OSC|10
Ohio Safety Congress & Expo

Developing & justifying your ergonomics improvements

Session 924

W. Gary Allread, PhD, CPE

Thursday, April 1, 2010 8 a.m. to 4 p.m.

INTRODUCTION

Start

Overview

Topics to be Covered

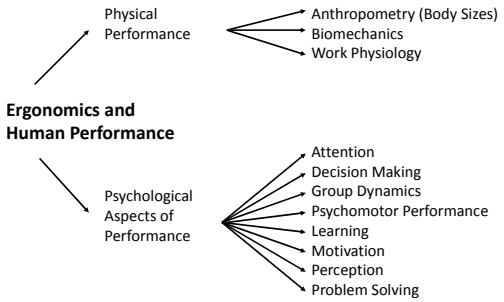
- o Reviewing risk factors for musculoskeletal disorders (MSDs) – the "big picture"
- o Determining methods to assess injury risk
- o Setting priorities for making ergonomics-related improvements
- o Developing ergonomics solutions
- o Cost-justifying ergonomics solutions

Ergonomics

Definitions

- o "An applied science, concerned with designing and arranging things people use so that the people and things interact most efficiently and safely" MERRIAM-WEBSTER
- o "The design of work systems around the capabilities and limitations of people"

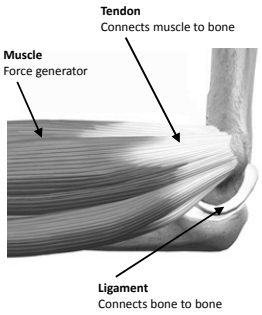
Ergonomics Considers…



Safety vs. Ergonomics

- o Safety – usually focuses on preventing <u>acute trauma</u> (i.e., injury often from a one-time, high-force incident)
- o Ergonomics – usually focuses on preventing <u>musculoskeletal disorders (MSDs)</u> (i.e., injury often from repeated exposure to low-forces)

Basic Anatomy and Injury Terms



- MSD
  - An injury to the body's soft tissues caused, over time, by work activities
- Strain
  - An injury to a muscle, often caused by overuse
- Sprain
  - An injury that occurs to ligaments caused by a sudden over-tearing

Injuries of Concern

Musculoskeletal Disorder (MSD)

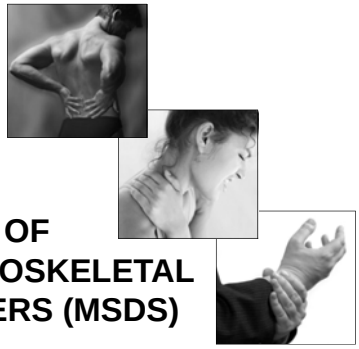
An injury to the body's soft tissues (e.g., muscles, tendons, ligaments) caused, over time, by work activities

Strain

An injury to a muscle, often caused by overuse

Sprain

An injury that occurs to ligaments caused by a sudden over-tearing

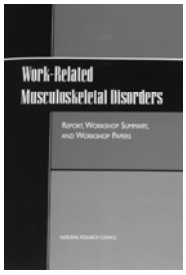


CAUSES OF MUSCULOSKELETAL DISORDERS (MSDS)

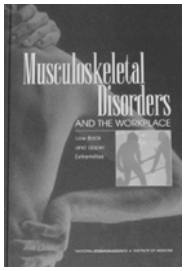
Causes of Musculoskeletal Disorders (MSDs)

- Physical Factors
  - Exposure to job demands (e.g., forces, postures, repetition)
- Work Organizational Factors
  - Exposure to how a job is structured (e.g., job control, time pressures, wages)
- Individual Factors
  - What employees bring to the job (e.g., age, gender, body size)

National Academy of Sciences Research



NAS, 1999



NAS, 2001

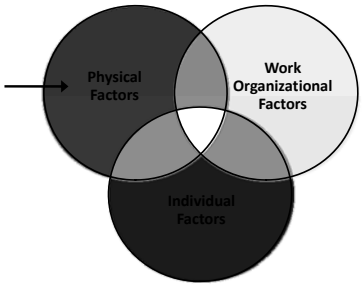
National Academy of Sciences Conclusions (2001)

- The weight of the evidence justifies the identification of certain work-related risk factors for the occurrence of MSDs of the low back and upper extremities
- …there is a clear relationship between back disorders and physical load; that is, manual material handling, load moment, frequent bending and twisting, heavy physical work, and whole-body vibration

National Academy of Sciences
Conclusions (2001)

- o For disorders of the upper extremities, repetition, force, and vibration are particularly important work-related factors
- o Work-related psychosocial factors were also recognized … to be associated with low back disorders
- o A number of individual factors appear to affect vulnerability to work-related MSDs

Interactions of MSD Risk Factors

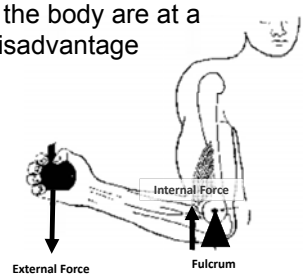


Physical Risk Factor Categories

- o Force
  - The level of muscular effort required to perform a task
- o Posture
  - The body position assumed during a task
- o Repetition
  - The number of (similar) exertions required during a task

