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Ergonomic Study

Rubber Sleeves

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Purpose

- Evaluate and Develop a practical ergonomic recommendations for users of rubber sleeves based on:
  - Observation data
  - Scientific Formulas
  - Mechanical Devices

Basis of Science

- Dr Allan Hedge, PhD Professor Cornell University:

Model predicting individual shoulder muscle forces based on relationship between electromyographic and 3D external forces in static position.

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Repetitive Motion Injuries (RMI)

•Repetitive Strain Injuries
•Cumulative Trauma Disorder

•Class of injuries that result from short and long term overuse of human joints and connective tissues.

•Connective tissues can become unusable from repeated exposure to micro-trauma.

•Slow onset of symptoms, people sometimes ignore the condition until the symptoms become chronic and permanent injury occurs.

Visualization of RMI Cycle

- Visualize RMI as joints/connective tissue as a bucket.
- Micro-trauma from activity drips into your joint's trauma bucket.
- The body can heal with time and safely absorb a certain amount of trauma.
- If overload of trauma is placed into the bucket than can be absorbed by the natural healing process, the result can be debilitating pain and impaired movement.

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RMI Factors

- **Force** — forceful exertions….micro-trauma over time.
- **Frequency/Repetition** — too much repetition or too little movement can contribute to micro-trauma.
- **Posture/Position**— there are certain postures in which we are more susceptible to injury, especially at the extremes of our range of motion. For example, reaching with heavy objects repeatedly is a RMI risk factor.

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Scientific Approach to Force on muscles of the shoulder

- Certain movements with added weight can cause muscles to exert forces
- The deltoid and supraspinatus muscles are two most primarily involved
- To find out how much force they have to exert we must first consider the weights of the rubber sleeves and the human arm itself.

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Typical Line worker Positioning

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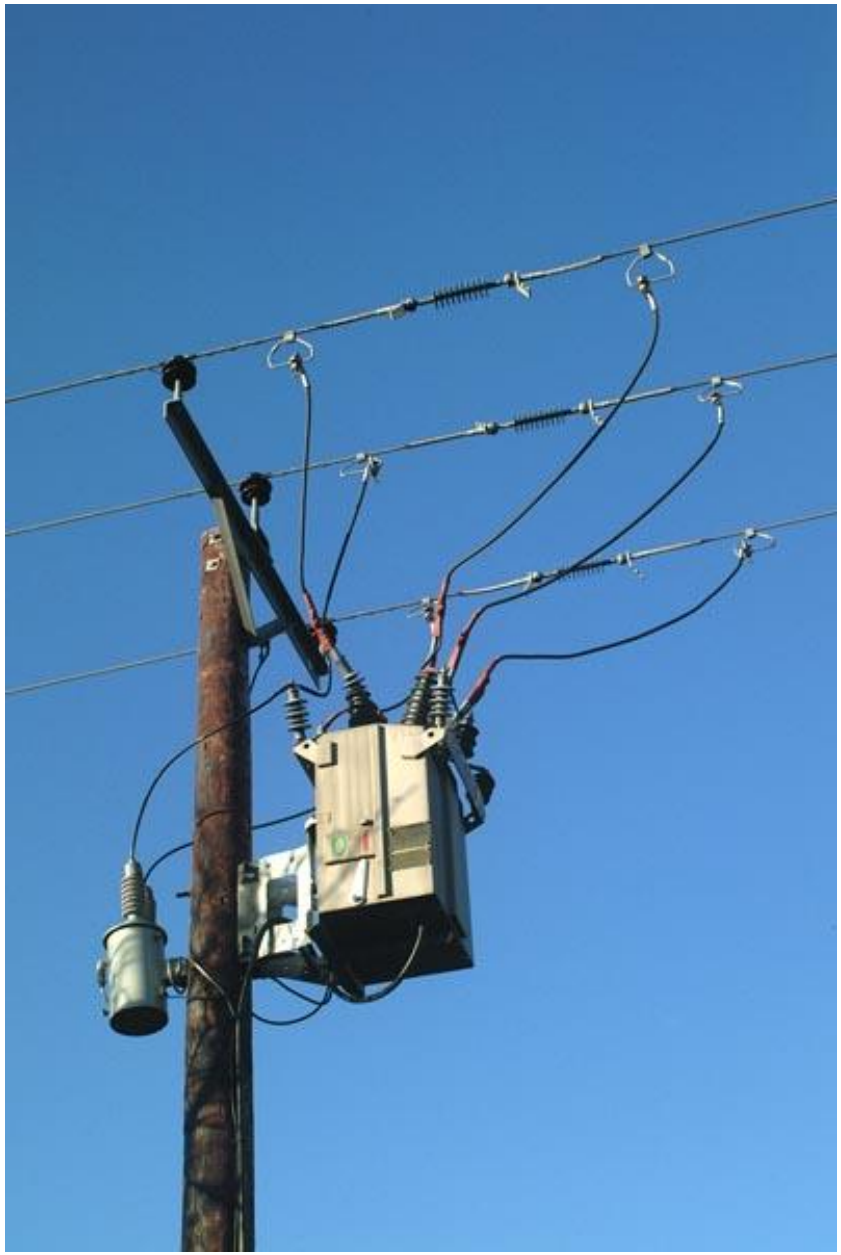

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Science of Ergonomics

- Distinction between “mass and “weight” must be established
- If forces acting on a motionless body are balanced, it will remain motionless
- Alternatively, if balanced forces act on a body that is already moving, it will continue moving with the same velocity (that is the same speed and direction)
- Any unbalanced force will change its velocity. Acceleration is the rate of change of velocity.

