MIS
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» makeitsafe.ca

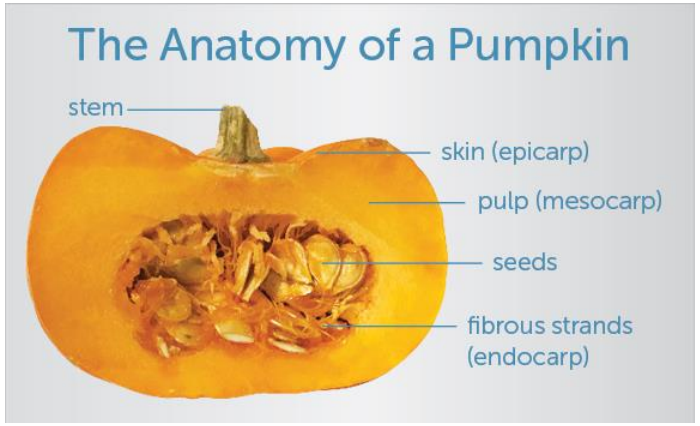
Assessing MSI Risk in Manual Material Handling Tasks

Aaron Derouin

Overview

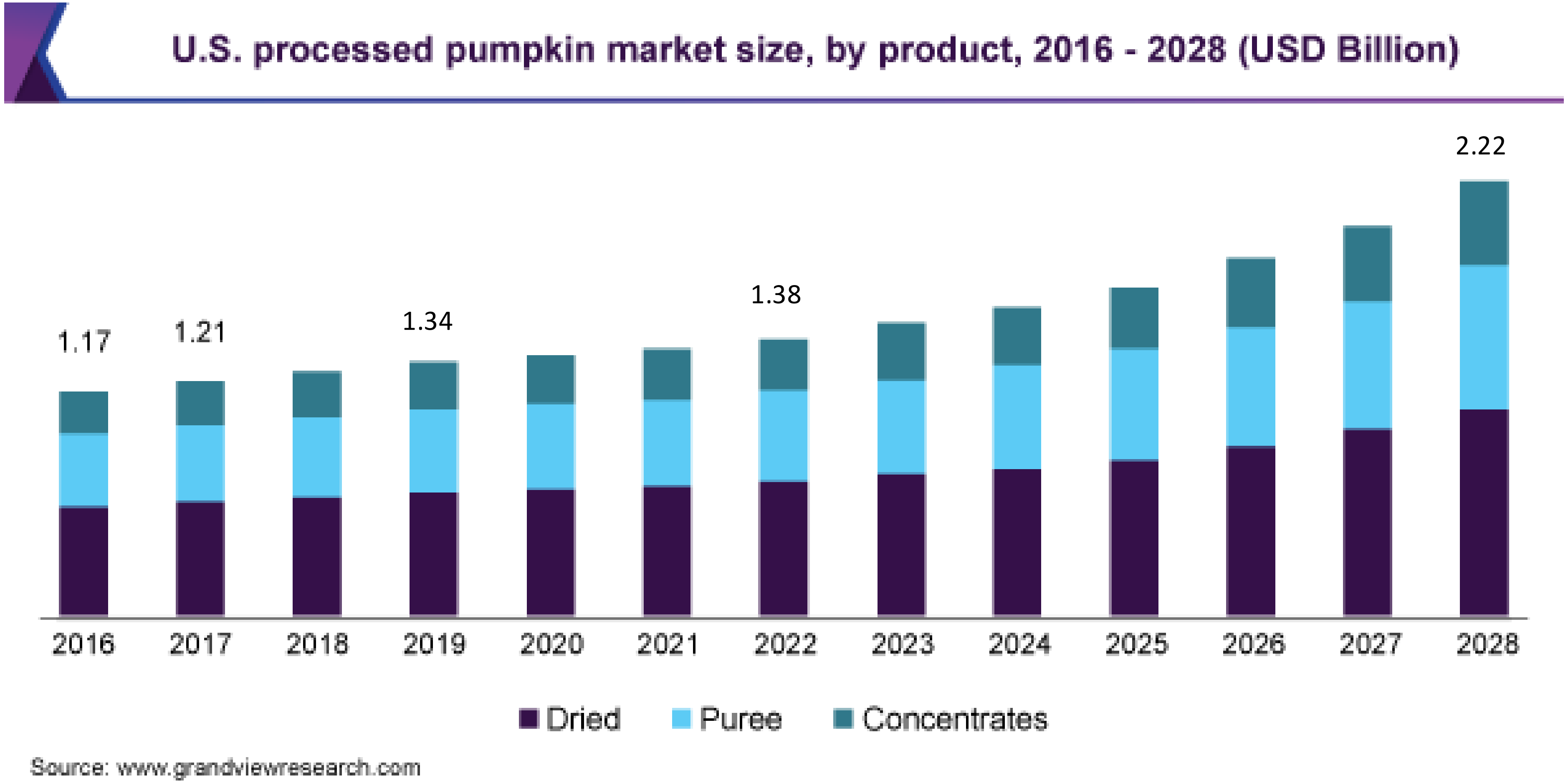
- Definitions for MSIs and WMSDs
- Injury Statistics and Costs for MSI and Manual Material Handling
- Background on Posture and Force risk factors
- Revised NIOSH Lifting Equation
  - Distinguish between lifting frequencies associated with Biomechanical, Psychophysical, and Physiological criteria
  - Understand and appreciate which postural input parameters are most sensitive
  - Understand how to measure the postural input parameters
    - Horizontal
    - Vertical
    - Distance
    - Asymmetry