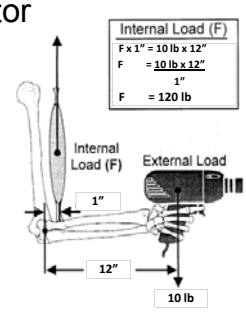
Force
Why It's a Risk Factor

1. Most joints in the body are at a mechanical disadvantage



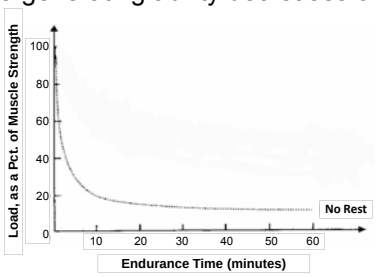
Force
Why It's a Risk Factor

2. Internal forces generated by muscles are much higher than external forces



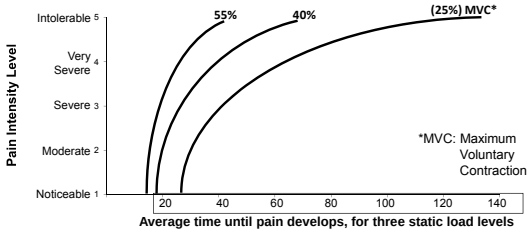
Force
Why It's a Risk Factor

3. Force-generating ability decreases over time



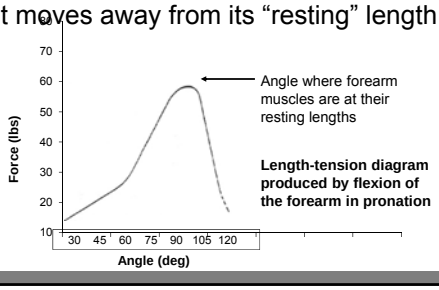
Force
Why It's a Risk Factor

4. Pain becomes more intense as force levels increase



Posture
Why It's a Risk Factor

1. A muscle's strength decreases dramatically as it moves away from its "resting" length



Using Posture to Gain Strength

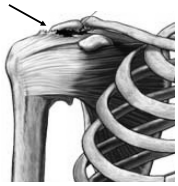
Repetition
Why It's a Risk Factor

1. Repeated use damages soft tissue

Healthy tendons

Inflamed and torn tendons

Rotator Cuff Tear



Physical Work
Links to MSDs

Evidence of a Causal Relationship between Physical Work Factors and MSDs

Body Part / *Risk Factor*	Strong Evidence	Evidence	Insufficient Evidence	Evidence of No Effect
Shoulder				
• *Posture*		■		
• *Force*			■	
• *Repetition*		■		
• *Vibration*			■	
Elbow				
• *Posture*			■	
• *Force*		■		
• *Repetition*			■	
• *Combination*	■			

Source: *Musculoskeletal Disorders and Workplace Factors*, National Institute for Occupational Safety and Health, 1997

Physical Work
Links to MSDs

Evidence of a Causal Relationship between Physical Work Factors and MSDs

	Body Part / *Risk Factor*	Strong Evidence	Evidence	Insufficient Evidence	Evidence of No Effect
Carpal Tunnel Syndrome	**Hand/Wrist**				
	• *Repetition*		■		
	• *Force*		■		
	• *Posture*			■	
	• *Vibration*		■		
	• *Combination*	■			
Tendinitis	**Hand/Wrist**				
	• *Repetition*		■		
	• *Force*		■		
	• *Posture*		■		
	• *Combination*	■			

Source: *Musculoskeletal Disorders and Workplace Factors*, National Institute for Occupational Safety and Health, 1997

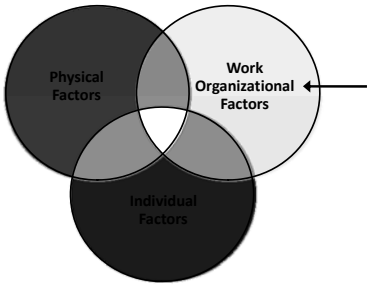
Physical Work
Links to MSDs

Evidence of a Causal Relationship between Physical Work Factors and MSDs

Body Part *Risk Factor*	Strong Evidence	Evidence	Insufficient Evidence	Evidence of No Effect
Back				
• *Lifting/Forceful Movement*	■			
• *Awkward Posture*		■		
• *Heavy Physical Work*		■		
• *Whole Body Vibration*	■			
• *Static Work Posture*			■	

Source: *Musculoskeletal Disorders and Workplace Factors*, National Institute for Occupational Safety and Health, 1997

Interactions of MSD Risk Factors



Work Organization
Definition

- o "The way work processes are structured and managed" (NIOSH)
- o How work is "organized, distributed, and supervised" (Smith et al., 1997)
- o One of the priority research areas of the National Occupational Research Agenda (NORA)

Work Organization Factors

- o Work Scheduling
  - Hours of work
  - Shift work
  - Ability to take breaks
  - Pacing
  - Fluctuations in work hours
- o Job Design
  - Complexity of tasks
  - Skill and effort required
  - Amount of work required (e.g. quotas, production standards)
  - Requirements for attention
- o Reward Structures
  - Pay & benefit structures
  - Personal recognition
  - Job security
  - Promotion opportunities

Work Organization Factors (continued)

- o Job Control
  - Autonomy
  - Access to information
  - Influence over job-related decisions
- o Interpersonal Aspects of Work
  - Supervisory styles
  - Employee involvement / teamwork
  - Communication / feedback
  - Conflict resolution
  - Supervisor and coworker **social support**

Possible Employee Responses to Stressors

<u>Positive</u> Responses to Work Stressors

- o Perceived challenge, not threat
- o Seek social support
- o Communicate, negotiate, problem-solve
- o Appropriate symptom reporting

<u>Negative</u> Responses to Work Stressors

- o Complain or withdraw
- o Passive or negative mood
- o Call in sick
- o Increase eating / drinking / smoking

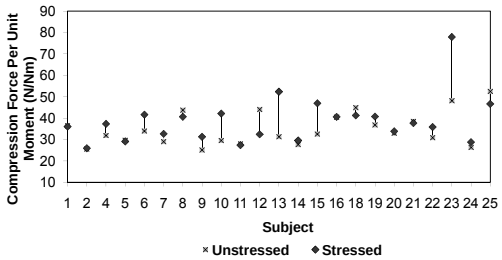
Effects of Psychosocial Stress
Research Study Results

Study Procedure

- o Un-stressed session
  - Subject performs lift tasks
- o Experiment interruption
  - Experimenters called out of room
- o Stressed session
  - Subject performs same lift tasks

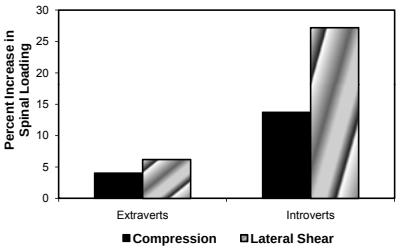
Source: Marras et al., The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine, *Spine*, 2000.

