text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM} \]

- LC - load constant of 23 kg or 51 lb.

** Each remaining multiplier may assume a value [0, 1]

HM - the horizontal multiplier: H is the horizontal distance of the hands from the ankles (the midpoint of the ankles)
VM - the Vertical Multiplier: V is the vertical location (height) of the hands above the floor at the start and end points of the lift.

DM - the Distance Multiplier: where D is the vertical travel distance from the start to the end points of the lift.

AM - the Asymmetry Multiplier: where A is the Angle of asymmetry, i.e., the angular displacement of the load from the medial (mid-saggital plane) which forces the operator to twist the body. It is measured at the start and end points of the lift.

FM - the frequency multiplier: where F is the frequency rate of lifting, expressed in lifts per minute.

CM - the coupling multiplier: where C indicates the quality of coupling between hand and load.

<table>
<thead>
<tr>
<th>NIOSH LIFTING EQUATION PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>** Abbreviation **</td>
</tr>
<tr>
<td>Load Constant</td>
</tr>
<tr>
<td>Horizontal Multiplier</td>
</tr>
<tr>
<td>Vertical Multiplier</td>
</tr>
<tr>
<td>Distance Multiplier</td>
</tr>
<tr>
<td>Asymmetric Multiplier</td>
</tr>
<tr>
<td>Frequency Multiplier</td>
</tr>
<tr>
<td>Coupling Multiplier</td>
</tr>
</tbody>
</table>
Instructions: Using the NIOSH lifting equation, perform an analysis of the lift below for the same person and then perform the same analysis for a second person. Calculate the RWL and LI for the origin and destination of both lifts.

Lifting Index (LI) = Load/RWL

Task: The subject is picking up a box directly in front of him/her. The box is located on the floor. After lifting the box, the subject must twist approximately 90 degrees at the waist to place the box on a table. The subject is required to perform this task approximately 10 times per minute. The anticipated task duration is approximately 1 hour. (This is hypothetically speaking; do NOT ask a subject to perform the task for an hour. Ask them only to demonstrate holding a load it for purposes of the lab)

Discussion: For each task present the following:

1. Description of each task
2. List any necessary assumptions
3. Explain the values for each of the parameters from the NIOSH lifting equation
4. Do the task requirements seem excessive? Explain
5. Compare and contrast the results of the two tasks
### Asymmetric Multiplier

<table>
<thead>
<tr>
<th>Amount of Asymmetry Degrees</th>
<th>Asymmetric Multiplier Value for AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>0.95</td>
</tr>
<tr>
<td>30</td>
<td>0.9</td>
</tr>
<tr>
<td>45</td>
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<td>60</td>
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</tr>
<tr>
<td>75</td>
<td>0.76</td>
</tr>
<tr>
<td>90</td>
<td>0.71</td>
</tr>
<tr>
<td>105</td>
<td>0.66</td>
</tr>
<tr>
<td>120</td>
<td>0.62</td>
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<tr>
<td>135</td>
<td>0.57</td>
</tr>
<tr>
<td>&gt;135</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 1  Graphic Representation of Hand Location

Figure 2  Graphic Representation of Angle of Asymmetry (A)
Hand-to-Container Coupling Classification

<table>
<thead>
<tr>
<th>Coupling</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Position at Origin or Destination</td>
<td>&lt; 50 in</td>
<td>&gt; 30 in</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>0.95</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5** Loading Punch Press Stock, Example 1

**Coupling Multiplier**

<table>
<thead>
<tr>
<th>Coupling</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Position at Origin or Destination</td>
<td>&lt; 50 in</td>
<td>&gt; 30 in</td>
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</tr>
<tr>
<td>Good</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>0.95</td>
<td>1.00</td>
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</tr>
<tr>
<td>Poor</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

**Hand-to-Container Coupling Classification**

<table>
<thead>
<tr>
<th>GOOOD</th>
<th>FAIR</th>
<th>POOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. For containers of optimal design, such as some boxes, crates, etc., a &quot;Good&quot; hand-to-object coupling would be defined as handles or hand-hold cut outs of optimal design. See notes (1 to 3 below)</td>
<td>1. For containers of optimal design, a &quot;Fair&quot; hand-to-object coupling would be defined as handles or hand-hold cut outs of less than optimal design. (See notes 1 to 4)</td>
<td>1. Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges (see note 5 below)</td>
</tr>
<tr>
<td>2. For loose parts or irregular objects which are not usually containerized, such as castings, stock and supply materials, a &quot;Good&quot; hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object (see note 6 below)</td>
<td>2. For containers of optimal design with no handles or hand hold cut-outs or for loose parts or irregular objects, a &quot;Fair&quot; hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees (see note 4 below)</td>
<td>2. Lifting non-rigid bags (i.e., bags that sag in the middle)</td>
</tr>
</tbody>
</table>
Hand to Container Coupling Notes

1. An optimal handle design has .75 - 1.5 inches (1.9 to 3.8 cm) diameter, 1 4.5 inches (1 1.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a non-slip surface.

2. An optimal handhold cut-out has the following approximate characteristics:
   - 1.5 inch (3.8 cm) height,
   - 4.5 inch (11.5cm) length,
   - semi-oval shape,
   - 12 inch (5 cm) clearance,
   - smooth non-slip surface, and
   - > 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard).

3. An optimal container design has 16 inches (40cm) frontal length, < 12 inches (30 cm) height, and a smooth non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90 degrees under the container as required when lifting a cardboard box from the floor.

A container is considered less than optimal if it has a frontal length > 16 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable contents, or requires the use of gloves.

A loose object is considered bulky if the load cannot be easily balanced between the hand-grasps.

5. A worker should be able to comfortably wrap the hand around the object without cawing excessive wrist deviations or awkward postures, and the grip should not require excessive force.
Decision Tree for Coupling Quality

Object Lifted

- **Container**
  - Optimal Container?
    - YES
    - Optimal Handles?
      - YES
      - GOOD
      - NO
      - Fingers Flexed 90 degrees?
        - YES
        - FAIR
        - NO
        - NO
        - YES
  - NO
  - POOR

- **Loose Object**
  - Bulky Object?
    - YES
    - Optimal Grip?
      - YES
      - GOOD
      - NO
      - NO
      - NO
      - NO
  - NO
### FREQUENCY MULTIPLIER TABLE (FM)

<table>
<thead>
<tr>
<th>Lifting Frequency (F) ‡</th>
<th>Work Duration</th>
<th>Lifts/min</th>
<th>&lt; 1 Hour</th>
<th>&gt; 1 but &lt; 2 Hours</th>
<th>&gt; 2 but &lt; 8 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V &lt; 30 †</td>
<td>V &gt; 30</td>
<td>V &lt; 30</td>
<td>V &gt; 30</td>
<td>V &lt; 30</td>
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</tbody>
</table>

† Values of V are in inches.

‡ For lifting less frequently than once per 5 minutes, set F = 2 lifts/minute.

**Lifting Frequency:** The average lifting frequency rate, expressed in terms of lifts per minute, must be determined. The frequency rate can be determined by observing a typical 15 minute work period, and documenting the number of lifts performed during this time frame. The number of lifts observed is divided by 15 to determine the average lifts per minute. Duration is measured using the following categories: **Short** (Less than one hour); **Moderate** (1 to 2 hours); **Long** (2 to 8 hours).
**JOB ANALYSIS WORKSHEET**

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>JOBSITE</th>
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<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>ANALYSIS'S NAME</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

**STEP 1. Measure and record task variables**

<table>
<thead>
<tr>
<th>Object Weight (lbs)</th>
<th>Hand Location (in)</th>
<th>Vertical Distance (in)</th>
<th>Asymmetric Angle (degrees)</th>
<th>Frequency Rate</th>
<th>Duration (hrs)</th>
<th>Object Coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Origin</td>
<td>Dest</td>
<td>A</td>
<td>A</td>
<td>F</td>
<td>C</td>
</tr>
<tr>
<td>L (AVG.)</td>
<td>H</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L (Max.)</td>
<td>V</td>
<td>H</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**STEP 2. Determine the multipliers and compute the RWL's**

**ORIGIN**

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM}$$

**DESTINATION**

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM}$$

**STEP 3. Compute the LIFTING INDEX**

**ORIGIN**

$$\text{LIFTING INDEX} = \frac{\text{OBJECT WEIIGHT (L)}}{\text{RWL}}$$

**DESTINATION**

$$\text{LIFTING INDEX} = \frac{\text{OBJECT WEIGHT (L)}}{\text{RWL}}$$

NIOSH Lifting Equation Job Analysis Worksheet
5. Information Processing Lab

Each of the following exercises is to be performed for one person in your group. Record the results of this study graph the outputs and discuss the results with respect to the human engineering expectations.

Exercise 1:

Primary task - word find puzzle;
Secondary task – look at flash card and solve math problem.

In this exercise the subject is required to do the following:

1. Solve a word find puzzles for 15 minutes and
2. During puzzle solving a secondary task is introduced.
3. The secondary task is the solving of a math problem
4. At 60 second intervals, the person is interrupted with a math problem presented on a flash card.
5. The subject is to provide a verbal answer for the math problem and then resume the word-find puzzle.

The group is to do the following for this exercise:

1. Time the exercise using a stop watch
2. Present the subject with the secondary task at one minute intervals
3. Record the accuracy of the response on the secondary task
4. Record the number of words found on each word find puzzle
5. Replace the word find puzzle when approximately 80% of the words are found
6. Count the number of words found during each minute of the exercise.
6. Record the subject's heart rate each minute

7. At the completion of the task ask the subject to rate the difficulty of task performance based on the Borg Scale

Directions:
Sit the subject in a chair with the word find puzzle directly in front of him/her. Begin the task by asking the person to start solving the word find puzzle. If the subject nears the completion of the word find puzzle present him/her with another puzzle and continue the task.