Protect Your Pumpkin

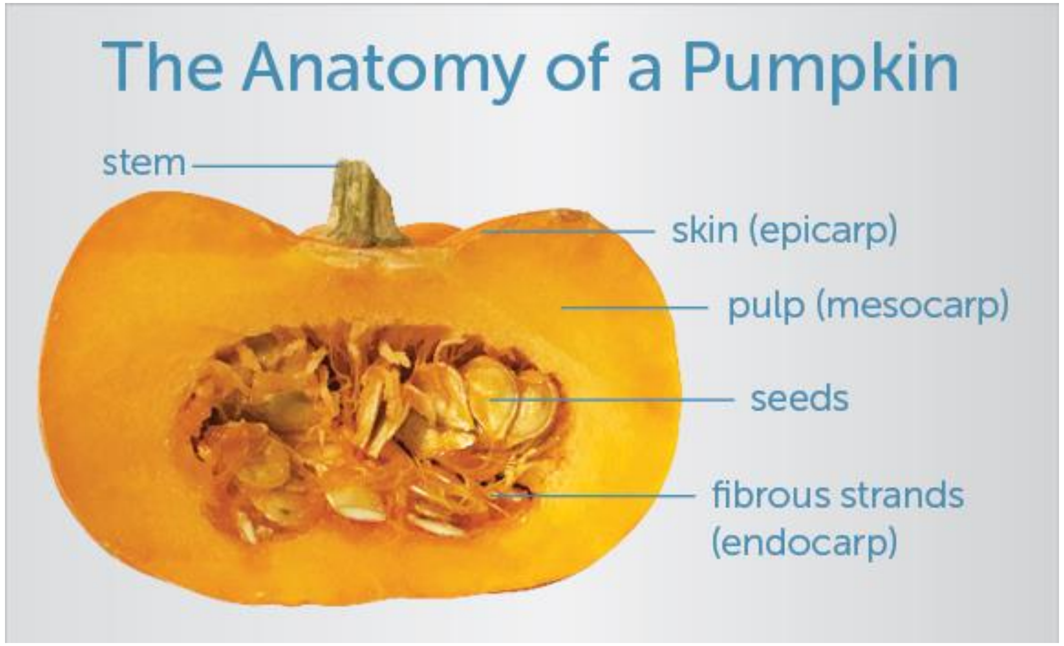


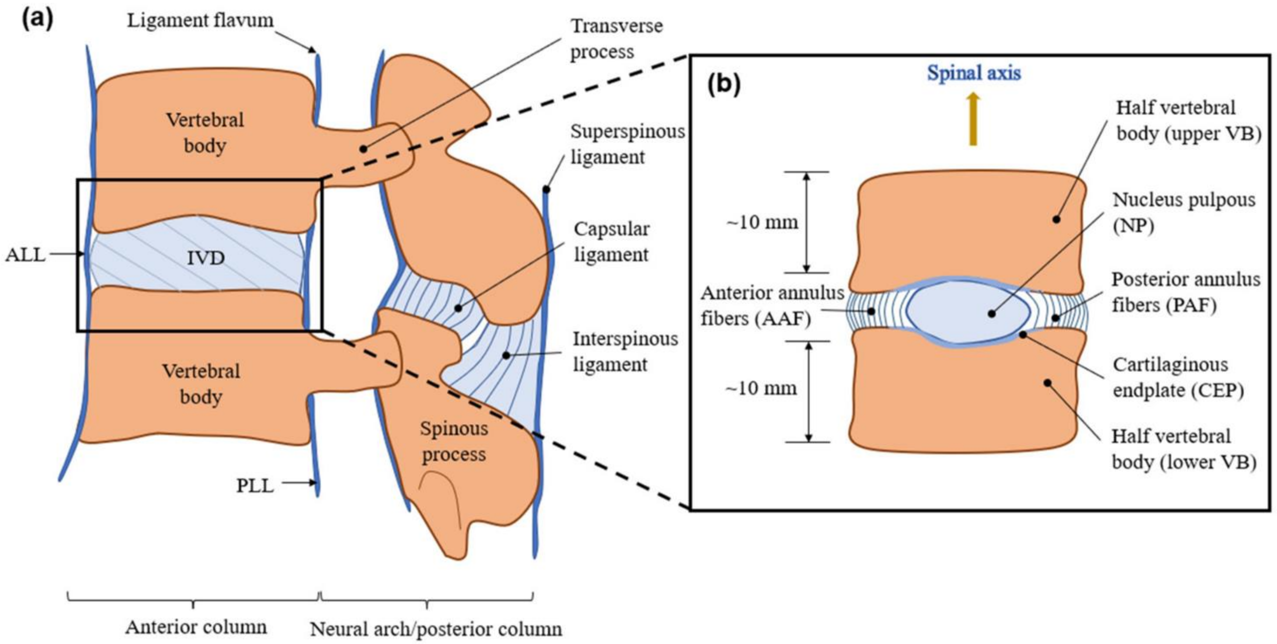
[OCT Peeks into Pumpkins - Wasatch Photonics]

Market Size of the Pumpkin Industry in U.S.



Protect Your Pumpkin → Preserve Your Pulp





[OCT Peeks into Pumpkins - Wasatch Photonics]

[Yang et al., 2022]

MSI: *CLC Definition*

An injury or disorder of the musculoskeletal system, which includes muscles, tendons, blood vessels, ligaments, nerves, joints, spinal discs, and related soft tissue

Canada Labour Code, Part II

"musculoskeletal injury" or *"MSI"* means an injury or disorder of the muscles, tendons, ligaments, joints, nerves, blood vessels or related soft tissue including a sprain, strain and inflammation, that may be caused or aggravated by work.

Source OHSR 4.46

Related Terms for MSIs

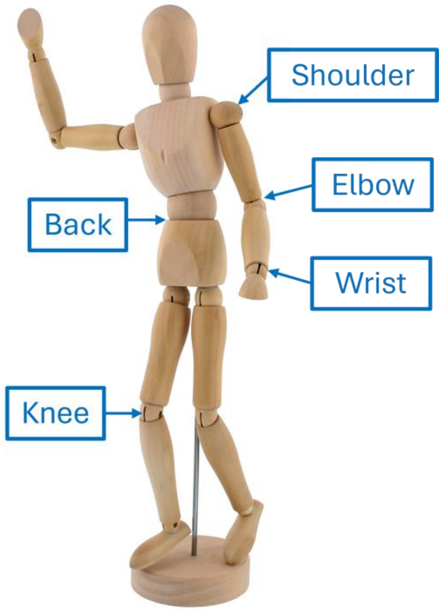
- Musculoskeletal Injuries (MSIs) also known as:
  - MSDs (Musculoskeletal Disorders)
  - WMSDs (Work-Related MSDs)
  - RSIs (Repetitive Strain Injuries)
  - CTDs (Cumulative Trauma Disorders)

Question 1

Most Frequently Injured Body Part?

What is the most frequently injured body part sustained while working?

a) Knee
b) Wrist
c) Elbow
d) Shoulder
e) Back



Most frequently injured body part sustained while working?

U.S. Workplace Injury Statistics

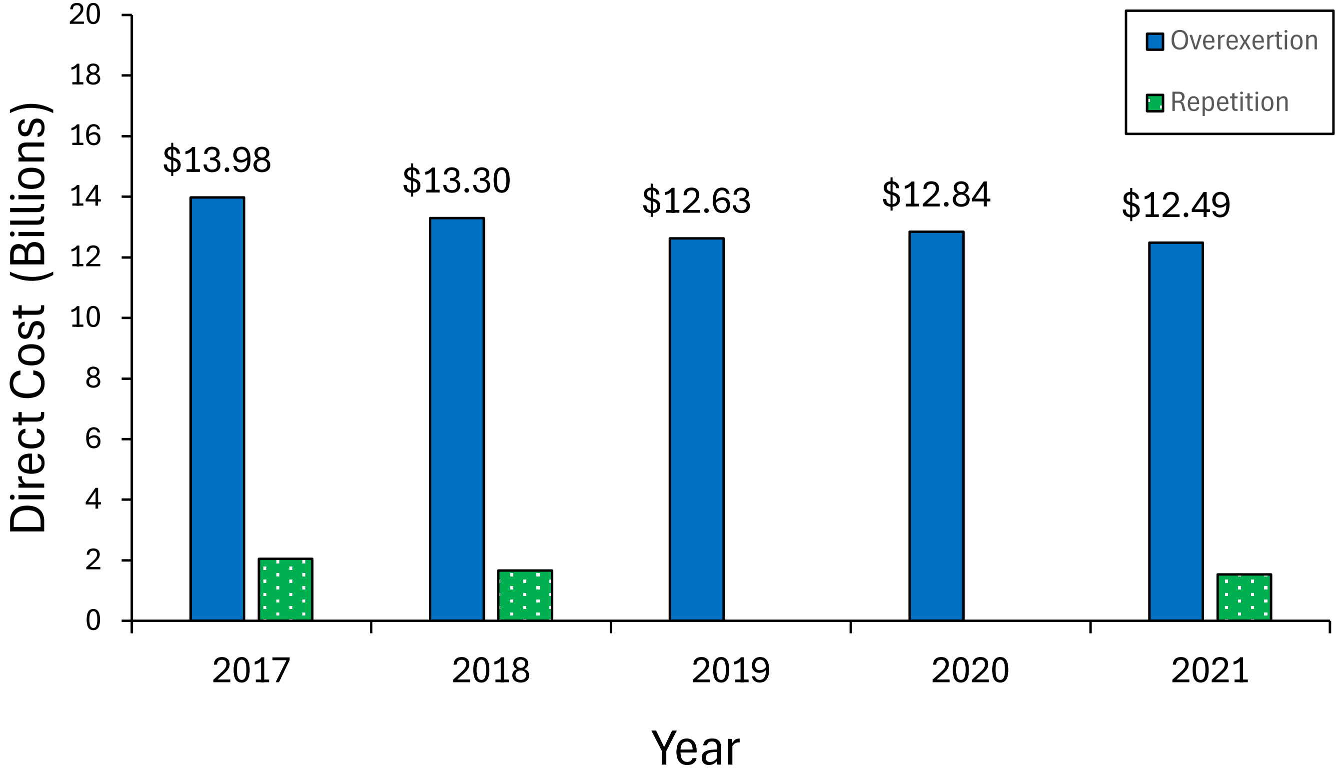
[*2019 Data from Liberty Mutual]