Spine Loading due to Psychosocial Stress



Source: Marras et al., The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine, *Spine*, 2000.

Spine Loading due to Psychosocial Stress: Personality



Source: Marras et al., The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine, *Spine*, 2000.

Work Organization
Links to Injury Risk

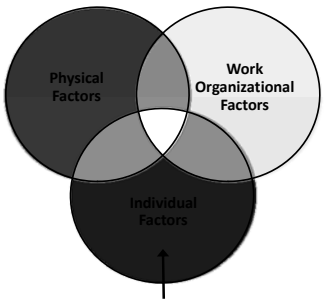
Factor	Odds Ratio
Job Stress	1.3 – 2.1
Job Dissatisfaction	1.4 – 2.4
Monotony	1.3 – 2.3

Work Organization
Links to Back Pain

Factor	Odds Ratio (95% Confidence Interval)
Low Coworker Support	1.2 (1.0 – 1.5)
Lack of Control over Job	1.3 (1.1 – 1.6)
Lack of Job Security	1.4 (1.1 – 1.6)
Low Supervisor Support	1.5 (1.2 – 1.8)
Job Dissatisfaction	1.6 (1.4 – 2.0)

Source: Johnson et al., Stressful Psychosocial Work Environment Increases Risk for Back Pain Among Retail Material Handlers, *American Journal of Industrial Medicine*, 2003.

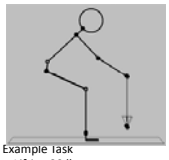
Interactions of MSD Risk Factors



Individual Factors

- o Gender (Kelsey 1975, Burdorf 1997 n.s.)
- o Body Size (Heliovaara 1987, Hansson 1987, Deyo 1989)
- o Age (Goh 2000, Mayer 2001)
- o History of Low Back Pain (Waxman 2000, Vingard 2002)
- o Income (Latza 2002)
- o Strength (Lee 1995)
- o MMH Skill (Buseck 1988)
- o Smoking (Deyo 1989, Feldman 1999, Miranda 2002)
- o Personality (Allread 2000, Marras 2000)

Gender Differences
Strength



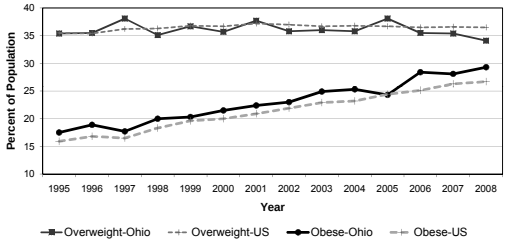
Example Task
- o Lifting 30 lbs
- o Hand Locations
  - o 25" above floor
  - o 16" away from body (mid-point of ankles)

Percent of Population having Adequate Strength to Perform a Task (Example)

Body Part	Male			Female		
	5th	50th	95th	5th	50th	95th
Elbow	99	99	99	99	98	97
Shoulder	95	94	92	42	35	23
Torso	97	95	91	91	86	73
Hip	93	90	85	81	72	52
Knee	99	99	97	99	99	97
Ankle	99	99	97	100	99	97

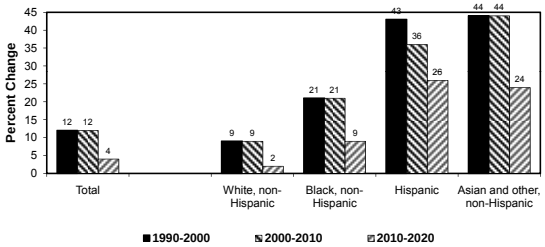
Source: 3D Static Strength Prediction Program (University of Michigan, www.engin.umich.edu/dept/ioe/3DSSPP)

Body Size Differences
Overweight & Obesity Stats – Ohio



Source: National Center for Chronic Disease Prevention & Health Promotion, Behavioral Risk Factor Surveillance System

Body Size Differences
Projected Change in US Labor Force



Source: Bureau of Labor Statistics

Effects of Aging
General Trends

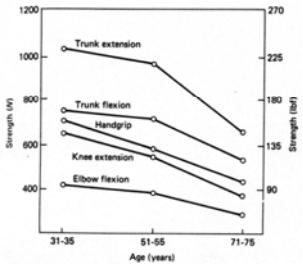
Decreases

- o Strength
- o Muscle mass
- o Bone density
- o Visual acuity
- o Auditory acuity
- o Fitness
- o Aerobic capacity
- o Cognitive speed and function

Increases

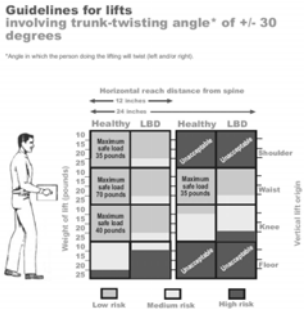
- o Obesity
- o Arthritis
- o High blood pressure
- o Diabetes
- o Depression
- o Heart disease

Effects of Aging
Strength Reductions



Source: JT Viitasalo, et al, 1985, Muscular Strength Profiles and Anthropometry in Random Samples of Men Aged 31-35, 51-55, & 71-75 years. *Ergonomics*, 28(11):1563-1574.