Exercise 2: Primary task: solving math problems by hand. Secondary task: Counting number of flashes of a lamp.

In this task the subject is required to solve math problems by hand for 15 minutes. At 60 second intervals, the subject will be asked to count the number of times a light flashes. This activity is to be continued until the subject reaches fifteen minutes. If the subject completes the math problems present him/her with another sheet of problems. The group will perform the following:

1. Count the number of math problems solved/minute
2. Present the secondary task (flashing of the light) every 60 seconds

3. Count the number of times the subject is correct about the number of flashes of light

4. Record correct/incorrect solutions to math problems per minute

5. Graph results

6. Take subjects pulse every 60 seconds

7. Ask the subject to rate the perceived difficulty of the mental workload each minute by asking the following question
   
   • “Give me a rating for your perceived mental workload on a scale from 6 to 20”

8. **At the completion of each minute ask the subject to rate the difficulty of task performance using the rating of perceived exertion (perceived mental level of the effort) from the Borg Scale (see attached).**

These results are to be presented in the group report.

**Group report:** Your report should contain the following sections:

- Introduction: Purpose of the lab, why this information is important

- Application areas for this knowledge in industry

- Laboratory equipment used: puzzles, math problems, etc.

- Design of the exercise:

- Present results: tables, graph

- Determine if a correlation exists between
- Percentage of correct responses and change in heart rate.
- Number of words found (problems solved) and time: (i.e. did the subject adjust to the task?)

- Conclusion: What the lab results suggest
Subject______________________________________________________________

<table>
<thead>
<tr>
<th>Observation</th>
<th>Primary Task Rating</th>
<th>Secondary Task Rating</th>
<th>Heart Rate</th>
<th>RPE from Borg Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>15</td>
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</tr>
</tbody>
</table>

*Difficulty of task performance based on the Borg Scale__________*

Notes: __________________________________________________________________
______________________________________________________________________
### BORG SCALE

**Rating of Perceived Exertion Chart**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>MINIMAL EXERTION</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>MODERATE EXERTION</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SOMEWHAT STRONG EXERTION</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>EXTREME EXERTION</td>
</tr>
</tbody>
</table>

*Instructions: Subjects are to select the level of exertion that is being experienced when queried by the evaluator.*
Word Search Puzzle
6. **Cumulative Trauma Disorder (CTD)/Work Related Musculoskeletal Disorder**

**Lab**

Application of McCauley Bush Fuzzy Rating Scale for Evaluation of Cumulative Trauma Disorder Risk

**INSTRUCTIONS:** Before the lab begins please excerpt from the article I wrote on pages 2-6. This article explains the mathematical model you will be using to calculate risk of CTD.

**Lab Objective:**

- To quantify risks of CTD using this linear weighted function.
- To gain experience in performing an assessment

**Environment and Subject:**

- Identify a workplace that you can gain access to in order to perform this lab. This should be an area that has some known CTD risks such as an office, grocery store, assembly environment, etc.
- Using the three categories of risk factors, rate the level of existence for each of the task-related risk factors. Provide a brief explanation of your rankings.
- Apply the model to the work environment and a real or “hypothetical” employee.
• Consider the organizational or psychosocial characteristics associated with the work environment. *Make any necessary assumptions to rate each of the different characteristics.*

**Application:**

• Provide a summary table for each of the categories of risk factors

• Calculate the risk for each category

• Calculate the risk for each employee (REMOTE OR OFF-SITE students only one employee)

• Calculate the organizational risks for the given workplace

• Calculate comprehensive risk level for each set of conditions.

**Subjects:**

• Apply the model to 3 workers and at least one work environment. (REMOTE OR OFF-SITE Students apply to one worker)

**Compare this methodology to the Rapid Upper Limb Assessment tool and provide and brief discussion of the similarities and differences.**

Please follow the lab report guidelines to develop your report.
Application of McCauley- Bush Fuzzy Rating Scale for Evaluation of Cumulative Trauma Disorder Risk

(The following is an excerpt from McCauley-Bell, Crumpton and Badiru, 1999)

The six to seven items identified as risk factors for each of the three modules (task, personal and organizational) were evaluated for relative significance. The priority weights for the risk factors in the task-related and personal modules are listed in Tables 11 and Table 12, respectively.

Table 11. AHP Results: Task-Related Risk Factors

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Factor</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Awkward joint posture</td>
<td>0.299</td>
</tr>
<tr>
<td>2</td>
<td>Repetition</td>
<td>0.189</td>
</tr>
<tr>
<td>3</td>
<td>Hand tool use</td>
<td>0.180</td>
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<tr>
<td>4</td>
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<td>6</td>
<td>Vibration</td>
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Table 11b. Levels of Existence for each factor

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<tr>
<th></th>
<th>Posture</th>
<th>Repetition</th>
<th>Hand Tool</th>
<th>Force</th>
<th>Task Duration</th>
<th>Vibration</th>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Medium</td>
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</table>

In the evaluation the organizational risk factors; equipment was the most significant factor. In the knowledge acquisition, the term equipment refers to the degree of automation for the machinery being used in the task under evaluation. The order of importance and priority weights for each of the risk factors is listed in Table 13. This module evaluated the impact of seven risk factors. However, upon further analysis and discussion, the awareness and ergonomics program categories were combined because
according to the experts and the literature, one of the goals of an ergonomics program is to provide awareness about the ergonomic risk factors present in a workplace.

Table 12. AHP Results: Personal Risk Factors

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Factor</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Previous CTD</td>
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</tr>
<tr>
<td>2</td>
<td>Hobbies and habits</td>
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</tr>
<tr>
<td>3</td>
<td>Diabetes</td>
<td>0.170</td>
</tr>
<tr>
<td>4</td>
<td>Thyroid problems</td>
<td>0.097</td>
</tr>
<tr>
<td>5</td>
<td>Age</td>
<td>0.039</td>
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<tr>
<td>6</td>
<td>Arthritis</td>
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Table 12b. Levels of Existence for Personal Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>Previous CTD</th>
<th>Hobbies &amp; Habits</th>
<th>Diabetes</th>
<th>Thyroid Problems</th>
<th>Age</th>
<th>Arthritis or DJD</th>
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</table>

Table 13. AHP Results: Organizational Risk Factors

<table>
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<th>Relative Weight</th>
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<td>Ergonomics program</td>
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<td>Peer influence</td>
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<td>5</td>
<td>Training</td>
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<td>CTD level</td>
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<tr>
<td>7</td>
<td>Awareness</td>
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</table>
Table 13b. Levels of Existence for Organizational Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>Equipment</th>
<th>Production rate/layout</th>
<th>Ergonomics program</th>
<th>Peer influence</th>
<th>Training</th>
<th>CTD level</th>
<th>Awareness</th>
</tr>
</thead>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<td>1.0</td>
</tr>
<tr>
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<td>0.5</td>
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</tr>
<tr>
<td>Low</td>
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</tr>
<tr>
<td>None</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

After the factors within the categories (or modules) were compared, an AHP analysis was conducted to determine the relative significance of each of the modules: task, personal and organizational characteristics. The priority weights obtained for the task, personal, and organizational characteristics are listed in Table 14. The task characteristics module received a relative weight of 0.637. The personal characteristics module had a relative weight of 0.258, less than half of the relative weight of the task characteristics module. Finally, the organizational characteristics module received the smallest relative weight, 0.105.

Table 14. AHP Results: Module Risk Comparison

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Module</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Task</td>
<td>0.637</td>
</tr>
<tr>
<td>2</td>
<td>Personal</td>
<td>0.258</td>
</tr>
<tr>
<td>3</td>
<td>Organizational</td>
<td>0.105</td>
</tr>
</tbody>
</table>

Determination of Aggregate Risk Level

After the linguistic risk and the relative significance are generated an aggregated numeric value is obtainable. Equation 9 represents the model for the calculation of the numeric risk value for the task module. In Equation 9, the $w_i$ values represent the numeric values obtained from the user inputs for each of the six risk factors and the $a_j$ values
represent the relative significance or factor weight obtained from the AHP analysis. The numeric risk levels for the personal and organizational characteristics are represented by Equations 10 and 11, respectively. Likewise, the values of $x_i$ and $y_i$ represent the user inputs while; the $b_i$ and $c_j$ values represent the AHP weights for the task and organizational characteristics, respectively. These linear equations are based on Fuzzy Quantification Theory I (Terano, 1994). The objective of Theory I is to find the relationships between the qualitative descriptive variables and the numerical object variables in the fuzzy groups. An alternative to this approach is to use CTD epidemiological data to establish the regression weights rather than the relative weights were derived from the AHP analysis with the experts. However, the lack of availability of comprehensive data for a regression model prevented the application of regression analysis. The resulting equations represent the numeric risk levels for each category.