Cost of MSI Related Injuries in the U.S. Overexertion and Repetition

Overexertion Injuries

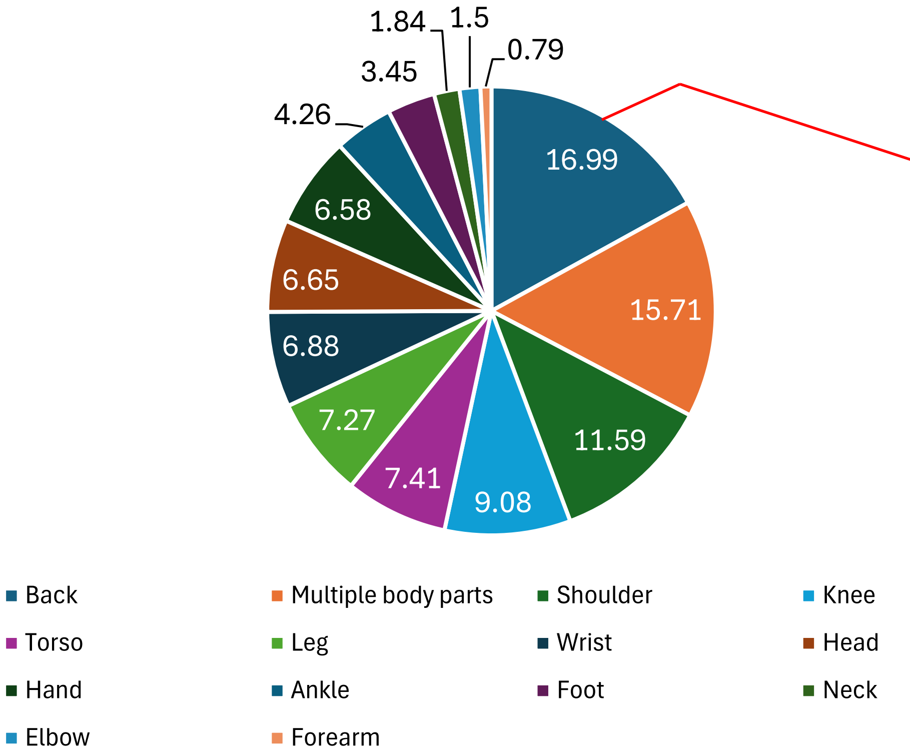
- 1st ranked injury type
- 22% of all injury costs

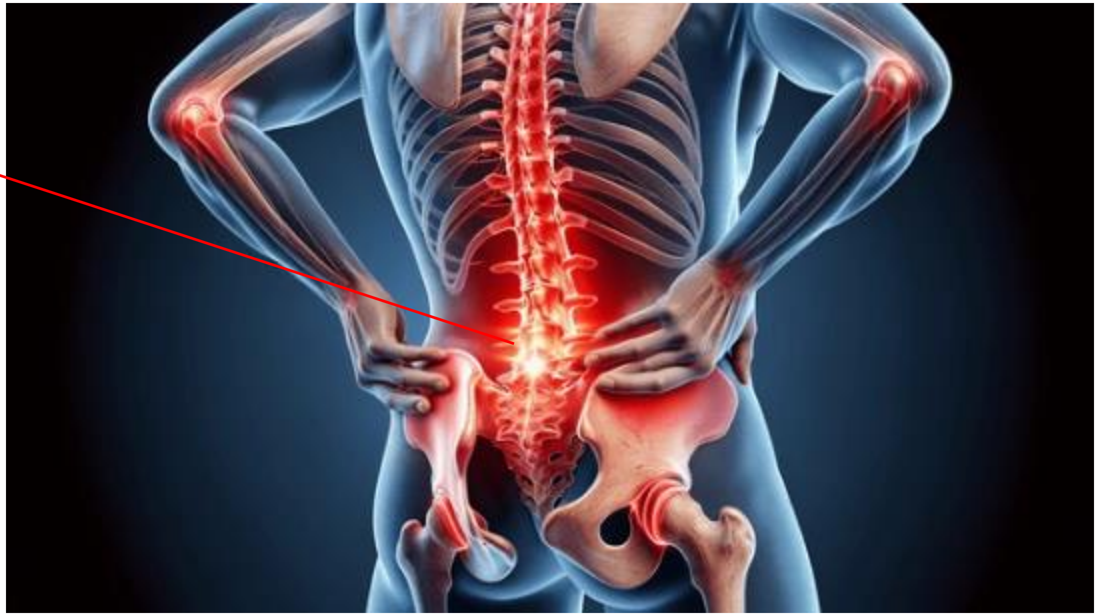
Overexertion and Repetitive Injury Data (Liberty Mutual Workplace Safety Index)



Injuries by Body Part in U.S.

Percentage of Body Parts Injured (U.S., 2024)



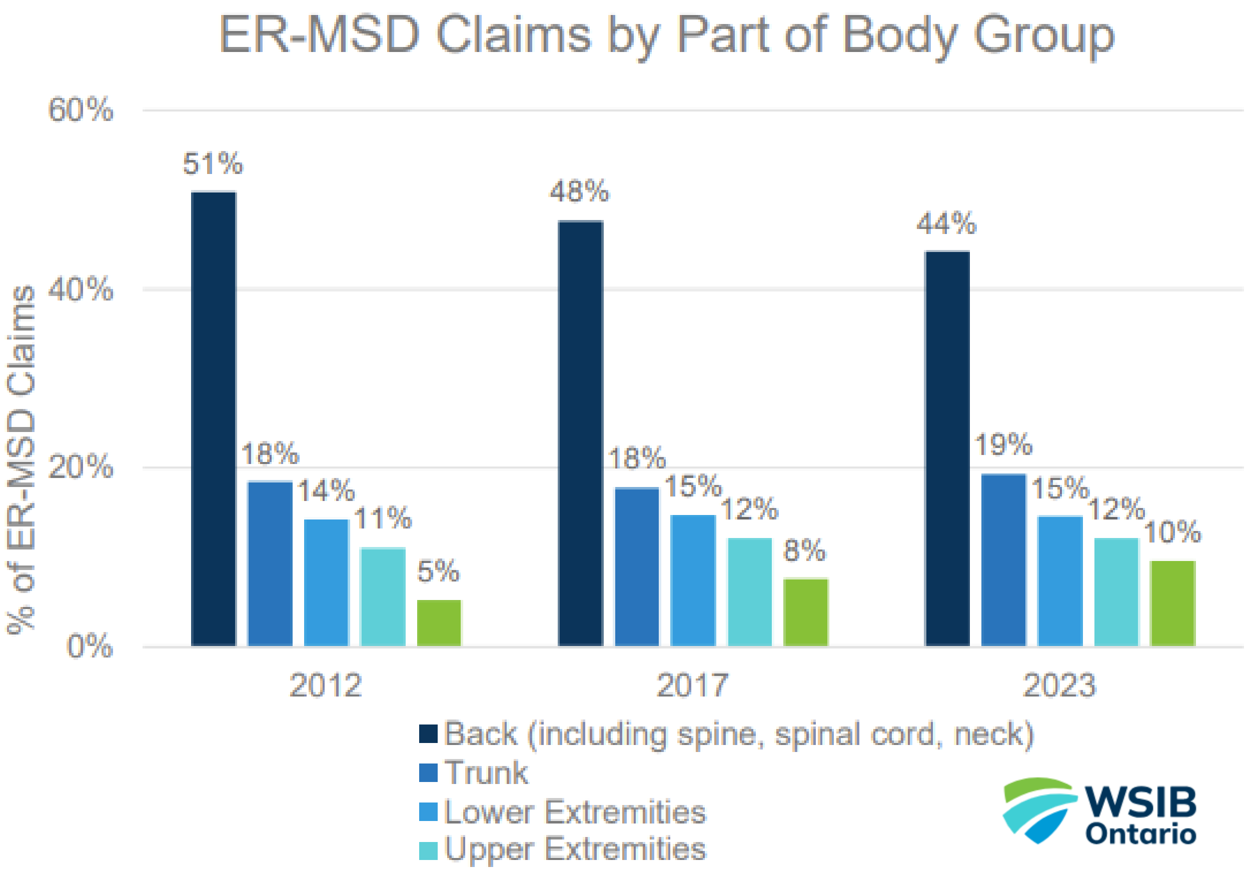


[Workplace Safety Indices – Insights and Methodologies
Liberty Mutual Insurance, 2024]