History of Low Back Pain



Complete Lifting Guidelines are available at www.ohiobwc.com

LBD = Low Back Disorder

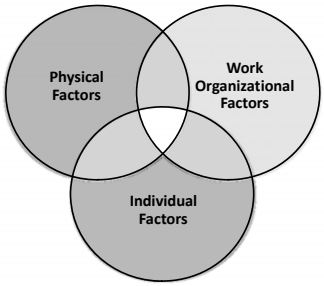
Individual Factors – Links to Possible Injury Risk (examples)

- Gender: Females used more force and had more deviated postures using computers than males (Wong et al 2009)
- Body Size: Smaller individuals had larger forces, muscle activities, and posture deviations than larger individuals (Wong et al 2009)
- Personality: Employees whose personalities were mismatched with their work reported more musculoskeletal discomfort (Allread 2000, Marras 2000)

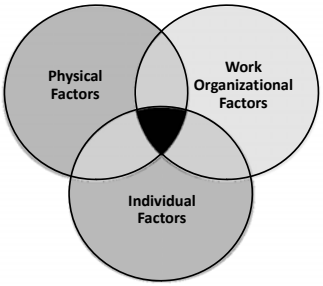
Individual Factors – Links to Back Pain (examples)

- Age: The spine becomes more unstable over time (Iguchi et al 2003)
- Body Size: A weak but significant association between back pain and obesity (Leboeuf-Yde 2000)
- Smoking: Smokers had an 18% increase in spine disc degeneration (Battie et al 1991)
- Previous Back Injury: 87% of studies found a positive relationship between prior injury and risk of another occurrence (Ferguson & Marras 1997)

Interactions of MSD Risk Factors



Interactions of MSD Risk Factors



PROACTIVELY ASSESSING INJURY RISK

Types of Ergonomics Assessments

Type	Advantages	Disadvantages
Self Reports	• Straightforward to use • Applicable to many work situations • Can survey many at low cost	• Employee perceptions of risk are imprecise, unreliable
Observation	• Inexpensive • Can be used across many workplaces • Non-disruptive to employees	• Intra- and inter-observer variability • Best for static postures and rather simple repetitive activities
Direct Measurements	• Large amounts of data • Highly accurate data	• Analysis time • Equipment investment

Source: Burdorf et al, *American Journal of Industrial Medicine*, 1997.

Self Reports

Technique	Precision	Cost	Feasibility
Question-naire	Low	Low	High
Diary	Low	Low	Medium
Interview	Low	Medium	High

Source: Burdorf et al, *American Journal of Industrial Medicine*, 1997.

Observation

Technique	Precision	Cost	Feasibility
Observers/ Checklists	Moderate	Medium	High
Video systems	High	High	Low

Source: Burdorf et al, *American Journal of Industrial Medicine*, 1997.

Observation

Ergonomics Assessment Tools*

o Checklists

- Washington State-Hazard Zone and Caution Zone Checklists (www.lni.wa.gov/Safety/Topics/Ergonomics/ServicesResources/Tools/default.asp)
- Ohio BWC-CTD Risk Factor ID Form (www.ohiobwc.com/employer/programs/safety/ergotools.asp)
- OSHA-Computer Workstations Checklist (www.osha.gov/SLTC/etools/computerworkstations/checklist.html)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

Direct Measurements

Technique	Precision	Cost	Feasibility
Heart Rate Monitors	Moderate	Low	High
Oxygen Consump-tion Monitors	Moderate	Medium	Low
Blood Pressure Devices	Moderate	Low	Low

Source: Burdorf et al, *American Journal of Industrial Medicine*, 1997.

Direct Measurements (continued)

Technique	Precision	Cost	Feasibility
Static Models	Low-Moderate	Low-Medium	Medium-High
Dynamic Models	Moderate	High	Low
Gonio-meters	High	Medium	Medium
Muscle activity (EMG)	High	High	Low

Source: Burdorf et al, *American Journal of Industrial Medicine*, 1997.

Direct Measurements
Ergonomics Assessment Tools*

o Whole Body Assessment Tools
- U of Michigan-3D Static Strength Prediction Program (www.engin.umich.edu/dept/ioe/3DSSPP/)
- Rapid Entire Body Assessment (REBA) (http://personal.health.usf.edu/tbernard/HollowHills/REBA.pdf)
- U of Michigan-Energy Expenditure Prediction Program (www.engin.umich.edu/dept/ioe/ENGEXP)
- ErgoImager (www.nexgenergo.com/ergonomics/ergoimager.html)
- Rodgers-Muscle Fatigue Assessment (http://personal.health.usf.edu/tbernard/HollowHills/Rodgers_MFA_M20.pdf)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

Direct Measurements
Ergonomics Assessment Tools*

o Upper Body Assessment Tools
- Rapid Upper Limb Assessment (RULA) (www.rula.co.uk/)
- Hand Activity Level TLV (www.acgih.org/Store/ProductDetail.cfm?id=1349, http://personal.health.usf.edu/tbernard/HollowHills/HALTLVM15.pdf)
- Strain Index (http://personal.health.usf.edu/tbernard/HollowHills/StrainIndexM12.pdf)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