Task-Related Risk:

$$R_1 = F(T) = a_1 w_1 + a_2 w_2 + a_3 w_3 + a_4 w_4 + a_5 w_5 + a_6 w_6 \quad [9]$$

Personal Risk:

$$R_2 = F(P) = b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 + b_6 x_6 \quad [10]$$

Organizational Risk:

$$R_3 = F(O) = c_1 y_1 + c_2 y_2 + c_3 y_3 + c_4 y_4 + c_5 y_5 + c_6 y_6 \quad [11]$$

Interpretation of Results
The numeric risk values obtained from each of the modules and the weights obtained from the AHP analysis were used to obtain the final crisp overall risk output. This output is a value that indicates the risk of subject injury for a specific task in a given workplace. The following equation was used to quantify the comprehensive risk of injury is a result of all three categories:

\[ Z = d_1 R_1 + d_2 R_2 + d_3 R_3 \]  \[12\]

Where,

- \( Z \) = overall risk for the given situation,
- \( R_1 \) = the risk associated with the task characteristics,
- \( d_1 \) = weighting factor for the task characteristics,
- \( R_2 \) = the risk associated with the personal characteristics,
- \( d_2 \) = weighting factor for the personal characteristics,
- \( R_3 \) = the risk associated with the organizational characteristics,
- \( d_3 \) = weighting factor for the organizational characteristics.

The weighting factors \((d_1, d_2, d_3)\) represent the relative significance of the given risk factor category's contribution to the likelihood of injury. These factors were determined through the AHP analysis. The numeric risk levels obtained from the previous equations exist on the interval \([0,1]\). On this interval 0 means no risk of injury and 1 means extreme risk of injury. The partitioning of the categories is shown in Table 15.
<table>
<thead>
<tr>
<th>Numeric Risk Level</th>
<th>Expected Amount of Risk Associated with Numeric Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.20</td>
<td>Minimal risk: Individual should not be experiencing any conditions that indicated musculoskeletal irritation</td>
</tr>
<tr>
<td>0.21 - 0.40</td>
<td>Some risk: may be in the very early stages of CTD development. Individual may experience irregular irritation but is not expected to experience regular musculoskeletal irritation</td>
</tr>
<tr>
<td>0.41 - 0.60</td>
<td>Average risk: Individual may experience minor musculoskeletal irritation on a regular but not excessive irritation</td>
</tr>
<tr>
<td>0.61 - 0.80</td>
<td>High risk: Individual is expected to be experiencing regular minor or major musculoskeletal irritation</td>
</tr>
<tr>
<td>0.81 - 1.00</td>
<td>Very high risk: Individual is expected to presently experience ongoing or regular musculoskeletal irritation and/or medical correction for the condition</td>
</tr>
</tbody>
</table>
7. **Warning Label Laboratory**

This lab is designed to teach the elements of warning label assessment and design. Please provide a photo or drawing of the warning labels that you evaluate in problem #1 and provide a drawing of the warning you develop in problem #2. (REMOTE OR OFF-SITE STUDENTS please do the following assignment but only evaluate ONE label in problem #1)

1) Find three warning labels on different items and answer the following questions.

   (a) What is the action that is being warned against?

   (b) What are the consequences of that action?

   (c) Where is the warning located and why do you think that location was selected?

   (d) How durable is the warning label?

   (e) How many languages are used in the warning?

   (f) In what sense is the warning “complete?”

   (g) Is the warning appropriate for the target audience?

   (h) What is the anticipated range of skill level for the product users/operators

   (i) Provide photos or drawings of the warnings your team evaluated

2) Develop a warning label for a product that your team is familiar with or has used in the past.

   a) Provide an explanation for the choice of signal word

   b) What would you warn against,
c) what consequences would you state, and

d) Where would you put the label?

e) Provide a drawing of your label and a detailed description

3) Provide a list or summary of guidelines for warning development that can be used in an industrial environment. In other words, a succinct list that a layperson could use to design warning labels in a workplace.

4) Include references in your lab report
8. Work Place Evaluation Lab

IN CLASS STUDENTS & REMOTE OR OFF-SITE STUDENTS

INSTRUCTIONS:

This lab is to be conducted outside of the ergonomic laboratory and is designed to prepare you for your class projects.

- Identify an occupational environment that contains a potential physical ergonomic problem(s).

- This may be a work area of your choosing but make sure you have access to this work area for at least 1 hour.

- Follow the steps listed below in Process for Ergonomic Evaluation to assess the work environment.

- Your lab report should include a thorough discussion of each of the following steps

- Follow the format for lab reports included in your syllabus in the preparation of your lab report.
**Work Place Evaluation:** Address each of the items below in the workplace that your lab group evaluates.

1) *Provide an initial Problem Analysis*

   a) Provide a thorough description of the work area

   b) What are the potential physical ergonomic problems?

   c) State the attributes that may contribute to ergonomic problems by the following categories

      i) Job design, workplace design, design of equipment and tools etc.

      ii) Human operator capabilities are not compatible with task

          - Do task requirements seem to exceed capabilities of operator?

          - Does the operator appear to be aware of the proper procedures?

      iii) Do the situational or external factors contribute to promote or reduce the ergonomic or safety level of the task?

          - supervisor

          - policies

          - stress or pressure

2) *Typical population of workers performing the tasks*

   a) Physical characteristics of employees

   b) Age of typical employees

   c) Level of training or education to perform task (you may estimate)

2) *Provide an overview of tools, equipment or processes used in the task*
a) Provide a discussion of the tools, equipment and processes required for task performance

b) Provide an approach for how you would perform an evaluation of tools and/or equipment in this work environment; you do NOT have to evaluate the tools and equipment but provide a description of HOW you would do the evaluation.

3) **Provide a more detailed explanation of suspected ergonomic problem areas and classify the nature of the problem in one or more ergonomic areas**
   a) anthropometric
   b) physiological
      i) musculoskeletal, cardiovascular, biomechanical
   c) psychological
      i) information overload
   d) environmental
      i) noise, heat

4) **Investigate and Quantify Job Requirements –STATE CLEARLY HOW YOU WOULD CONDUCT THIS ANALYSIS BUT DO NOT PERFORM THE ANALYSIS**
   c) Responsibilities for task performance
   d) Describe duties of at least three elements of the task?
   e) How much time is required on the task and major task elements?
   f) What skill level is required?
   g) Does the task have performance standards to be met (i.e. is a certain level of production required in the task)?
h) What additional working conditions need to be evaluated?
   i) Other

5) *Determine the guidelines, references or legislation that you would apply to determine if the work area is ergonomically sound; You may use suggest the use of the types of guidelines listed below in your response or any validate methodology*

   a) NIOSH Guidelines
   b) OSHA Standards
   c) ANSI Standards
   d) ISO Standards
   e) Ergonomic literature sources or other accepted methodologies (i.e. RULA)

6) *Analysis of Human Performance and Physiological Response – STATE CLEARLY HOW YOU WOULD CONDUCT THIS ANALYSIS BUT DO NOT PERFORM THE ANALYSIS; where appropriate in your workplace evaluation, describe how the following measures would be obtained and why.*

   a) Performance measures
      i) productivity over the shift
         a) Total unit completed units per hour, idle time, time on arbitrary tasks, interruptions, distractions, accidents, etc.
         b) Performance measures
      ii) quality of output
         a) Number of defects, number of mistakes, and number of times referenced instructions, etc...
c) Physiological measures
   
a) Direct measurements
   
   - heart rate, blood pressures, breathing rate, muscle activity (EMG reading),
     body/skin temperature, oxygen consumption
   - Anthropometric measurements

b) Psychophysical measures (subjective techniques)
   
a) Perceived exertion, difficulty, energy expended, level of fatigue

7) Design or Redesign Strategies-STATE CLEARLY THE PROPOSED DESIGN

*IMPROVEMENTS THAT YOU BELIEVE WOULD RESULT FROM EFFECTIVE ERGONOMIC APPLICATIONS*

   a) Engineering approach
   
   i) Eliminate the problem by design

b) Administrative controls
   
   i) Work aids, assistive devices, etc.

c) Personal protective equipment
ON-CAMPUS STUDENTS

*Laboratory Instructions:* The data for this lab is to be collected in the Ergonomic Lab during your scheduled lab time and the equipment may be removed to collect data. The equipment MUST be returned by the completion of your lab time.

Use the laboratory models of the ear, eye and heart to perform this lab. Use the sound level meter and light meters to collect the data as required. The lab is to be performed in your designated lab groups unless you are a REMOTE OR OFF-SITE student.

REMOTE OR OFF-SITE STUDENTS

*Instructions:* Identify a piece of ergonomic equipment on the internet that is a model or mock up for each of the four categories below. Write a summary page overview of this piece of ergonomic equipment and include the following (NOTE: You are required to do this for all four categories below):

5) Identify applications or research environments where this piece of equipment or software would be useful in an ergonomic setting

6) Go to the internet and identify at least two applications where this tool or a similar tool was used in a research or application environment.

7) Provide costs associated with the purchase of the equipment or software

8) Include all references and sources
**Part A - Visual Sense:** Use the model in the laboratory to describe the operation of the eye from the time that an object is perceived by the eye until it image is received in the brain. Your discussion should include the following:

a) Description of the various elements of the eye  
b) Description of the process that the eye is going through to perform the receipt of the image  
c) List an example task activity where this visual action is required.  
d) Use the light meter to assess the light level in the following three different environments  
   a. Environments  
      i. Student Center  
      ii. Parking garage (any) or Stairwell in Engineering 2  
      iii. Ergonomics laboratory  
   b. Explain a type of task that could be done in this environment and determine if the illumination level is appropriate

**Part B – Auditory Sense:** Use the model of the ear in the laboratory to describe the operation of the ear. Your discussion should include the following:

a) Description of the various elements of the ear by three segments  
b) Description of the process of receiving sound
c) List an example task activity where this auditory sense action is required.

d) Use the sound level meter to determine the sound level in the following environments

   a. Environments

      i. Student Center – pick a restaurant or location

      ii. Atrium area of Engineering 2

      iii. Parking garage (exit or entrance)

   b. Explain a type of task that could be done in this environment and determine if the noise level is acceptable

Part C – Cardiovascular System:

Using the model of the heart, describe what happens when a person is required to engage in aerobic activity. Your discussion should include the following:

   a) Description of the major segments of the heart

   b) Description of the cardiovascular process

   c) Description of what happens when a rapid increase in cardiovascular activity is required.

   d) List of potential risk factors that limit the functionality of the heart

   e) List an example task activity where this auditory sense action is required.