Canadian MSI Injury Data and Statistics

[Industry Statistics, WSBC]

Workers Safety Insurance Board – Ontario
ER-MSDs Claims by Body Part



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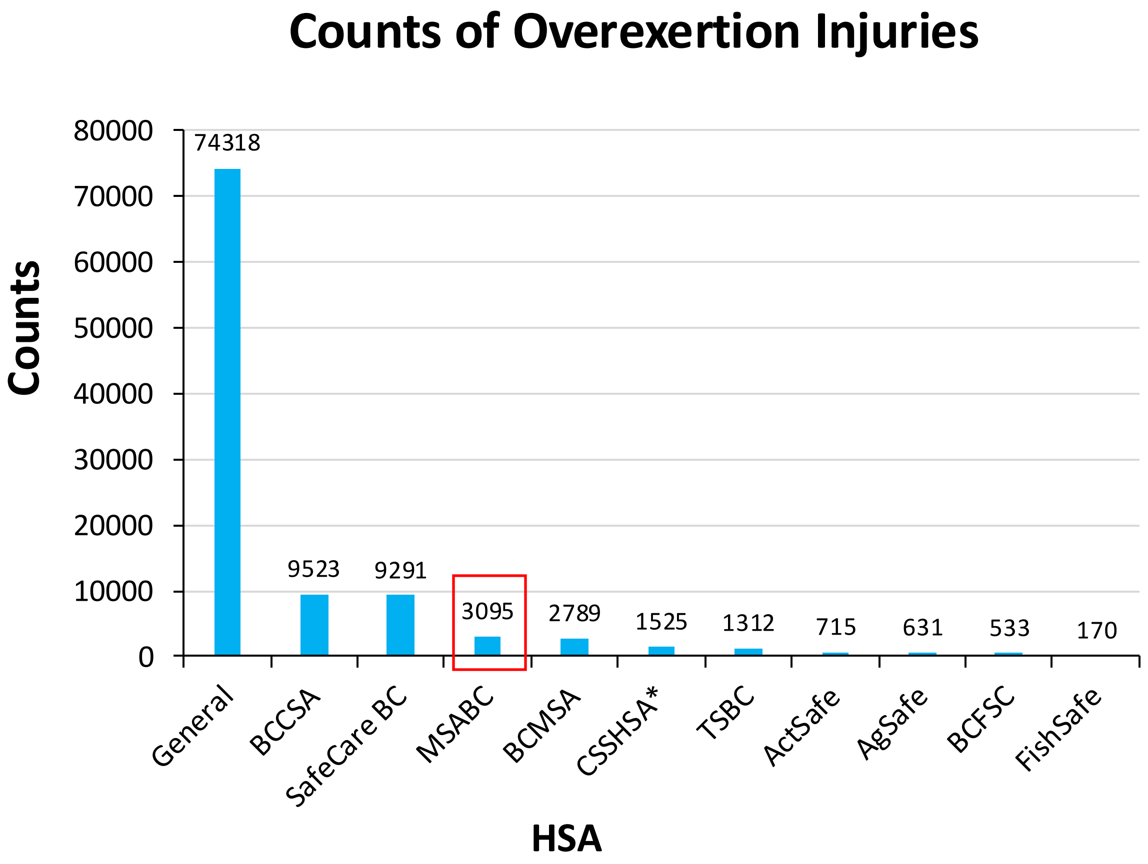
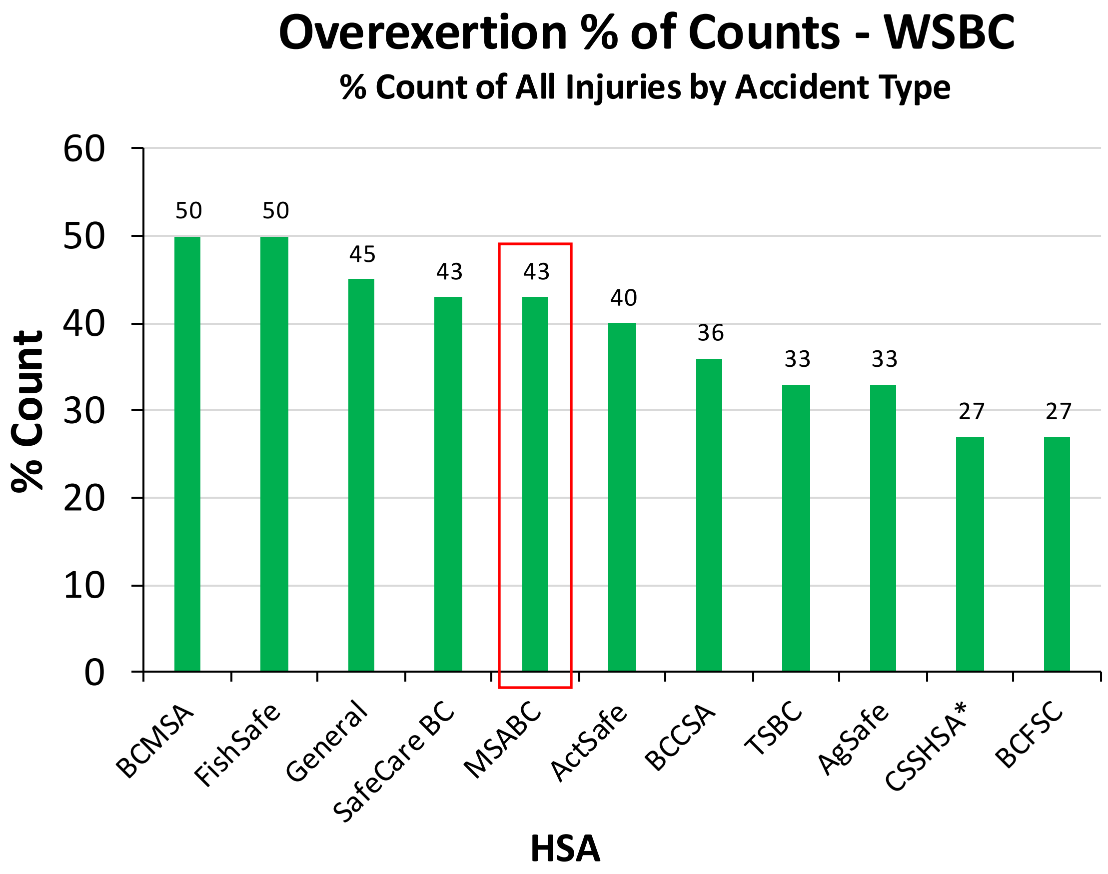
WorkSafe BC – Overexertion Statistics
Counts - Industry Sector/ HSA