Newton Second Law

- As an example: A falling stone speeds up from 10 meters per second to 20 meters per second squared (m/s2). Newton's second law of motion tells us that:
- **Force=Mass x Acceleration**
- The scientific unit of force is called the Newton.
- One Newton is the force needed to give a mass of one kilogram an acceleration of one m/s2.

Mass – Weight- Gravity

- Science makes a sharp distinction between mass and weight.
- Mass of an object (generally measured in kilograms or pounds) tells us about inertia and how hard it is to accelerate.
- Its weight (measured in newtons) is the force that gravity exerts on it.
- Example

  If you took an object to the moon, its mass would remain the same but its weight would be less because gravity is weaker there.

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Metric Mass of a Rubber Sleeve

- On earth an object falling freely in a vacuum has an acceleration of 9.8 m/s2.
- Therefore by newtons second law a mass of one kilogram has a weight of 9.8 newtons.
- A rubber sleeve has an average English mass of 1.625 pounds per arm
- That equals to .748 kilograms. So each sleeve has a metric mass of .748 kg x 9.8 = 7.33 newtons.

Distribution of Load

- The mass of a typical human male arm is 3.6 kilograms corresponding to a weight of approximately 35 newtons.
- Now we can calculate the effects of the weight on the shoulder.
- The sleeve mass is .748 kilograms and it is distributed from the shoulder to the wrist with thickness of 1.27-2.54 millimeters.
- This is a **great advantage** from a stress perspective, as load is distributed over the entire surface nearly evenly.
- Unlike a mass held and extended at the end of the appendage (insulated live line tool, pneumatic device, etc.) (see next paragraph on Undistributed loads) the rubber sleeve has less impact on the shoulder via the mass distribution over length of arm.

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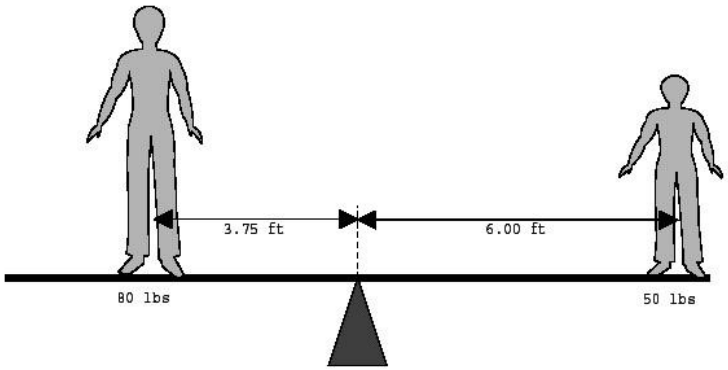
Non-Distributed Load

• The turning effect of a force is given by its moment the force multiplied by the perpendicular distance from its line of action to the pivot.

• Multiplying the force in newtons by the distance in meters gives the moment in Newton meters

•The 35 newton weight of the human arm acts as the center of gravity which is .32 meters *from the joint* giving a moment of 11 newton meters which is **<u>significantly less</u>** than a 3lb tool is held in an extended position.



80 pounds X 3.75 feet = 300 foot-pounds
50 pounds X 6.00 feet = 300 foot-pounds
(seesaw is balanced)