Direct Measurements
Ergonomics Assessment Tools*

o Low Back Assessment Tools
- Revised NIOSH Lifting Equation (www.cdc.gov/niosh/docs/94-110/, www.emcins.com/losscontrol/quick_links/employee_safety_health/ergonomicsNIOSH.aspx)
- ACGIH Threshold Limit Values for Lifting (www.acgih.org/Store/ProductDetail.cfm?id=1788)
- Washington State-Lifting Calculator (www.lni.wa.gov/Safety/Topics/Ergonomics/ServicesResources/Tools/default.asp)
- Ohio BWC-Lifting Guidelines (www.ohiobwc.com/employer/programs/safety/liftguide/liftguide.asp)
- Lumbar Motion Monitor (www.nexgenergo.com/ergonomics/lumbarmm.html)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

Direct Measurements
Ergonomics Assessment Tools*

o Manual Materials Handling Assessment Tools
- Liberty Mutual Psychophysical Tables (http://libertymmhtables.libertymutual.com/CM_LMTablesWeb/taskSelection.do?action=initTaskSelection)
- Washington State-Pushing, Pulling and Carrying Tasks Calculator (http://ergonomics.healthandsafetycentre.org/calculator/ergo/ppcc/intro.htm)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

Direct Measurements
Ergonomics Assessment Tools*

o Packaged Assessment Tools
- edgar (www.theergonomicscenter.com/reception/front_center.shtml)
- ErgoIntelligence (www.nexgenergo.com/ergonomics/ergointel.html)
- ErgoMaster (www.nexgenergo.com/ergonomics/ergomast.html)
- eTools Ergo Software (www.auburnengineers.com/ergosite)
- ErgoTEAM (www.thehumanengine.com/ergoteam.html)

***Note**: Not a complete list. Inclusion here does not indicate an endorsement of the product or its accuracy

WORKSHOP

Ergonomics Assessments
Jobs on Videotape

- o What type of assessment is appropriate?
- o Will that tool address all the relevant questions?

Ergonomics Assessments
Jobs on Videotape

- o What type of assessment is appropriate?
- o Will that tool address all the relevant questions?

Medical Product Assembly

Ergonomics Assessments
Jobs on Videotape

- o What type of assessment is appropriate?
- o Will that tool address all the relevant questions?

Appliance Packing & Palletizing

Ergonomics Assessments
Jobs on Videotape

- o What type of assessment is appropriate?
- o Will that tool address all the relevant questions?

Toilet Tank Transfer

Ergonomics Assessments
Discussion on User Experiences

- o What ergo tools have you used?
- o What did you like/not like about them?
- o What types of tools would you like to see in the future?

SETTING PRIORITIES FOR ACTION

Action Plan for Ergonomics Improvements

- o Using Self Reports (e.g., questionnaires, diaries, interviews)
- o Does this approach provide enough accurate information?
- o Issues:
  - Can possibly spot general trends
  - The "squeaky wheel gets the grease" effect
  - Responses may be biased (e.g., employees don't express problems for fear of negative consequences, or employees overstate risks)

Action Plan for Ergonomics Improvements

- o Using Observation (e.g., checklists, videotaping)
- o Issues:
  - More quantitative than self-reporting
  - Does observation accurately portray extent of job demands or variation between employees?

Action Plan for Ergonomics Improvements

- o Using Observation (e.g., checklists, videotaping)
- o Checklists – example output:

Where to set action priorities?

Furniture Warehouse Job Task	Checklist Score
Unload truck (non-palletized product)	57
Store incoming product in warehouse – large items	52
Store incoming product in warehouse – small items	49
Put incoming product on carts (inbound dock)	48
Load product onto forklift – large items	40
Lift damaged product to work table – large items	39
Load product onto forklift – small items	35
Lift damaged product to work table – small items	27
Push palletized items to truck (outbound dock)	17
Rearrange product in truck	10

Action Plan for Ergonomics Improvements

- o Using Observation (e.g., checklists, videotaping)
- o Checklists – example output:

Where to set action priorities?

Furniture Warehouse Job Task	Checklist Score
Unload truck (non-palletized product)	57
Store incoming product in wa[illegible] large items	52
Store incoming product in[illegible] ll items	49
Put incoming product on[illegible]	48
Load product onto forklift – lar[illegible]	40
Lift damaged product to work[illegible] ge items	39
Load product onto forklift – s[illegible]	35
Lift damaged product to work[illegible] mall items	27
Push palletized items to truck (outbound dock)	17
Rearrange product in truck	10

Action Plan for Ergonomics Improvements

- o Using Observation (e.g., checklists, videotaping)
- o Checklists – example output:

Where to set action priorities?

Furniture Warehouse Job Task	Checklist Score
Unload truck (non-palletized product)	57
Store incoming product in wa[illegible] large items	52
Store incoming product in[illegible] ll items	49
Put incoming product on[illegible]	48
Load product onto forklift – lar[illegible]	40
Lift damaged product to work[illegible] ge items	39
Load product onto forklift – s[illegible]	35
Lift damaged product to work[illegible] mall items	27
Push palletized items to truck (outbound dock)	17
Rearrange product in truck	10

Action Plan for Ergonomics Improvements

- o Using Observation (e.g., checklists, videotaping)
- o Checklists – example output:

Where to set action priorities?

Furniture Warehouse Job Task	Checklist Score
Unload truck (non-palletized product)	57
Store incoming product in wa[illegible] large items	52
Store incoming product in[illegible] ll items	49
Put incoming product on[illegible]	48
Load product onto forklift – lar[illegible]	40
Lift damaged product to work[illegible] ge items	39
Load product onto forklift – s[illegible]	35
Lift damaged product to work[illegible] mall items	27
Push palletized items to truck (outbound dock)	17
Rearrange product in truck	10

Action Plan for Ergonomics Improvements

o Using Direct Measurements (e.g., O_2 consumption, goniometers, lifting guides)

o Issues:

- Higher level of quantification than observation
- Some scores have been validated
- Does this approach suffer from "paralysis by analysis?"