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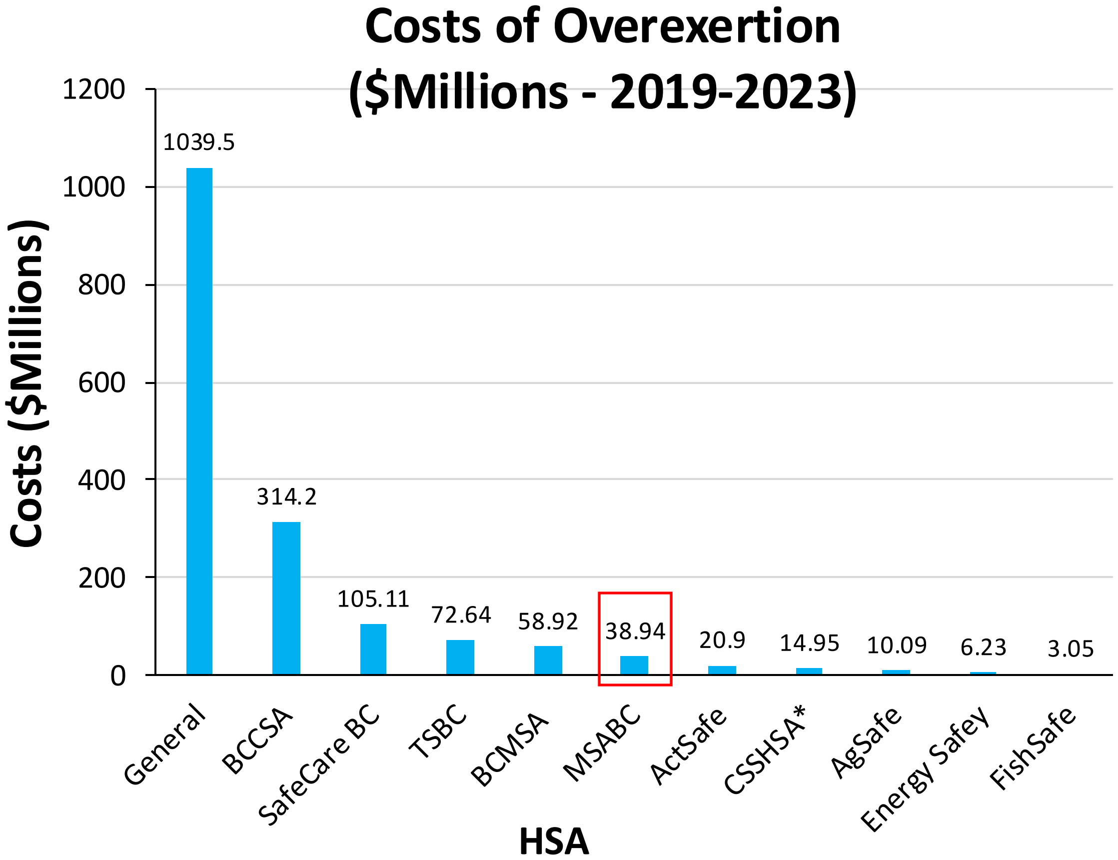
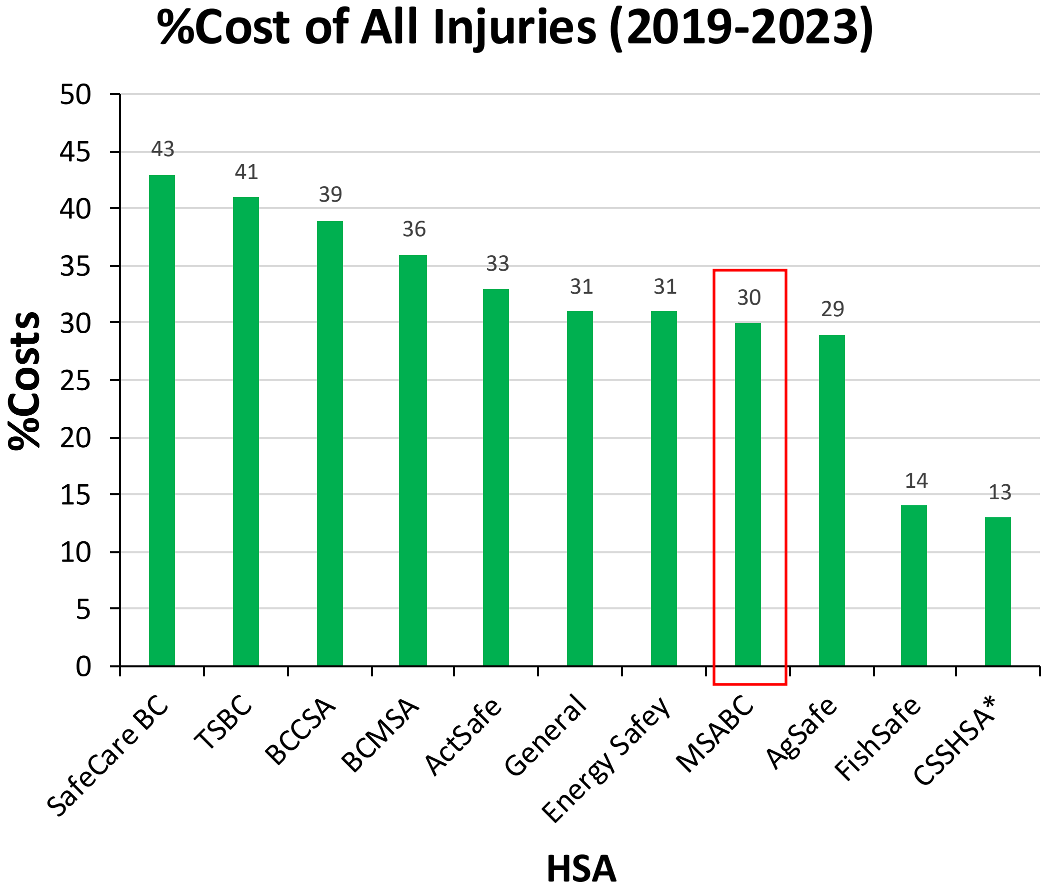
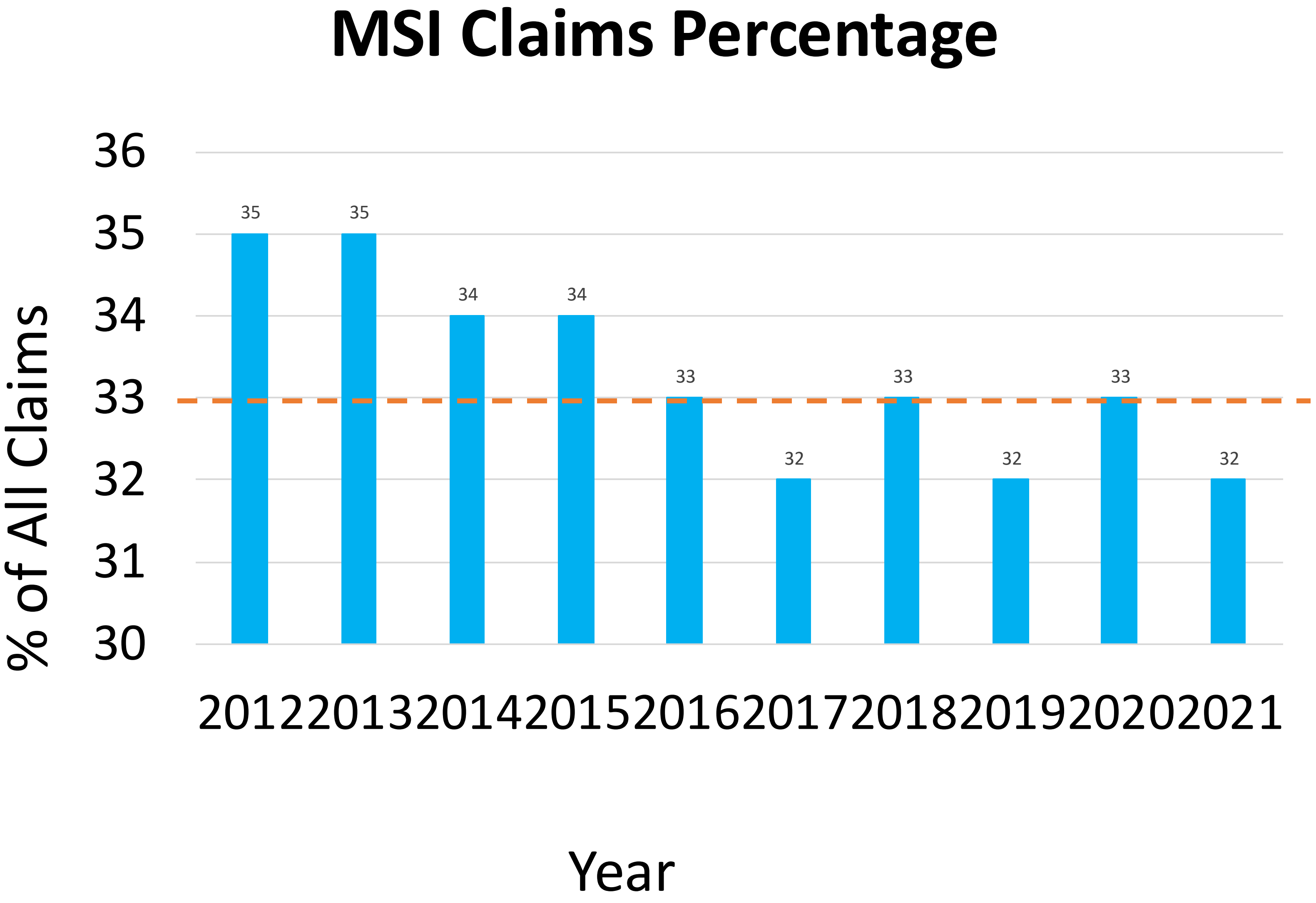
WorkSafe BC – Overexertion Statistics
Cost - Industry Sector/ HSA