Part D – Skeletal System

Using the model of the skeletal system and the individual spinal disc address the ergonomics questions below regarding the skeletal system:
a) Describe the natural form of the spine by type of vertebrae

b) Discuss the role of the spinal disc and type of occupational deterioration that can occur

c) Discuss how aging impacts the health of the intervertebral discs

d) Discuss of importance of the spinal system in the stability of the worker
9. **Anthropometric and Segment Weight Lab**

**IN CLASS INSTRUCTIONS:** Utilize the anthropometric tools and height distribution chart to answer Part 1 through Part 4 of the lab assignment below.

**REMOTE OR OFF-SITE INSTRUCTIONS:** Please use a tape measure, meter stick and standard scale to obtain measurements listed below for one person. Follow the instructions in Part 2, 3 and 4 to obtain response for the data collected in Part 1.

**Part 1:**

Anthropometric measurements: Using the anthropometric measuring tools obtain the following measurements for two people within your group

11. Knee to hip height
12. Ankle to knee height
13. Knee to Shoulder height
14. Wrist to Shoulder height
15. Wrist to elbow height
16. Shoulder to top of head height
17. Sitting eye level height
18. Persons overall height
Part 2:

Using the Body segment length in proportion to stature charts, calculate the estimated length of segments 1 – 6 using the relationship between height and segment length. How does this compare to the actual measurements obtained for each person? Discuss the usefulness and disadvantages of this type of estimation.

Part 3:

Using the “Percentage Distribution of Total Body Weight” and the subjects’ body weight, calculate the estimated weight of the following body segments.

6. Head and Neck
7. Torso
8. Forearm
9. Wrist to elbow
10. Thigh
11. Shank

Part 4:

Describe an environment where “Anthropometric Measurements” listed in Part 1 and corresponding “Percentage Distribution of Total Body Weight” are used in design. Explain how these measurements would be used to support design decisions or analysis.

Anthropometric Terminology
• **Height**: A straight line, vertical point to point measurement

• **Breadth**: A straight line, horizontal vertical point to point measurement

• **Depth**: A straight-line, point to point horizontal measurement running fore-aft

• **Distance**: A straight-line, point to point measurement between landmarks

• **Circumference**: A closed measurement following a body contour

• **Curvature**: A point-to-point measurement following the contour, usually not circular
10. **Lifting Lab**

**OBJECTIVE:** To utilize the NIOSH lifting analysis in a biomechanical analysis.

**INSTRUCTIONS:** Using the NIOSH lifting equation, perform an analysis of two lifts for the same person and then perform the same analysis for a second person.

Task 1:

a. The subject is picking up a box directly in front of him/her. The box is located on the floor. After lifting the box, the subject must twist approximately 90 degrees at the waist to place the box on a table. The subject is required to perform this task approximately 10 times per minute. The anticipated task duration is approximately 1 hour.

Task 2: The subject picks a load from the table and places it above shoulder level on a shelf. This task is performed approximately 10 times per minute. Assume that the task duration is 3 hours (the person does not have to perform the task for this amount of time).

Discussion: For each task present the following:

6. Description of each task
7. List any necessary assumptions
8. Use the NIOSH lifting equation to obtain the necessary values for evaluation
9. Explain the values for each of the parameters from the NIOSH lifting equation

10. Apply the Snook & Cirello, Liberty Mutual Tables to this task to determine the appropriateness of the lift

11. Do the task requirements seem excessive based on the NIOSH Lifting Equation? Explain

12. Do the task requirements seem excessive based on the Liberty Mutual Tables? Explain

13. Compare and contrast the results of the two tasks

**NIOSH Lifting Guidelines**

A decade after the first NIOSH lifting guide, NIOSH revised the technique for assessing overexertion hazards of manual lifting. The new document no longer contains two separate weight limits (Action Limit (AL) and Maximum Permissible Limit (MPL)) but has only one Recommended Weight Limit (RWL). It represents the maximal weight of a load that may be lifted or lowered by about 90% of American industrial workers, male or female, physically fit and accustomed to physical labor.

This new equation resembles the 1981 formula for AL, but includes new multipliers to reflect asymmetry and the quality of hand-load coupling. The 1991 equation allows as maximum a “Load Constant” (LC) - permissible under the most favorable circumstances -- with a value of 23 kg (51 lb.)

\[ \text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM} \]
LC - load constant of 23 kg or 51 lb.

** Each remaining multiplier may assume a value [0,1]

HM - the horizontal multiplier: H is the horizontal distance of the hands from the ankles (the midpoint of the ankles)

VM - the Vertical Multiplier: V is the vertical location (height) of the hands above the floor at the start and end points of the lift.

DM - the Distance Multiplier: where D is the vertical travel distance from the start to the end points of the lift

AM - the Asymmetry Multiplier: where A is the Angle of asymmetry, i.e., the angular displacement of the load from the medial (mid-sagittal plane) which forces the operator to twist the body. It is measured at the start and end points of the lift.

FM - the frequency multiplier: where F is the frequency rate of lifting, expressed in lifts per minute.

CM - the coupling multiplier: where C indicates the quality of coupling between hand and load. (see figure)
BORG SCALE

Rating of Perceived Exertion Chart

1  MINIMAL EXERTION

2

3

4

5  MODERATE EXERTION

6

7  SOMEWHAT STRONG EXERTION

8

9

10  EXTREME EXERTION

Instructions: Subjects are to select the level of exertion that is being experienced when queried by the evaluator.
11. **Location of Centers of Gravity on Human Segments Lab**

Objective of Lab: This lab is designed to help you understand how to locate the centers of gravity or mass for various segments in the body.

**IN CLASS INSTRUCTIONS:** Select two people in your group to serve as subjects for Part 1.

**REMOTE OR OFF-SITE STUDENTS INSTRUCTIONS:** Select one subject and please do the same activities in Part 1 and Part 2 below.

**Part 1:**

*In this part LIVE students don’t need to estimate the length for the below segments.*

a. For the subjects being measured, obtained the lengths of the following links.

Also, using the attached figures estimate the length, location for the center of gravity for each person for the following segments.

1. Forearm
2. Thigh
3. Calve
4. Torso, Neck and Head
b. Describe an occupational or product design environment where this information would be useful in biomechanics research or applications.

**Part 2:**

Assume you have been hired as a consultant for the National Basketball Association and the Women's National Basketball Association. They are presently redesigning the weights used to train the athletes and you been asked to obtain the center of gravity for the average NBA player and WNBA player. The only anthropometric information that you have been provided is the average height of the players.

Suppose the average height for NBA players is 6'5" and the average height for WNBA players is 5'10".

a. Use the "height ratio to segment link" to obtain the segments lengths below:

- Upper Arm
- Forearm
- Hands
- Calve
- Thigh

b. Then use the center of gravity figure to obtain the c.g. for four segments that you think are most important for in athletic equipment design. Provide all results in your lab report
Segment Centers-of-Gravity shown as percentage of segment lengths [Dempster, 1955].

12. Two-Joint Angle Influence on Adjacent Joint Mobility Lab

Objective of Lab: This lab is designed to help you understand the importance of adjacent joint angle in joint mobility.

INSTRUCTIONS: Select two subjects from your lab group and obtain the measurements listed below in Part 1; Ask a single subject to perform the movements described in Part 2 and

If you are a REMOTE OR OFF-SITE students you are only required to take measurements for 1 subject in Part 1. If you do not have a goniometer, we will provide you with data from one of the in class lab groups.

Part 1:

Data collection:

- Using the Goniometer, take the following joint angle measurements for 2 subjects
  a. Shoulder flexion
     • Shoulder flexion when the elbow is straight
     • Shoulder flexion elbow flexed
  b. Knee flexion
     • Knee flexion when the hip is not flexed
     • Knee flexion when the hip is flexed
  c. Ankle Angle
• Ankle dorsiflesion when the knee is flexed
• Ankle dorsiflexion when the knee is not flexed

For the data obtained in parts a through c:

a. Generate a mean and standard deviation for your data set
b. Compare these means (when adjacent angle not flexed) to the values obtained in Table 4.3 of your text
c. Create a graph that shows the angle of the joint when it is flexed Vs. not flexed for the adjacent angle.

Part 2:

Description of movement using anthropometric, biomechanical and anatomically appropriate terminology

a. Ask a subject to perform the following motions
d. Movement of the lower limb up and out
e. Movement of the shoulder forward and down
f. Movement of the foot up and out

b. For each of these motions
g. Describe the movement using any anatomically correct convention of movement terms (for example, Table 4.1 text),
h. Describe the plane(s) in which the movement takes place.
13. Seated Work Assessment Lab

Instructions: During the lecture, you will be observing your professor performing the task required to provide a lecture using the computer workstation set-up in the classroom.