Action Plan for Ergonomics Improvements

o Using Direct Measurements (e.g., O_2 consumption, goniometers, lifting guides)

o NIOSH *Lifting Guide* –example output:

Furniture Warehouse Job Task	Lifting Index
Store incoming product in warehouse – large items	3.4
Unload truck (non-palletized product)	3.2
Put incoming product on carts (inbound dock)	2.5
Store incoming product in warehouse – small items	2.3
Lift damaged product to work table – large items	2.0
Load product onto forklift – large items	1.9
Load product onto forklift – small items	1.4
Lift damaged product to work table – small items	0.8
Rearrange product in truck	0.7
Push palletized items to truck (outbound dock)	n/a

Action Plan for Ergonomics Improvements

o Using Direct Measurements (e.g., O_2 consumption, goniometers, lifting guides)

o NIOSH *Lifting Guide* –example output:

Furniture Warehouse Job Task	Lifting Index
Store incoming product in warehouse – large items	3.4
Unload truck (non-palletized product)	3.2
Put incoming product on carts (inbound dock)	2.5
Store incoming product in warehouse – small items	2.3
Lift damaged product to work table – large items	2.0
Load product onto forklift – large items	1.9
Load product onto forklift – small items	1.4
Lift damaged product to work table – small items	0.8
Rearrange product in truck	0.7
Push palletized items to truck (outbound dock)	n/a

WORKSHOP

DEVELOPING ERGONOMICS INTERVENTIONS

Intervention Type
Engineering Solution

Examples:

o Process changes

- "Engineer out" the problem

o New technology / equipment

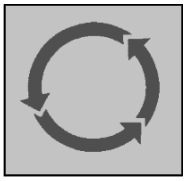
- Eliminate or greatly reduce job demands

Intervention Type
Work Design

Examples:

o Job rotation
- Distribute demands across more employees

o Job enlargement
- Expand number of job tasks



Intervention Type
Employee-Centered Solution

Examples:

o Ergonomics training
- Teaches about risk factors, prevention methods, etc.

o Wellness programs
- Aim is to improve physical fitness levels and increase tolerance to the job

Impact of an Intervention
By Intervention Type

Type of Ergonomic Intervention	Estimated Benefit-to-Cost Ratio
• Prevent / Control Ergonomics Issue • Use engineering or administrative methods to improve job	1.37
• Provide Management Leadership & Involve Employees • Integrate ergonomics into the company's business operations	1.33
• Implement an Ergonomics Process • Implement a systematic method to identify and solve ergonomics issues	1.24
• Give Ergonomics Training • Provide ergonomics information to all employees, at the appropriate level	0.54

Source: Jervis & Collins, 2001, *Professional Safety*

WORKSHOP

Ergonomics Intervention Type

o Engineering Solution?

o Administrative Control?

o Training Approach?

o Other Solution?

Ergonomics Intervention Type
What is Most Appropriate?

o Engineering Solution?

o Administrative Control?

o Training Approach?

o Other Solution?

Medical Product Assembly

Ergonomics Intervention Type
What is Most Appropriate?

- o Engineering Solution?
- o Administrative Control?
- o Training Approach?
- o Other Solution?

Appliance Packing & Palletizing

Ergonomics Intervention Type
What is Most Appropriate?

- o Engineering Solution?
- o Administrative Control?
- o Training Approach?
- o Other Solution?

Toilet Tank Transfer

COST-JUSTIFYING PROPOSED ERGO IMPROVEMENTS

Overview

Job / work process needing improvement

Q How much money is the problem currently costing the company?

Solution(s) to problem

Q What feasible interventions exist?

Is the solution "worth it"? What is the payback period?

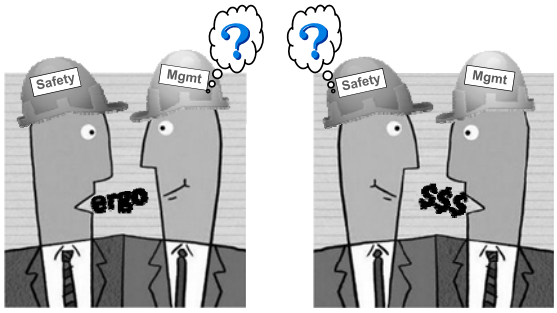
Q How do I justify the cost of a job change?

Benefits of Ergo Interventions
Examples

Workplace	Intervention	Cost	Outcome
Office	• Installed new office furniture	$1,578,000 (over 5 yrs)	• 20% increase in productivity • $5 million saved over 10 yrs (1.7-yr payback)
Nursing Home	• Installed several patient handling devices (e.g., lift systems, electric beds)	$13,053	In 18 months: • Strain/sprain rates fell from 22 to 14 incidents per 100 employees, and restricted-days rate fell from 121 to 44 days per 100 employees • Turnover rate fell from 55% to 32%
Distribution Center	• Installed a single pallet lift	$3,000	• Time to unload pallet decreased 20% • Time savings of $10,500 • Reduced workers' comp costs by $5,000
Parts Manufacturing	• Tilt stands • Anti-fatigue mats	$22,986	In seven months: • Reduced strain/sprain rate by 88% • Lost days eliminated; restricted days rate fell 76%
Construction	• New attach-ments to earth-moving equip.	$33,502	In ten months: • Reduced strain/sprain rate by 80% • Reduced restricted days rate by 22%

Source: www.pshfes.org/cba.htm

Ergonomics Dilemma #1



Ergonomics Dilemma #2

- o Much of the Return-on-Investment (ROI) data used to justify ergonomics solutions are not available or easily obtained
  - Example: What are the costs to hire and train replacement employees?
  - Example: What are the cost savings from reducing musculoskeletal disorders?