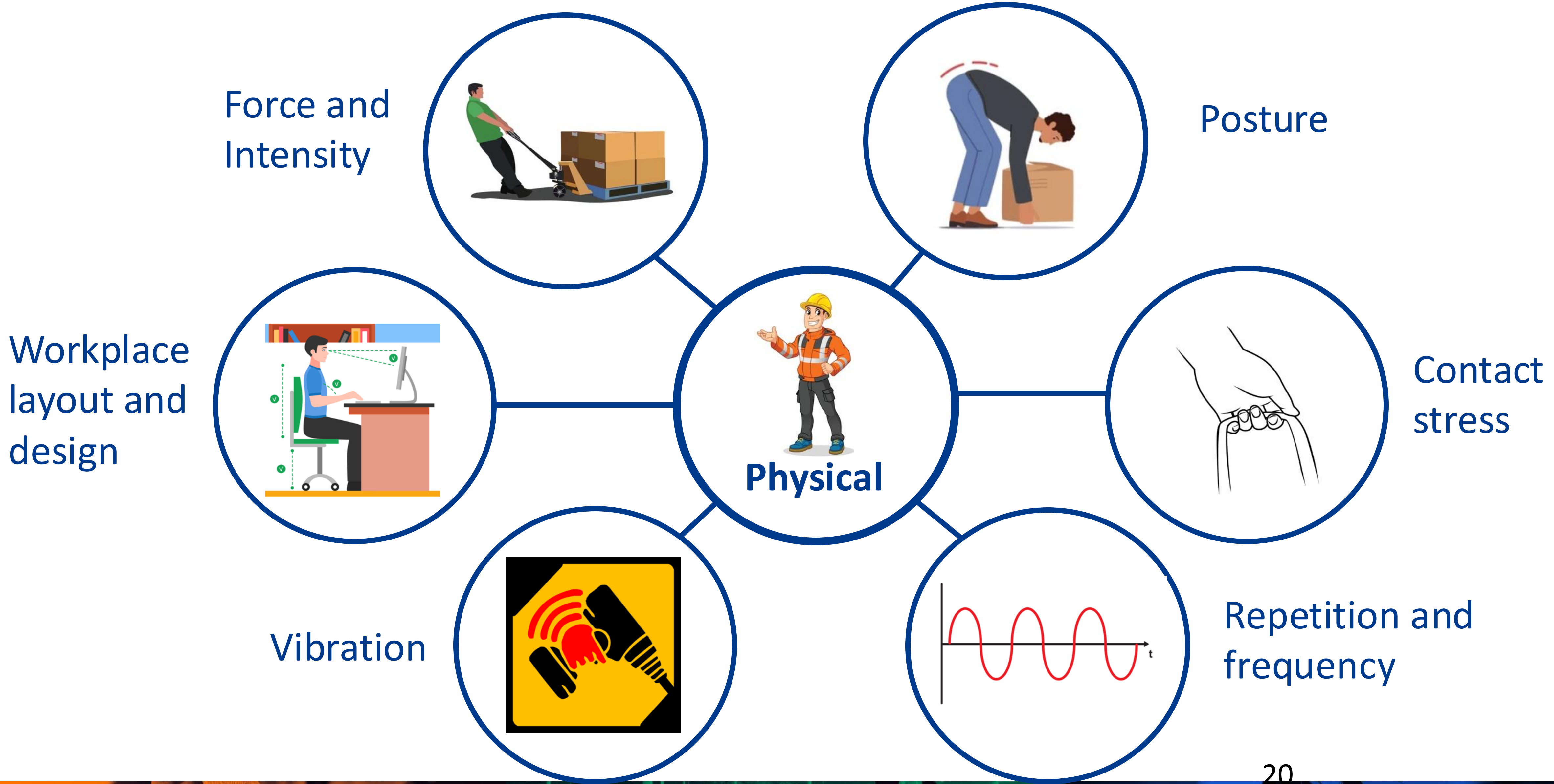




WorkSafeBC Statistics

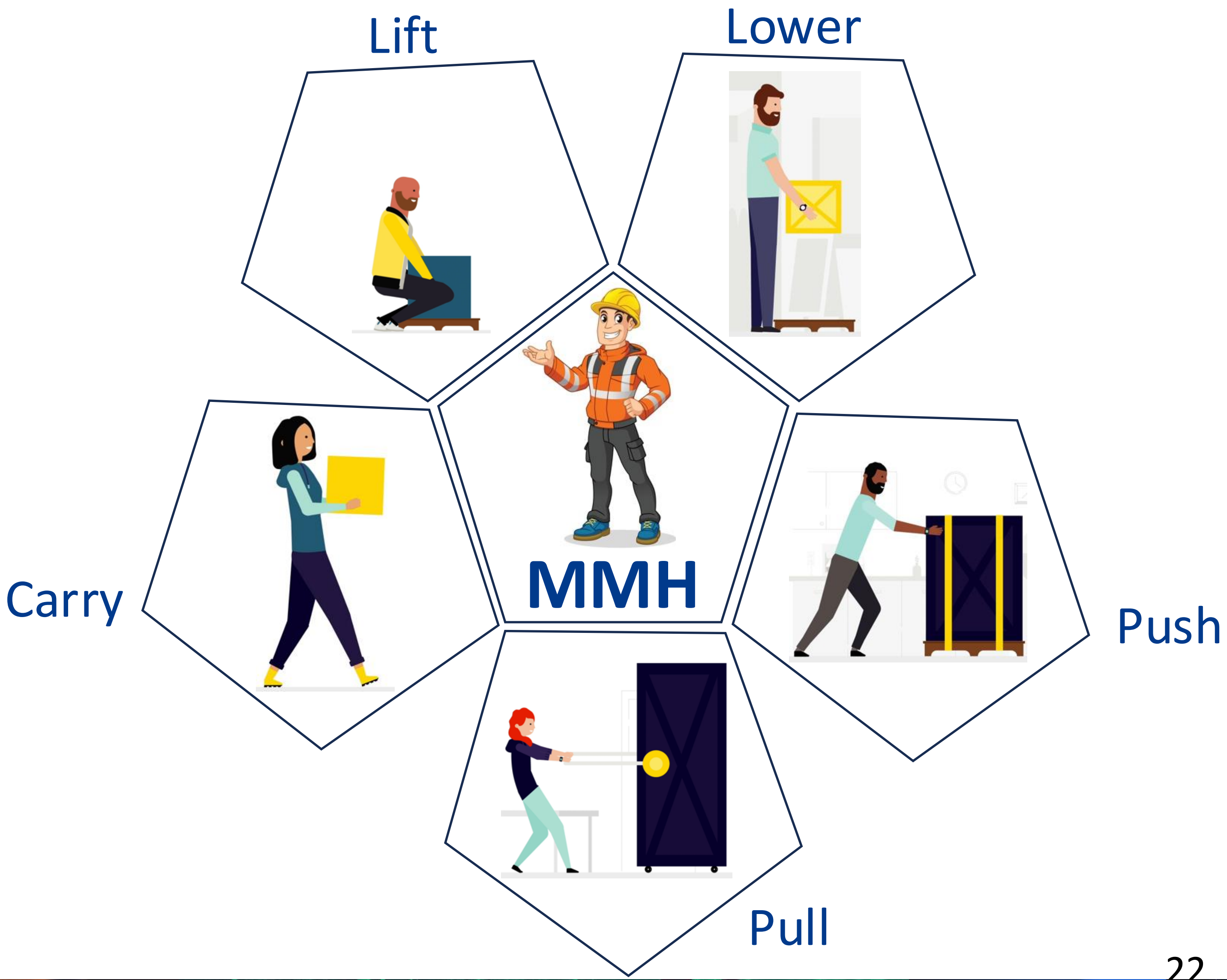


MSI Risk Factors –*Physical Demands Analysis*

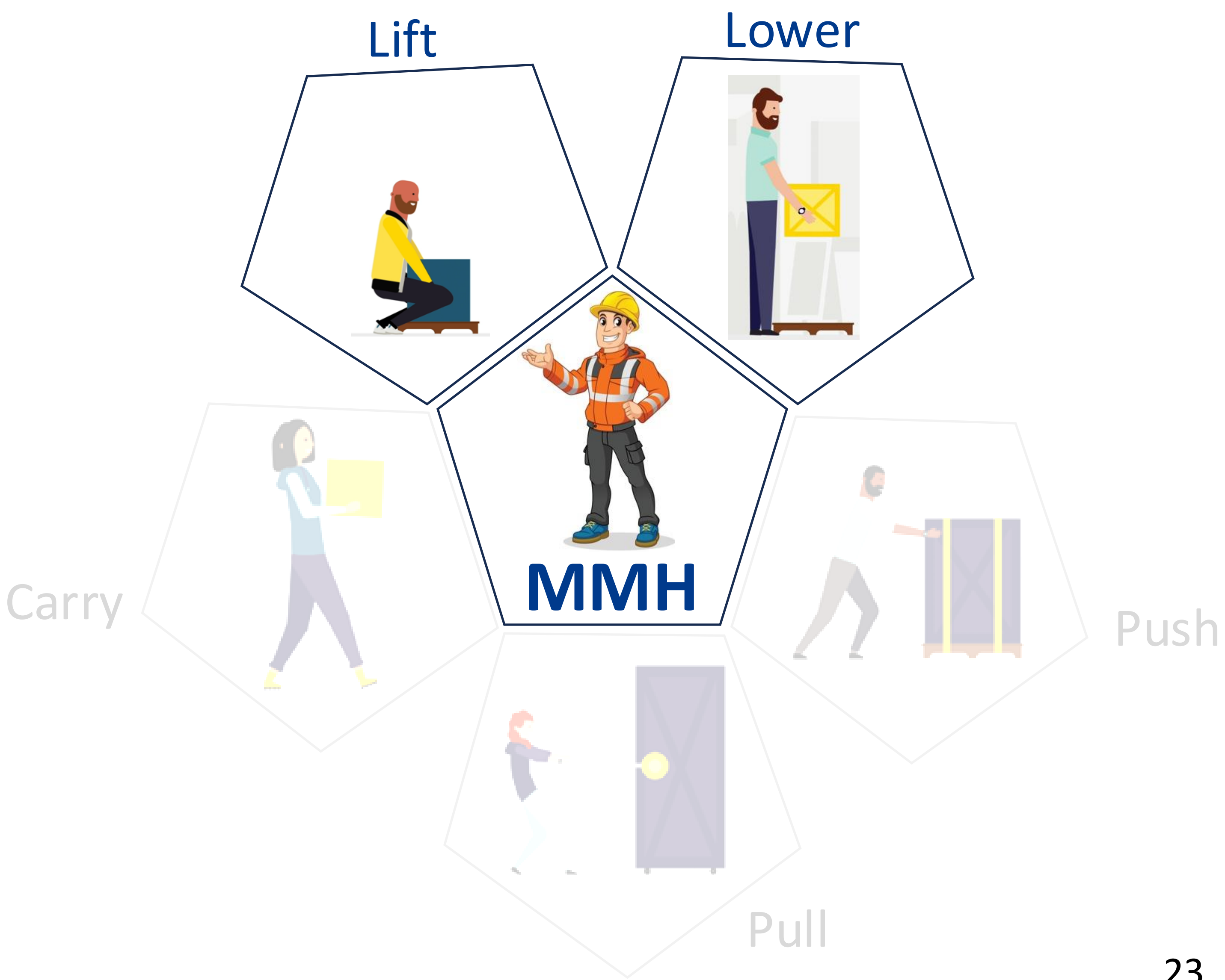


MSI Risk Factors –*Physical Demands Analysis*

Manual Material Handling (MMH)



Manual Material Handling (MMH)