Figure 1

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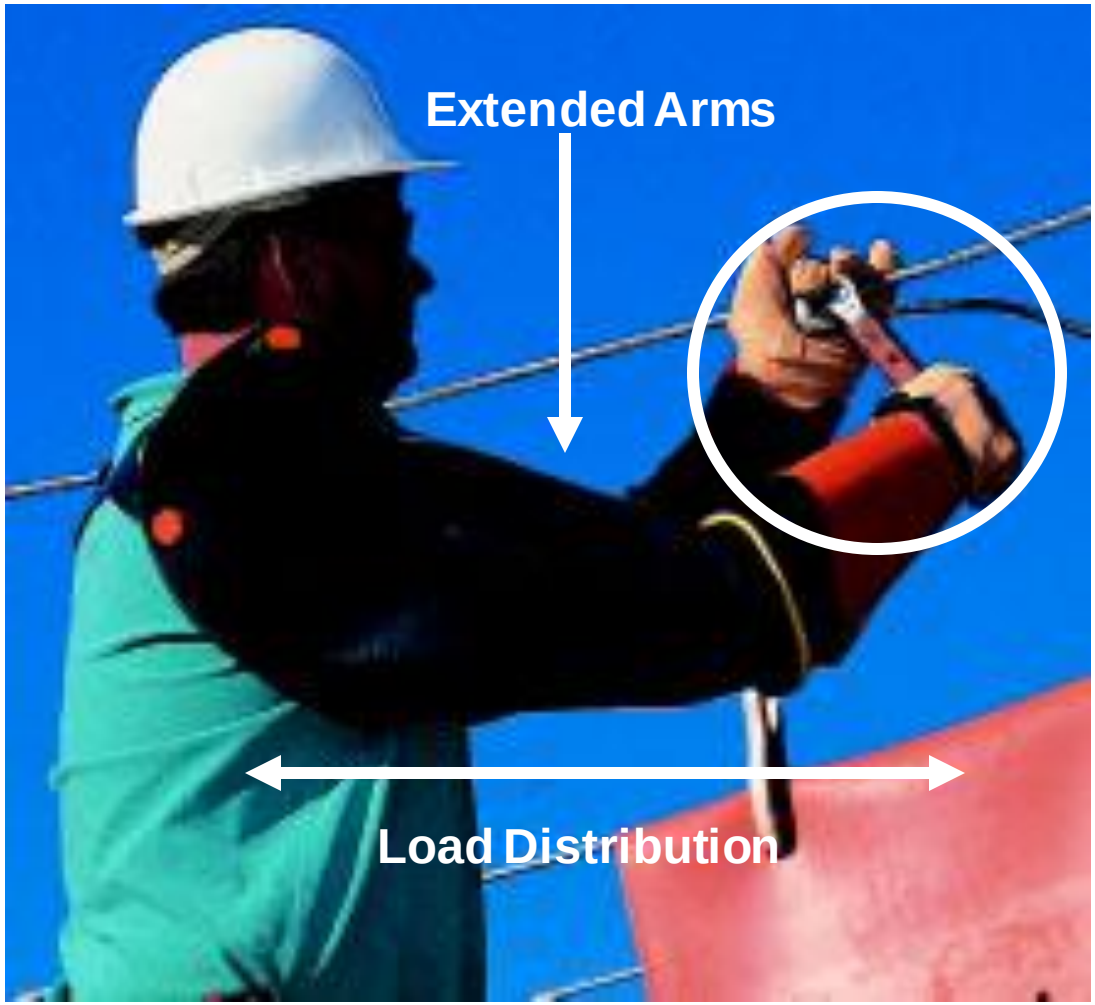
Load Distribution



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Ergonomic Formula & Observation #1

- Repetition + Position +Force + Time + No Rest = RMI

Transfer of Primary & Secondary Conductors

Arm Lifts Repetition	Leaning Over Bucket Position	Duration (time)	No Rest Time	Total
119	37	35 minutes	29 minutes	220 (70%)
Lunch Break				
46	17	15 Minutes	15 Minutes	93 (30%)

Cumulative job total 313
Additional force from rubber sleeves =165 newton meters

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Typical work….Reaching Above

Ergonomic Formula & Observation #2

- Repetition + Position +Force + Time + No Rest = RMI

Transformer Replacement Primary & Secondary Conductors

Arm Lifts Repetition	Leaning Over Bucket Position	Duration (time)	No Rest Time	Total
24	11	18 minutes	15 minutes	68 (31%)
Lunch Break				
59	18	42 Minutes	35 Minutes	154 (69%)

Cumulative job total 222
Additional force from rubber sleeves =83 newton meters

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Review of Observation Data

1. Duration (time) on primary and secondary equipment was nearly identically inverted from Job 1 to Job #2.
2. Job #1 on July 13th was approx 30% more demanding in a human factor requirement in a relatively similar time frame to Job #2 performed on July 14.
3. Forces exerted at the shoulder would be equivalent between primary and secondary line observing similar movements and use of tools and equipment.
4. Arm extensions above the forward plane create additional force on the shoulder joint.

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Approximate Values for RMI with rubber sleeves for overhead line work

< 200 RMI	200-300RMI	>300RMI
Less Stress	Average Stress	Higher Stress

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Review of Observation Data
Repositioning

- Workers reported fewer complaints when buckets were repositioned at the same level as the conductor/device **OR** slightly above the conductor/device allowing the arms to fall into a lower position.

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Level or Higher position over the work is better..

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Review of Observation Data
Summary Recommendations

- Although the rubber sleeves added an additional amount of force on the shoulder joint, it is not significant when the bucket is repositioned to a level or elevated position.

Summary and Opportunities going forward

- Repositioning of bucket vs. stretching or leaning
  - Training opportunity
- Duration of task
  - Rest periods

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Final Summary

- Use of rubber sleeves adds some stress to the shoulder
- Not much more than a very heavy outer garment
- Minimal in comparison to extending hand held tools

- Rubber sleeves are a necessary protective device when working in proximity of energized conductors and equipment.