REMOTE OR OFF-SITE STUDENTS: perform an assessment of a typical office workers workstation

1. During your observation analysis, use the class notes to answer the following questions:
   a. Does the work area promote proper posture
   b. What are the estimated loads on the spine for the various postures
   c. Does the seat accommodate the requirements of the work area
   d. Do the work envelopes (vertical and horizontal) accommodate the needs of the workplace
   e. Is there an appropriate work distribution
   f. Is there adequate lighting in the work area

2. After the lecture, you will perform an analysis of the equipment, chair and movement required for her to perform the job of lecturing for two hours.

3. After completion of your observation complete the Workstation checklist provided in with your hand outs.
Prepare your results as a group lab report and answer the following questions

- Do the seating accommodations support the body optimally for the task performed
- What appear to be the major biomechanics’ violations of this task
- What are the primary improvements that can be made to improve the work area
**Ergonomic Workstation Checklist**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( ) ( ) Does the working space allow for a full range of movement?</td>
</tr>
<tr>
<td>2.</td>
<td>( ) ( ) Are mechanical aids and equipment available?</td>
</tr>
<tr>
<td>3.</td>
<td>( ) ( ) Is the height of the work surface adjustable?</td>
</tr>
<tr>
<td>4.</td>
<td>( ) ( ) Can the work surface be tilted or angled?</td>
</tr>
<tr>
<td>5.</td>
<td>Does the workstation require:</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· bending or twisting at the waist?</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· reaching above the shoulder?</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· Static muscle loading?</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· extending the arms?</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· bending or twisting the wrists?</td>
</tr>
<tr>
<td>( ) ( )</td>
<td>· raised elbows?</td>
</tr>
<tr>
<td>6.</td>
<td>( ) ( ) Is the employee able to vary posture?</td>
</tr>
<tr>
<td>7.</td>
<td>( ) ( ) Are hands and arms free from pressure from sharp edges on work surfaces?</td>
</tr>
<tr>
<td>8.</td>
<td>( ) ( ) Is an armrest provided where needed?</td>
</tr>
<tr>
<td>9.</td>
<td>( ) ( ) Is a footrest provided where needed?</td>
</tr>
</tbody>
</table>
10. ( ) ( ) Is the floor surface flat?

11. ( ) ( ) Are cushioned floor mats provided for employees who are required to stand for long periods?

12. ( ) ( ) Is the chair or stool easily adjustable and suited to the task?

13. ( ) ( ) Are all task requirements visible from comfortable positions?

14. ( ) ( ) Is there a preventive maintenance program for mechanical aids, tools, and other equipment?
<table>
<thead>
<tr>
<th>Things to look for:</th>
<th>Possible solutions, depending on further analysis:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged hunched or elevated shoulder while holding the phone</td>
<td>Telephone headset</td>
</tr>
<tr>
<td></td>
<td>Speakerphone</td>
</tr>
<tr>
<td>Elbows splayed out (shoulder abduction)</td>
<td>Lower work surface</td>
</tr>
<tr>
<td></td>
<td>Lower chair armrests</td>
</tr>
<tr>
<td></td>
<td>Bring chair armrests in closer</td>
</tr>
<tr>
<td></td>
<td>Awareness and habit training</td>
</tr>
<tr>
<td>Raised or tensed shoulders</td>
<td>Habit or tension training</td>
</tr>
<tr>
<td></td>
<td>Lower work surface or keyboard</td>
</tr>
<tr>
<td></td>
<td>Lower chair armrests</td>
</tr>
<tr>
<td></td>
<td>Raise chair, if foot contact with the floor can be maintained</td>
</tr>
<tr>
<td>Twisting the head to the side</td>
<td>Bring viewed item closer to centerline of view</td>
</tr>
<tr>
<td>Elbow flexed for long periods using the telephone</td>
<td>Telephone headset</td>
</tr>
<tr>
<td></td>
<td>Speakerphone</td>
</tr>
<tr>
<td>Elbow or forearm resting for long periods on hard or sharp work surface, chair armrests</td>
<td>Pad or round surfaces, corners, and armrests</td>
</tr>
<tr>
<td></td>
<td>Replace armrests</td>
</tr>
<tr>
<td></td>
<td>Telephone headset</td>
</tr>
<tr>
<td></td>
<td>Habit training</td>
</tr>
<tr>
<td>Wrist training</td>
<td>Lower, raise, or change slope of the keyboard</td>
</tr>
<tr>
<td>Wrist rest</td>
<td></td>
</tr>
<tr>
<td>Padded or rounded surfaces, corners</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Hands held actively over the keyboard during keying pauses</strong></td>
<td>Habit training</td>
</tr>
<tr>
<td></td>
<td>Wrist or forearm rest</td>
</tr>
<tr>
<td><strong>Rapid, sustained, or prolonged keying</strong></td>
<td>Greater work variety</td>
</tr>
<tr>
<td></td>
<td>Aggressive break schedule</td>
</tr>
<tr>
<td></td>
<td>Reduce overtime</td>
</tr>
<tr>
<td><strong>Forceful keying, key pounding</strong></td>
<td>Habit training</td>
</tr>
<tr>
<td></td>
<td>Light-touch keyboard</td>
</tr>
<tr>
<td><strong>Significant amounts of hand stapling, punching, lifting, opening mail, or other forceful exertions, especially combined with awkward postures</strong></td>
<td>Mechanical aids, such as electric stapler or punch</td>
</tr>
<tr>
<td></td>
<td>Reduce size of lifted loads</td>
</tr>
<tr>
<td></td>
<td>Bring heavy loads close to the body, at a medium height</td>
</tr>
<tr>
<td></td>
<td>Substitute sliding (worksurface) or wheeling (floor)</td>
</tr>
<tr>
<td></td>
<td>Sharpen letter openers</td>
</tr>
<tr>
<td><strong>Prolonged mouse use</strong></td>
<td>Greater work variety</td>
</tr>
<tr>
<td></td>
<td>Aggressive break schedule</td>
</tr>
<tr>
<td></td>
<td>Alternate hands</td>
</tr>
<tr>
<td></td>
<td>Alternative pointer devices</td>
</tr>
<tr>
<td></td>
<td>Arm support, including small table</td>
</tr>
<tr>
<td></td>
<td>Mouse close to body (extended keyboard tray)</td>
</tr>
<tr>
<td></td>
<td>Learn keystroke substitutes for menus</td>
</tr>
<tr>
<td><strong>Prolonged sitting, especially in only one posture</strong></td>
<td>Greater work variety</td>
</tr>
<tr>
<td></td>
<td>Aggressive break schedule</td>
</tr>
<tr>
<td></td>
<td>Chair that supports posture change, through movement, size, or easy adjustability</td>
</tr>
<tr>
<td></td>
<td>Habit training</td>
</tr>
<tr>
<td></td>
<td>Move phone to the other side of the office to force standing, or suggest standing when on phone</td>
</tr>
<tr>
<td></td>
<td>Check chair fit</td>
</tr>
<tr>
<td></td>
<td>Monitor in-out mechanism</td>
</tr>
<tr>
<td></td>
<td>Sit-stand work surface</td>
</tr>
<tr>
<td><strong>Lumbar back area not supported</strong></td>
<td>Lumbar cushion</td>
</tr>
<tr>
<td></td>
<td>Backrest height and tilt</td>
</tr>
<tr>
<td></td>
<td>Check chair fit, especially backrest/lumbar height</td>
</tr>
<tr>
<td><strong>Feet dangling, not well supported, or a posture which seems to put pressure on the backs of the thighs</strong></td>
<td>Lower chair</td>
</tr>
<tr>
<td></td>
<td>Lower work surface</td>
</tr>
<tr>
<td></td>
<td>Habit training</td>
</tr>
<tr>
<td></td>
<td>Foot rest (last resort)</td>
</tr>
<tr>
<td>Issue</td>
<td>Solution</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| Chair backrest not used for long periods                           | Check chair fit, especially seat pan depth and height  
|                                                                     | Check leg room  
|                                                                     | Check monitor distance  
|                                                                     | Habit training |
| Twisted torso                                                      | Rearrange work  
|                                                                     | Provide more knee space  
|                                                                     | U-shaped work surface layout  
|                                                                     | Swivel chair |
| Frequent or prolonged leaning or reaching                           | Rearrange work  
|                                                                     | Mouse pad wrist or forearm rest  
|                                                                     | Bring mouse and keyboard closer to body |
| Working with one or both arms "reaching" toward a mouse or keyboard | Bring keyboard closer to body  
|                                                                     | Mouse pad wrist or forearm rest  
|                                                                     | Bring mouse closer to keyboard |
| Light sources that can be seen by the worker                       | Cover or shield light sources  
|                                                                     | Rearrange work arena  
|                                                                     | Lower other viewed objects to lower field of view |
| Reflected glare on the screen                                      | Shield light sources  
|                                                                     | Shade screen  
|                                                                     | Glare screen  
|                                                                     | Move monitor so light enter from side angle, not back  
|                                                                     | Lower light levels  
|                                                                     | Move light sources |
| Too much contrast between screen and surroundings or document; worker feels relief when bright areas are shielded | Lower ambient light levels  
|                                                                     | Turn off or dim task lights  
|                                                                     | Change screen polarity to black on white |
| Very bright ambient lighting (above 500 lux or 50 fc) or shadowed areas caused by over-illumination | Lower ambient light levels to 200-500 lux (20-50 fc) |
| Monitor closer than approximately 40 cm (16")                       | Push monitor back  
|                                                                     | Habit training for reclining  
|                                                                     | Computer glasses  
<p>|                                                                     | Bring keyboard forward, possibly with a keyboard tray |</p>
<table>
<thead>
<tr>
<th>Issue</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different viewed objects (screen, documents) at different distances from the eyes</td>
<td>Use document stand or otherwise equalize distances to within about 10 cm (4”)</td>
</tr>
<tr>
<td>Screen or documents not oriented perpendicular to the line of sight</td>
<td>Change monitor, document stand angle</td>
</tr>
</tbody>
</table>
| Prolonged near focusing throughout the day with few far-focusing opportunities | Habit training  
Rearrange space to provide view  
Introduce glazing |
| Monitor image dim, fuzzy, flickery, small, or otherwise difficult to read | Upgrade monitor  
Use software to enlarge image |
| Shiny, low-contrast, or small-print documents | Improve lighting on documents if documents cannot be changed |
| Forward position of the head (peering) or squinting | Check for monitor image quality problems or monitor distance  
Suggest consultation with vision specialist |
| Eyestrain complaints | Check all aspects of visual environment  
Suggest consultation with vision specialist |
| Neck extended backwards, head tilted back, even slightly | Remove CPU from under monitor  
Remove tilt-swivel base from monitor (leave ventilation space)  
Check for bifocals and suggest full-frame "computer glasses" prescription |
| Neck flexed (downward) | Raise document or monitor to a comfortable height  
Adjust posture  
Habit retraining  
Check glasses for inadequate prescription |
14. **Work Place Observational Analysis**