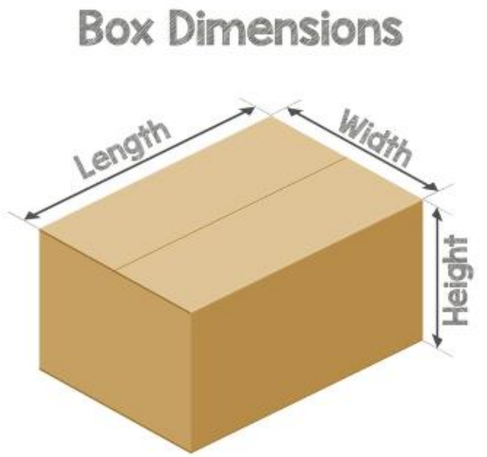
Question 2

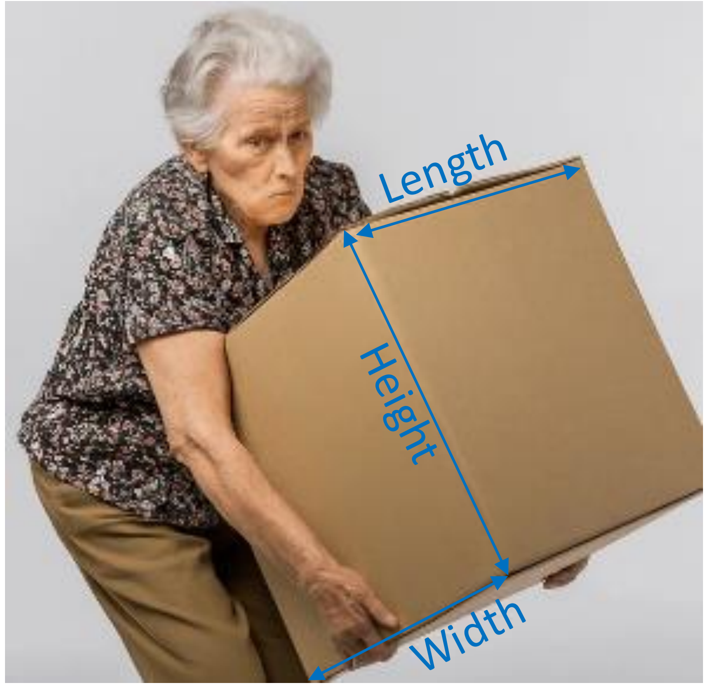
Box Dimensions Most Associated with MSI risk

Box dimension most frequently linked with lower back injury risk (BEFORE)

While lifting, which box dimension is most frequently associated with injury risk to the back and spine?