Source: Boff & Rouse, 1997, *Handbook of Human Factors and Ergonomics*

Direct Benefits of Ergonomics
(measurable)

Examples:

- o Reduced healthcare costs
- o Fewer employee absences
- o Increased productivity

Indirect Benefits of Ergonomics
(not easily measured)

Examples:

- o Improved employee attitudes
- o Fewer job-related mistakes
- o Higher product quality
- o Less time spent investigating injuries

Assessing the Costs of MSDs
Current Costs

Job / work process needing improvement

Q How much money is the problem currently costing the company?

Solution(s) to problem

Q What feasible interventions exist?

Is the solution "worth it"? What is the payback period?

Q How do I justify the cost of a job change?

Assessing the Costs of MSDs
Direct Current Costs

- o Direct costs associated with the job's MSDs
  - Ideal: Actual company data
  - Available: National direct cost data

MSD Type	Average Direct Cost
Carpal Tunnel Syndrome	$24,695
Sprain	$23,098
Strain	$27,363
All Other MSDs	$30,647

Source: National Council on Compensation Insurance, Inc (NCCI)

Direct Cost Estimates
All Injury Types

Injury Type	Average Direct Cost*
AIDS	$ 4,469
Amputation	$ 48,318
Angina Pectoris	$ 28,136
Asbestosis	$ 23,346
Asphyxiation	$ 88,126
Black Lung	$ 34,165
Burn	$ 27,380
Byssinosis	$ 13,523
Cancer	$ 52,785
Carpal Tunnel Syndrome	$ 24,695
Concussion	$ 68,456
Contagious Disease	$ 15,657
Contusion	$ 23,748
Crushing	$ 45,272
Dermatitis	$ 8,295
Dislocation	$ 59,207
Dust Disease	$ 27,682
Electric Shock	$ 86,448

Injury Type	Average Direct Cost*
Enucleation	$ 62,699
Foreign Body	$ 17,585
Fracture	$ 37,911
Freezing	$ 13,365
Hearing Loss or Impairment	$ 15,304
Heat Prostration	$ 21,053
Hernia	$ 18,850
Infection	$ 20,938
Inflammation	$ 24,881
Laceration	$ 15,398
Loss of Hearing	$ 13,145
Mental Disorder	$ 37,420
Mental Stress	$ 27,004
Multiple Injuries	$ 115,961
Multiple Physical Injuries	$ 58,607
Myocardial Infarction	$ 85,962
No Physical Injury	$ 22,093

Injury Type	Average Direct Cost*
Poisoning-Chemical	$ 43,690
Poisoning-General	$ 44,761
Poisoning-Metal	$ 25,054
Puncture	$ 15,381
Radiation	$ 36,124
Respiratory Disorders	$ 35,266
Rupture	$ 61,506
Severance	$ 59,394
Silicosis	$ 31,393
Sprain	$ 23,098
Strain	$ 27,363
Syncope	$ 31,138
VDT-Related Diseases	$ 51,404
Vascular	$ 56,316
Vision Loss	$ 49,693

Source: National Council on Compensation Insurance, Inc (NCCI)

Assessing the Costs of MSDs
Indirect Costs

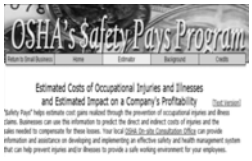
- o Indirect costs associated with the job's MSDs ("Iceberg Theory")
  - Ideal: Actual company data **??**
  - High Variability: from 1:1 to 20:1
  - Available: National indirect cost data

Direct Cost of MSDs	Indirect Cost Ratio
$0 – $2,999	4.5
$3,000 – $4,999	1.6
$5,000 – $9,999	1.2
$10,000+	1.1

Source: National Council on Compensation Insurance, Inc (NCCI)

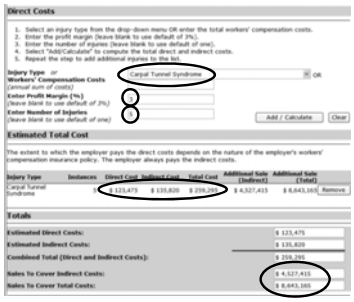
Estimating Injury Costs
Free/Cheap Resources*

- o OSHA's $afety Pays Program (www.osha.gov/dcsp/smallbusiness/safetypays/estimator.html)



* This list does not indicate an endorsement by the Institute for Ergonomics

Example
OSHA's $afety Pays Program



Estimating Injury Costs
Free/Cheap Resources*

- o The Hartford *Losstimator* (www.thehartford.com/corporate/losscontrol/losstimator/Default.htm)

* This list does not indicate an endorsement by the Institute for Ergonomics

Estimating Injury Costs
Free/Cheap Resources*

- o Safety Management Group – Injury Cost Calculator (www.safetymanagementgroup.com/injury-cost-calculator.aspx)

* This list does not indicate an endorsement by the Institute for Ergonomics

Estimating Injury Costs
Free/Cheap Resources*

- o National Safety Council (www.nsc.org/news_resources)
  - Average economic costs for a disabling work injury (2008)
    - o Without employers' uninsured costs: $39,600
    - o With employers' uninsured costs: $42,500

* This list does not indicate an endorsement by the Institute for Ergonomics

Assessing the Costs of an Ergonomics Intervention

Job / work process needing improvement — Q How much money is the problem currently costing the company?

↓

Solution(s) to problem — Q What feasible interventions exist?

↓

Is the solution "worth it"? What is the payback period? — Q How do I justify the cost of a job change?