Lab Objective: To allow biomechanics students to refresh their workplace evaluation skills through an observation. This lab is designed to teach the application of ergonomic and biomechanics knowledge in the evaluation and determination of biomechanics related work place risk factors.

**Lab Environment:** Any restaurant or work environment in the area.

**Instructions:**

a) Identify a task being performed in the student center, Central Florida or local area.

b) Provide a detailed description of the task which you do your evaluation and the environment in which it is performed.

c) Observe the task for at least 30 minutes (explain to the workers that this is a class lab) – DO NOT INTERFERE WITH TASK PERFORMANCE.

d) Complete the workstation analysis checklists attached while observing the task (submit this sheet as an appendix to your lab report).

e) Also, during and after task observation, consider the categories below. Using the categories identify the types of ergonomic issues associated with each category;
you are to use the checklist but if there are risk factors not shown on the checklist please list and discuss them.

- Anthropometric issues: Posture, lifting & strength requirements
- Workplace layout
- Equipment: Tools, Equipment (i.e. evaluation of needed hand tools)
- Environmental factors (user interface with equipment, temperature, etc.)
- Cardiovascular: Duration and intensity of tool use (hand tools, power tools, etc.)

Use the Washington State WISHA Screening tool developed by Dr. Thomas Bernard to assess the level of risk associated with the different aspects of the work environment.

Discuss the findings of your analysis and prepare your Lab Report using the course guidelines.
15. Muscle Contraction Lab

Objective:

The purposes of this lab are to: (1) distinguish between 3 types of muscle contractions; and (2) identify the type of muscle contraction(s) being performed during selected phases of movement through visual analysis.

Terminology:

Concentric – shortening contraction during which the overall length of the muscle becomes shorter

Eccentric – a lengthening, in a controlled manner, of a previously tensed muscle

Isometric – a contraction where no change in muscle length takes place

Activities:

A. Perform the following simple movements. With regard to the muscles of interest listed below, identify the type of contraction taking place, concentric, eccentric, or isometric.

1. (Wrist flexors) Holding your pencil in your fist with your forearm supinated, curl the pencil upward.

2. (Shoulder abductors) Holding your arms straight out by your sides in a “T” position, slowly lower your arms down to your sides.
3. (Elbow flexors) Make a fist and place it under, but touching, your desktop with your elbows flexed at approximately 90 degrees. The table weighs approximately 300 pounds. Lift up on the table.

4. (Elbow extensors) Perform the down phase of a push-up against a wall.

5. (Elbow extensors) Perform the up phase of a push-up against a wall.

6. (Knee flexors) With your back and heels against a wall, try to curl your leg bringing your heel to the back of your thigh.

B. You need to go to a gym for the below activities; or you can "simulate" them in the ergonomics lab or at home if you are a REMOTE OR OFF-SITE student.

1. Knee Extensions:
   a) Perform an extension with a comfortable weight. What type of contraction is the quadriceps exhibiting?
   b) Have your partner put the pin in at 2-3 plates heavier. Then, have your partner assist you in lifting this weight until you are in a terminal extension. Without the help of your partner, slowly lower the weight. What kind of contraction is the quadriceps exhibiting?

2. Knee Flexion: (you would be in a prone position on your stomach for this exercise)
a) Perform a curl with a comfortable weight. Before you lower the weight, have your partner gently push down on the machine pads at your feet giving you resistance as you lower. What kind of contraction are the biceps femoris exhibiting?

b) Have your partner put the pin in at the very bottom plate. Attempt to lift the load. What kind of contraction are the hamstrings exhibiting?

3. Bench Press:

a) Perform a bench press, up and down phases, with a comfortable weight. What kind of contraction is exhibited by the pectoral muscles during the up phase?

b) What kind of contraction is exhibited by the pectoral muscles during the down phase?

4. Sit-ups:

a) Perform a sit-up any way you feel comfortable. What kind of contractions are the abdominals exhibiting during the up phase?

b) What kind of contractions are the abdominals exhibiting during the down phase?

5. Bicep Curls:

a) Using a dumbbell of comfortable weight, perform a full bicep curl. What kind of contraction is the bicep exhibiting during the lowering phase?
b) Curl the dumbbell up approximately 45 degrees. Have your partner apply force on the dumbbell that is equal to your curling force. What kind of contraction are the biceps performing with your partner’s involvement?

**Discussion:**

1. List at least one example in a sport or exercise of each type of muscle contraction discussed in this lab (concentric, eccentric, isometric). Be specific as to a joint and phase of skill.

2. Explain how gravity by itself is a resistive force.

3. Which type of contraction, concentric or eccentric, do you think would cause more fatigue to occur in a muscle? Why? (Make sure you justify your answer)
II. Ergonomic Application Labs
1. **Anthropometry and Design**

Objective: To understand the measurement of human physical measurements used in human-machine / product design.

Introduction: Anthropometrics identifies the correct human body dimensions used to design a product, workstation, equipment, etc. for productive use by the end-user. For maximum effectiveness, designs should accommodate from the 5th percentile female to the 95th percentile male or 95% of the population.

5th percentile Female – 5 feet tall
5% of the female population has smaller body dimensions. Use to establish the “reach” dimensions.

95th percentile Male – 6 foot 1 inch tall
5% of the male population has a larger body dimensions. Use to determine “clearance” dimensions.

Design Guidelines:
- Design for the average person means those larger or smaller than average will not be accommodated
- When designing for a reach distances the smallest users should be considered
- When designing for clearance, the largest users should be considered
- Adjustability should be considered for all design aspects to accommodate a majority of the population

Task: Based on the above guidelines, determine the design rules for each scenario. Although the design rules are not always feasible solutions, use them to identify the anthropometric relationship.

   Rule 1: Design for the 95th Percentile
   Rule 2: Design for the 50th Percentile
   Rule 3: Design for the 5th Percentile
   Rule 4: Design for adjustability (5th to 95th Percentile)

   a) Adjustability of an office desk chair
   b) Amount of weight a building scaffold will hold
   c) Height of an overhead fixture
   d) Height of a non-adjustable laboratory counter
   e) Force required to activate the brake on a car
   f) Spacing between emergency stop and start buttons
   g) Reach for a continuous operation start button
   h) Force required to operate a lifting device
   i) Maximum reach distance to console controls in a car
   j) Machine guarded access opening
   k) The grip span for toddler sippy cup
   l) Amount of force required to remove the cap of a prescription medicine bottle
   m) Amount of force required to remove the cap of an arthritis medicine bottle
Task: Use the anthropometric wheel to answer the following.

2) A stationary table needs to be installed that will accommodate product re-work. The re-work requirements include opening the packaging (2x4x6 inches), removing the paper inserts and replacing with a new paper insert. The re-worked packaging is then placed in a shallow bin.
   a) What is the required height of the table? Which body dimensions and percentiles were used to determine the height?
   b) What are the maximum vertical and horizontal reaches for placing the packaging in the bins? Which percentiles were used to determine the reaches?

3) A visual display control needs to be placed on a machine. The operator must frequently monitor the controls to collect data, start and stop the machine. The controls will be placed on an articulating arm, however, the arm can not move vertically, only horizontally. The visual controls are on a 17 inch computer monitor.
   a) At what height should the visual control be mounted? What body dimension and percentile were used to determine the height?
   b) What are the minimum and maximum horizontal distances for the articulating arm? What factors need to be considered to determine these distances?

4) Five separate components are required to complete a product. All components can be stored at one workstation. This is a one operator job with small components and each requiring precise quality checks prior to assembly. The job requires the operator to retrieve a single component from five separate bins and assemble them in order.
   a) Should this job be a seated or standing workstation?
   b) What reach should be considered for this job?
   c) What body dimension and percentile were used to determine the reach?
2. **Manual Material Handling**

**Objective:** To identify the needs required to maintain the safety of the operator while maximizing the production capabilities of the operation

**Introduction:** Manual material handling can be one of the most physically demanding jobs in industry. Controls to reduce the risk of injury include training proper manual lifting and transporting methods to providing appropriate handling equipment.

**Task:** The job requires palletizing 1950 cases per shift. The schedule permits for 1 or 2 employees to palletize for an 8 hour shift with breaks totaling 1 hour. Therefore 1 employee would palletize for 7 hours and 2 employees palletizing 3.5 hours each. The operator(s) are required to palletize 5 cases per minute to meet production needs. Each case weighs 22.5 lbs (10.2 kg). The cases are not always palletized at the strongest lifting posture. Some lifts require continuous bending in non-neutral postures.

- What are the risk factors?
- What are the posture risks?
- What are the force risks?
- What are the repetition risks?
- Is this considered a high risk job for 1 employee? For 2 employees?
- How many cases would significantly reduce the job to minimal risk?
- What is the case weight that would significantly reduce the job to a minimal risk?
- If 2 employees are scheduled for the job, what other tasks would increase the risk of injury to the operators?
- Would an increase in the number of cases retrieved (2 or 3 at a time) reduce or increase the risk of injury?
3. **Ergonomics by Design**

Objective: To identify the pros and cons of including ergonomics in the various stages of a product development process. Identify the link between product development and ergonomics. Costs related to proactively implementing ergonomics in the design stages vs. costs associated with adding during the production stages. Costs include injury potential.

**Introduction:** 7 Phases of a Product Development Process
1) Concept Formation - Creating the business plan for a new product idea. This includes market research, understand the customer and visualization.
2) Concept Evolvement – Refining the idea into a saleable product. This phase includes acquiring quoting, benchmarking similar products, establishing feasibility.
3) Collaboration Development – The program is commissioned and formal teams are created. Cross functional teams established to determine engineering needs, timing and budgets, supplier selection, etc.
4) Product Engineering – Engineering the product through drawings, prototype builds, functional and quality testing.
5) Equipment Development - Building tooling and equipment to manufacture the product. Creating and prove-out of the manufacturing process is conducted. Operator jobs are defined and created. Pilot builds are completed during this phase.
6) Validation – Compliance testing of all processes, equipment and products. Final evaluation of all requirements needed for production. Final testing, dimensional inspections and appearance approvals are completed in this phase.
7) Production – Manufacturing Operating System is in operation building customer-ready products.

**Task:**
- What is (are) the most cost effective phase(s) to implement ergonomics for operator-equipment interaction?
- What is the most costly phase(s)? Why?
- What is the least costly phase(s)? Why?
- What are the pros and cons (if any) of implementing ergonomics in the early phases?
- What are the pros and cons (if any) of implementing ergonomics in the final phases?
4. **Design an operator job**

**Objective:** Creating a production line with ergonomics a major component in the development of each operator job.

**Introduction:** When a product is manufactured, how the operator will interact with the process is a key decision. If full automation is not an option, the manual process will require the operator to handle product components. This includes assembly and final packaging.

**Task:** Create a product and outline the manufacturing process. Allow the product to have 5 workstations including a utility operator (responsible for replenishing the line with product components) all working simultaneously, each depending on the next operator. For each job, identify the ergonomic concerns and how they will be avoided. Discuss the operator-equipment/components/product interaction.

1) Where are the components placed? (include reach distances)
2) Are all the workstations seated or standing or a mixture of both?
3) Is this a cell or line formation?
4) What types of tools are used to minimize ergonomic risks?
5) Are operators skilled to the particular task or are they job sharing/rotating? What are the pros and cons of job sharing/rotating?
5. **Manufacturing Key Measures (Cost Justification)**

**Objective:** Understand how ergonomics enhances operations based on manufacturing key measures.

**Introduction:** Production lines that have not incurred injuries are difficult to justify the cost of implementing ergonomics. However, if highly repetitive tasks are present, prevention is important. Because ergonomic injuries are cumulative, there is a high probability that injuries will occur. In order to make a case for the cost required to implement ergonomics, changes need to positively affect the manufacturing key measures.

**Task:** Identify 5 manufacturing key measures and indicate how ergonomics can positively impact the operation. What ergonomic impacts are directly related to each key measure?

Sample Key Measures: Quality, Efficiency, Materials, Delivery, Inventory, Floor Space, Build Consistency, Productivity
Quality – rotation, boredom
Efficiency – minimize movements
Materials – minimize the number of components
Build Consistency – products of the same quality, all products built the same.
6. Rotation

Objective: To understand the importance of rotation, how to create a line rotation and how to account for restricted operators on a production line.

Introduction: Rotation is a quick and effective way of reducing the stresses that cause ergonomic related injuries. This includes the reduction of mental fatigue. Rotation is included in a production line to prevent injuries. This is accomplished by varying the use of muscle groups which avoids muscle fatigue. When rotation is implemented properly, the operation can create a variety of skills in its workforce and maintain the quality and consistency of the manufactured product. In a proper rotation, alternating muscle groups and job difficulty is most important.

Task: Refer to the ‘Design an operator job’ lab:

1. Create a rotation for 4 healthy operators on the production line.

2. Create a rotation for 3 healthy operators and one restricted operator (the restricted operator is complaining of shoulder pain). What are the restricted movements of a person with shoulder pain?

Example:

<table>
<thead>
<tr>
<th>Task</th>
<th>Body Part Most Affected</th>
<th>Most Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1:</td>
<td>Hands/Wrists</td>
<td>Hard</td>
</tr>
<tr>
<td>Task 2:</td>
<td>Shoulders</td>
<td>Easy</td>
</tr>
<tr>
<td>Task 3:</td>
<td>Shoulders</td>
<td>Moderate</td>
</tr>
<tr>
<td>Task 4:</td>
<td>Neck/Eyes</td>
<td>Easy</td>
</tr>
<tr>
<td>Task 5:</td>
<td>Back</td>
<td>Hard</td>
</tr>
</tbody>
</table>

Rotation: 1, 2, 5, 4, 3
7. **Cumulative Trauma Disorders**

1) Choose a job to analyze.
2) By visual analysis, identify the physical and personal risk factors that are present.
3) Complete an ergonomic job analysis of this job using two different ergonomic analysis tools.
4) What are the risk factors identified using the job analysis tool?
5) What are the controls to reduce the risk factors of the job?
6) What are the potential Cumulative Trauma Disorders associated with this job?
*7) When an operator is hurt, what are the essential steps to full recovery?
8. Administrative and Engineering Controls

Objective: To identify the use of administrative controls in settings where engineering controls are unavailable.

Introduction: Administrative and Engineering controls are two types of solutions used to control ergonomic-related risks. Administrative controls are changes in work procedures such as written policies, supervision and training with the goal of reducing the effects of ergonomic risk factors. These controls include job rotation, wellness exercise, methods training, biomechanics training, work scheduling, medical management and job conditioning.

Engineering controls are physical changes to a job or equipment that reduces or eliminates ergonomic hazards. These include workstation and tool design, work methods design, equipment development, product design and design for maintainability.

The uses of administrative solutions many times are the result of complaints by the operator from physical stress and/or an increase in injuries. When engineering solutions are not available, administrative solutions must not jeopardize the success of the operation or positively impact the operations key measures (ie. productivity, efficiency, quality).

Task: Sometimes administrative controls are considered quick fixes for situations that require resources to implement engineering controls that are not readily available. In the following scenarios, assume engineering controls are not an option. Identify the type(s) of administrative controls that will reduce the risk of ergonomic-related injuries.

1. The job requires three operators to hand cap thousands of 2ml vials daily. Only one operator can hand cap at a time. The hand capping is highly repetitive, requiring pinch grip forces and awkward postures. Operators two and three replenish the line of raw materials and package the hand capped completed vial respectively. There are recurring complaints of physical discomfort and symptoms of DeQuervain’s disease. Justify administrative controls that will assist in reducing the affects of the CTD.

2. The job requires two operators to palletize 23 lb cases. Each operator must handle 975 cases in 3.5 hours. The cases are delivered by conveyor to the operator 5 per minute and are placed on a pallet. The risks include repetition, lifting (depending on the origination of the lift) and pushing (depending on the placement of the case). What administrative controls should be implemented to minimize the risks of this physically demanding job?

3. An operator is required to retrieve bottles from a conveyor line and place them in a packaging box. Due to the set up of the production line, high repetition and awkward postures (extreme shoulder and elbow abductions and wrist flexion) are required to perform the job. There are 3 operators on the line. Two operators are responsible for packing the bottles simultaneously. The third operator restocks the line and palletizes the completed boxes. Palletizing poses additional risks.
Thoughts of reducing the line speed were discussed, however, this would slow down the production and operation needs would not be met.

4. The operation requires 100% manual finishing. This process is hand intensive requiring high repetition and awkward postures. This job requires very skilled operators. The average age of the 15 operators is 49 and the average length of employment performing the same task, 10 years. There have been numerous complaints of symptoms and diagnoses of Epicondylitis, carpal tunnel syndrome and other upper extremity injuries. Management would like to replace the manual process with an engineering solution. However, because the product only captures a small market, an engineering solution would not be cost effective. What would be appropriate administrative control(s) for this aging workforce?

5. The utility operator’s job is to maintain working materials at all the workstations. He is also responsible for palletizing the packaged finished product. The materials needed for the line are retrieved from the inventory rooms. The materials are packaged in boxes weighing 10 to 25 lbs. Boxes are lifted from the floor to levels requiring ladders or step stools. These boxes are placed on large three tier carts and transported from the inventory room to the line. To restock the line, the utility operator transfers the materials from the boxes to the line bins. Movements include bending, lifting (levels from the floor to above shoulder height), carrying, and squatting. Lower back and shoulder discomfort are prevalent in this job. There are several types of mechanical equipment already in place however, the job is physically demanding. What administrative controls can be used to reduce the affects of the physical discomfort?
II. Additional Handouts
OVERVIEW OF ERGONOMIC ANALYSIS

Analysis Techniques

Techniques: Ergonomic evaluations, safety evaluations, surveys, interviews, task evaluation, observation of the jobs, utilization of validated task evaluation and measurement tools.