Example:
Cart Pushing/Pulling

Problem:

- o Employees must manually push parts racks through the facility
- o In past year, employees reported <u>five back or shoulder injuries</u> doing this activity; this is an increase over previous years

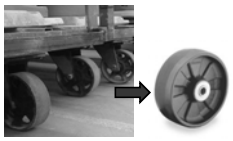
Example:
Cart Pushing/Pulling

- o Estimated costs* of <u>three low back strains</u> and <u>two shoulder strains</u> in past year
  - Estimated Direct Costs $ 136,815
  - Estimated Indirect Costs (110%) $ 150,497
  - **Estimated Total Costs** **<u>$ 287,312</u>**

* Using the Washington State Cost-Benefit Calculator

Possible Solutions:
Cart Pushing/Pulling

o New rack wheels that have less floor contact



- o Predicted result:
  - No injury reduction
  - Less worker fatigue

o Move racks using a mechanized method

- o Predicted result:
  - Reduced exposure
  - Less wasted effort

Estimated Costs for Solutions:
Cart Pushing/Pulling

- o Wheel replacement
  - 600 wheels @ $20 each = $12,000
- o Mechanized cart mover
  - 10 movers @ $5,000 each = $50,000

Computing the Justification
Best Solution? Adequate ROI?

Job / work process needing improvement — Q How much money is the problem currently costing the company?

↓

Solution(s) to problem — Q What feasible interventions exist?

↓

Is the solution "worth it"? What is the payback period? — Q How do I justify the cost of a job change?

Comprehensive Analysis

Parameter	Notation	Value Used in Example Simulation
Biomechanical exposure (3D Static Strength Prediction Program)	E	6794N (pre-intervention); 2110N (post-intervention)
Injury rate	$I(E)$	c
Daily probability of making transition from state 1 to state 3	$p^{1\to3}(E)$	c
Daily probability of making transition from state 1 to state 4	$p^{1\to4}$	0.0000001
Daily probability of making transition from state 2 to state 3	$p^{2\to3}$	c
Daily probability of making transition from state 2 to state 4	$p^{2\to4}$	0.0000001
Daily probability of making transition from state 3 to state 4	$p^{3\to4}$	0.0000001
Daily probability of making transition from state 3 to state 2	$p^{3\to2}$	c
Daily cost directly related to injury on day d	b_d^{injury}	$70.48
Delay between injury and change in workers' compensation premium	t_{delay}	0
Fraction of actual cost paid by employer	δ	1
Change in cost directly related to injury that is paid by employer in year t	$B_t^{new\ injury}$	c
Daily cost directly related to injury that is paid by employer through workers' compensation in year t	B_t^{injury}	c
Change in cost directly related to injury in year t	B_t^{injury}	c
Change in daily cost of replacement labor on day d	$B_d^{replacement\ labor}$	$120/day
Change in cost of replacement labor in year t	$B_t^{replacement\ labor}$	c
Change in production and quality in year t	$B_t^{production\ quality}$	0
Before-tax savings for year t	F_t	c
Weibull scale parameter for lost time		0.047
Weibull shape parameter for lost time		0.737
Discount rate	R	7%
After-tax savings for year t	A_t	c
Marginal tax rate	A	35%
Depreciation in year t	D_t	c
Taxes on the change in cost in year t	T_t	c
Initial cost of ergonomic intervention in year 0	C_0	$3,000
Annual cost of intervention (maintenance, etc.) in year t	C_t	$100
Planning horizon in years	H	10 years
Salvage value at end of planning horizon	S	$200

Source: Hughes & Nelson, 2009, *Applied Ergonomics*

Simplistic Analysis

Type of Ergonomic Intervention	Estimated Benefit-to-Cost Ratio
• Prevent / Control Ergonomics Issue • Use engineering or administrative methods to improve job	1.37
• Provide Management Leadership & Involve Employees • Integrate ergonomics into the company's business operations	1.33
• Implement an Ergonomics Process • Implement a systematic method to identify and solve ergonomics issues	1.24
• Give Ergonomics Training • Provide ergonomics information to all employees, at the appropriate level	0.54

Source: Jervis & Collins, 2001, *Professional Safety*

Justifying Ergo Interventions
Free Resources*

- o Washington State Ergonomics Cost Benefit Calculator (www.pshfes.org/cba.htm)
- o Cornell Return-on-Investment (ROI) Estimator (http://ergo.human.cornell.edu/cuROIEstimator.htm)

* This list does not indicate an endorsement by the Institute for Ergonomics

Justifying Ergo Interventions
Other Resources*

- o Return on Health, Investments Safety and Environmental (ROHSEI) software (www.orc-dc.com/node/821)
- o productAbility software (~$565) (www.productability.co.uk)

* This list does not indicate an endorsement by the Institute for Ergonomics

Example:
(WA State Ergo Cost Benefit Calculator)

Inputs

- o Workers' Compensation data
  - No. of employees exposed to ergo issue
  - Hourly employee salary
  - Types and numbers of MSDs
- o Possible solution(s)
  - Cost of solution(s) (e.g., equipment)
  - Related costs
  - Degree of solution's effectiveness
  - Amount of productivity improvement

Example:
(WA State Ergo Cost Benefit Calculator)

Outputs

- o Benefits from possible solution(s)
  - Reduction in claims and costs
  - Increase in productivity
  - Savings after 1, 3, & 5 years
- o Payback period
  - Cost and benefits summary
  - Payback period
  - Estimated benefits after 1, 3, & 5 years

WORKSHOP

Take-Home Messages

- The causes of MSDs can be varied and complex
- The method(s) used to evaluate a job depends on available resources, knowledge, and expertise
- With ergonomics, there often is a trade-off between the type of solution and its effectiveness
- Speaking the same language as company managers will greatly help to move ergonomics initiatives forward

Questions?

W. Gary Allread, PhD, CPE
Program Director
Institute for Ergonomics
The Ohio State University

e: allread.1@osu.edu
p: 614-292-4565
w: www.ergonomics.osu.edu