An investigation technique to analyze work tasks to determine human performance requirements, physiological requirement, and other job requirements. In other words, it measures what the person is doing on the job. Investigative techniques include resources such as the NIOSH lifting guideline, Rapid Upper Limb Assessment Tool (RULA), and a hybrid of multiple techniques to address unique problems.

Purpose:
1) To identify task elements or user expectations that may be reducing productivity or making job unnecessarily difficult, or causing injuries or illnesses or promoting preventable risks.
2) To identify factors and categories of ergonomic, biomechanics or safety problems
3) To develop solutions to ergonomic problems

Benefits:
1) identify sources of injuries, fatigue, discomfort, and reduced productivity
2) information on type of capabilities needed to perform the job
3) information on percentage of population capable of performing the job

How is the analysis done?
1) Initial problem analysis
2) Problem Classification – may be more than one category of risk/concern
3) Investigate and quantify job requirements
4) Analyze human performance and physiological requirements
5) Determine user/operator population
6) Identify validated ergonomic and biomechanics resources to be used to assess the ergonomic status of the given environment
7) Develop strategies for design or redesign when needed(as many design solutions; more than 1)
8) Discuss financial implications
9) Develop draft implementation plan

2) Initial Problem Analysis
   d) thorough description of the problem
   e) Analysis of attributes that contribute to the problem
      iii) job design, workplace design, design of equipment and tools etc.
iv) human operator
   1) requirements exceeds capabilities of operator?

2) Operator or user knowledge of the procedures or operational requirements?
   iv) situational or external factors
      1) supervisor
      2) policies
      3) stress or pressure

3) Upon identification of the problem attempt to classify the nature of the problem in
one or more ergonomic areas
   e) anthropometric
   f) physiological
      i) musculoskeletal, cardiovascular
   g) psychological
      i) information overload
   h) environmental
      i) noise, heat

3) Investigate and Quantify Job Requirements
   j) Describe duties of each task
   k) Percent of time spent on each task
   l) Job responsibilities
   m) Analysis of knowledge and skill needed
   n) Performance standards to be met
   o) Evaluation of working conditions, safety hazards
   p) Evaluation of tools and equipment used
      • Perform evaluations of tools and equipment for adherence to ergonomic
        principles.

4) Analysis of Human Performance and Physiological Response
   b) Performance measures
      ii) productivity over the shift
         c) total unit completed, units per hour, idle time, time on arbitrary
            tasks, interruptions, distractions, accidents, etc.
         d) Performance measures
      iii) quality of output
         b) number of defects, number of mistakes, number of times
            referenced instructions, etc..

b) Physiological measures
   i) direct measurements
      a) heart rate, blood pressures, breathing rate, muscle activity
         (EMG reading), body/skin temperature, oxygen consumption
   c) Psychophysical measures (subjective technique)
      i) perceived exertion, difficulty, energy expended, level of fatigue

4) Design or Redesign Strategies: Develop methodologies or tools to support the
followings levels of ergonomic intervention
   b) Engineering approach
      ii) eliminate the problem by design or redesign
c) Administrative controls
   ii) Suggest appropriate work aids, assistive devices, etc.

c) Personal protective equipment (*Caution: treat symptoms not the cause of the problem*)

5) Determine characteristics of user populations (physical, cognitive, etc.)
6) Develop draft implementation strategy for incorporating ergonomic interventions into system
7) Discuss economic implications (when feasible)
8) Project report development

**What is involved in a survey technique:**

1) Analyze existing data - accident reports, medical visits, absenteeism, environmental conditions etc..
2) Discuss with supervisory people to obtain information on
   a) production pressures and perceived staffing adequacy for production goals
   b) seasonal or infrequent work demands
   c) specific jobs or tasks of concern from a safety or performance standpoint, such as heavy lifting or difficult visual work
   d) What is done to accommodate worker with reduced capacity, etc..
3) Much of the information can be collected from the person doing the job
4) Make sure all of the factors of concern have been identified

**Examples of Job Task characteristics**

Examples under three main categories:

1) *Physical demands*: strength, heavy lifting or force exertion, endurance requirements
2) *Mental load*: skill requirements, training time needed, monotony of job
3) *Perceptual needs*: visual acuity needs, color vision needs
Handling Baggage at Airports

Airline employees, including ticket agents and ramp agents, handle passenger baggage at several points throughout the baggage handling process. The body postures, repetitions, and forces required to lift, lower, push, pull, or carry passenger baggage can create potentially serious ergonomic hazards for the agents.

Assumptions regarding Risk Factors:

Task Factors

1. Repetition – multiple bags are handled in one load

2. Duration – takes approximately 30 minutes to load or unload for a team

3. Operator can unload up to 16 aircraft in a 8 hour work period

4. Force – suitcases up to 32kg pounds are handled individually and over 32 kg are handled by two operators

5. Awkward posture of the upper body

6. Awkward hand and joint posture

7. Manual material handling

8. Operators wear gloves
9. Heavy objects are labeled

Personal Characteristics

1. 80% of employees are men and 20% are women

2. Most are less than 55 years old

3. Employees are accustomed to physical labor

Organizational Factors

1. Non-union organization

2. No current risk of layoffs

3. History of CTD’s (including back injuries) in approximately 20% of employees; this rate has been fairly consistent for the last 5 years however, the proportion of back injuries has been reduced while upper extremity CTD’s is gradually increasing

4. The work environment varies with the weather and time of day

CASE STUDY EXERCISE

1. Select one of the following baggage handling environments:

   a. Airline employees or baggage handlers of checked baggage at the check in counters for the airport

   b. Baggage handlers that load and remove bags from the aircraft
2. Develop a methodology to do a task analysis for assessment of MMH and CTD risk factors

3. Briefly describe what you believe the task entails

4. What do you expect the primary risk factors to be in this environment?

5. Who are the individuals that you will consult in the organization to work with you in the ergonomic evaluation?
Ticket Counter (Check-In Area)

Ticket agents generally encounter hazards while working at a computer workstation and while transferring baggage. Agents often stand at a computer workstation for long periods of time, which may result in fatigue and awkward postures. They also retrieve, weigh, and tag the passenger baggage as well as move it onto a feeder conveyor. Lifting heavy or awkward baggage can lead to various ergonomic hazards resulting in injuries. However, these hazards may be avoided by implementing simple controls in the following areas.

**Potential Hazards:**

- Standing on hard floors or sitting for long periods of time can fatigue the back and leg muscles.

- Working while assuming awkward neck and wrist postures can cause discomfort and may lead to musculoskeletal disorders (MSDs). (Figure 1)
Potential Hazards:

- Awkward neck and wrist postures from using monitors (VDTs), keyboards, and mouse devices that are placed too low may create stress in the joints and muscles.

- Contact stress to wrists may result from contact with counter edges.

- Extended or repetitive reaches across the counter to retrieve items from passengers (bag tags, boarding cards, etc.) or to lift or tag baggage can cause back and shoulder injuries. (Figure 3)
### Potential Hazards:

- Handling heavy, large, or oddly shaped baggage requires use of excessive force and awkward postures, increasing the risk of musculoskeletal injury.

- Handling uneven loads, such as when grabbing two bags of different weights or carrying a single bag with one hand, can lead to uneven muscle exertions and poor postures, making muscles, ligaments, and discs more prone to injury.

- Repeatedly handling baggage can increase the risk of musculoskeletal injuries.
  - Frequent lifting may not allow sufficient recovery time and increase the risk of muscle fatigue.

- Lifting a bag by the handle can result in awkward postures and may cause injury if handles break. (Figure 1)

- Baggage straps getting snagged or caught on a beltloader may cause injury.

- Falling baggage can cause injury to unsuspecting workers as well as those who try to stop or catch the falling bags.

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### Potential Hazards:

- Positioning the end (closest to the cart) of the beltloader too low may cause agents to bend at the waist when placing or removing baggage. This can lead to unnecessary stresses on the body.

- Positioning the end of the beltloader too high may cause agents to raise their shoulders or extend their elbows away from their body when placing or removing baggage.
Potential Hazards:

- Positioning the end of the beltloader (near cargo bin) too low forces agents to bend and lift bags up to put them into the cargo bin.

- Positioning the end of the beltloader too far away from the cargo bin may require agents to reach and pull bags into the compartment.
Potential Hazards:

- Handling heavy, awkward, and large bags in a limited space (Figure 14) places the handler in stressful positions that can result in injury.

- Frequent lifting may lead to insufficient recovery time and muscle fatigue.

- Performing extended reaches while working in limited spaces can stress the neck and shoulders.

- Sitting on the edge of the cargo bin while lifting or arranging baggage (Figure 15) causes the handler to twist while lifting or sliding baggage.
Potential Hazards:

- Kneeling in the cargo bin can strain the knees, especially when handling heavy baggage. (Figure 17)

- Jumping out of bins or off of equipment causes trauma to joints.

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Loading Bridge

Potential Hazards:

- Taking gate-checked baggage by hand from the gate to the cargo bin places stress on the worker's shoulders and back, especially if the bags are large or heavy.

- Taking strollers, wheelchairs, or other oddly shaped and heavy items up or down loading bridge stairs can be dangerous, especially during wet or icy conditions.