A) Length
B) Width
C) Height
D) None of the above





Ergonomics Program Design Requirements - WSBC *OHS Regulations 4.46-4.53*

4.51 *OHSR*

4.47 *OHSR*

4.48 *OHSR*

4.49 *OHSR*, Risk Factors

4.50 *OHSR*

4.51 *OHSR*

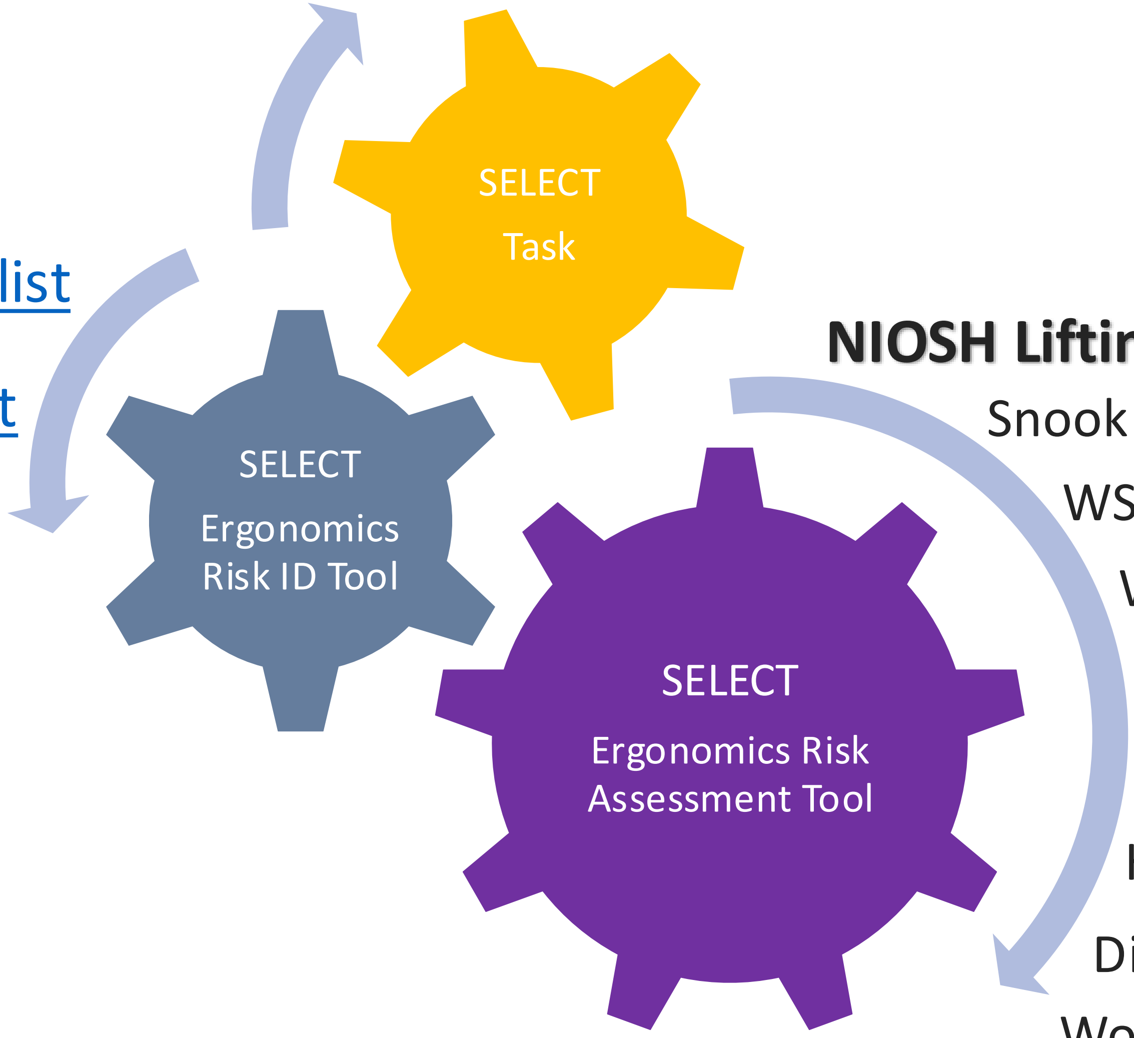
4.52 *OHSR*

MSI Risk Identification and Assessment Process

[Washington State Hazard Zone Checklist]

[WSBC MSI Worksheet]

- ✓ Low
- ❑ Moderate
- ❑ High



NIOSH Lifting Equation

Snook Tables/ LM-MMH

WSBC MMH Calculators

Wash. State Lift Calculator

RULA/ REBA

Revised Strain Index

HandPak

Digital Human Models

Work(s)

Risk Identification and Assessment for MSIs

Lifting and Lowering

Risk Identification

Musculoskeletal Injury (MSI) Risk Assessment Worksheet

WORK SAFE BC

Instructions

1. Review the Guide to Musculoskeletal Injury (MSI) Risk Assessment for information on how to conduct an MSI risk assessment. The guide also describes the physical demands risk factors and contributing risk factors that you need to consider as part of a risk assessment.
2. In the "Description" section of this worksheet:
   - Note the date of the assessment and who is conducting the assessment.
   - Name and describe the job or task being assessed.
   - Note which worker representatives are participating.
3. This worksheet has five sections that address different risk factors. The first part of each section covers physical demands risk factors. The second part of each section covers contributing risk factors.

1. Force required

Physical demands risk factors

Determine if any of the following MSI risk factors are present. Check the boxes for the highest level of risk.

Lifting or lowering		
Low risk	**Moderate risk**	**High risk**
☐ Any lifting or lowering that is less than moderate risk. 	Lifting or lowering objects: ☐ Above shoulder height, below the knees, or at arm's length. ☐ Twice or more per minute for more than 1 hour per shift. ☐ That weigh 2.3 kg (5 lb.) or more, twice or more per minute. ☐ That weigh more than 8.2 kg (18 lb.), once per shift. **Note:** If any box above is selec... proceed to high-risk...	If you find any lifting or lowering that presents a moderate risk, do a lift/lower risk assessment for high risk (see page 5).

Risk Assessment

Lift/lower risk assessment (to determine if high risk)

Use this section to assess forceful exertion from lifting and lowering. You can also use the WorkSafeBC online Lift/Lower Calculator to assess lifting and lowering forces. If a job or task involves a number of lifts with various weights or postures, assess the following scenarios:

1. The worst-case scenario — the heaviest weight and the most awkward posture.
2. The most commonly performed lift. When determining the frequency + duration adjustment in Step 3, consider all the lifting done in a typical workday.

Step 1: Determine the actual weight of the lifted object

What is the lifted object?

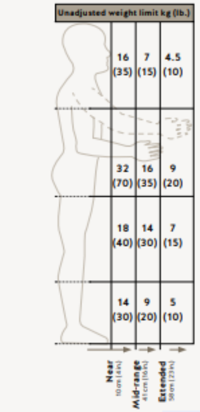
☐ 1. Heaviest/most awkward

☐ 2. Most common

Actual weight =

Step 2: Determine the unadjusted weight limit

Look for the most extreme hand position during the lift/lower task. Mark it on the following diagram.



...adjusted weight limit =

Step 3: Determine the frequency + duration adjustment

Find out how many times the worker lifts per minute and how many total hours per day the worker spends lifting. Look up the frequency + duration adjustment in the following table.

How many lifts per minute?	How many hours per day?		
	Less than 1 h	1 h to 2 h	more than 2 h
1 lift every 2–5 min	1.00	1.00	0.85
1 lift every min	0.95	0.95	0.70
2–3 lifts every min	0.90	0.85	0.60
4–5 lifts every min	0.85	0.70	0.50
6–7 lifts every min	0.60	0.50	0.35
8–9 lifts every min	0.40	0.30	0.15
10+ lifts every min	0.20	0.10	0.05

Note: For lifting done less than once every five minutes, use 1.0.

Frequency + duration adjustment =

Step 4: Determine the twisting adjustment

If the worker twists more than 45° while lifting, the twisting adjustment is 0.85. Otherwise, use 1.0.

Twisting adjustment =

Step 5: Calculate the weight limit

To get the weight limit, multiply the unadjusted weight limit (Step 2) by the frequency + duration adjustment (Step 3) and the twisting adjustment (Step 4).

_____ x _____ x _____ = _____

Step 2 | Step 3 | Step 4

Actual weight =

Step 6: ...

Posture – *Defined*

- "A position of the body, or the way in which someone holds the body when standing, sitting, or walking"

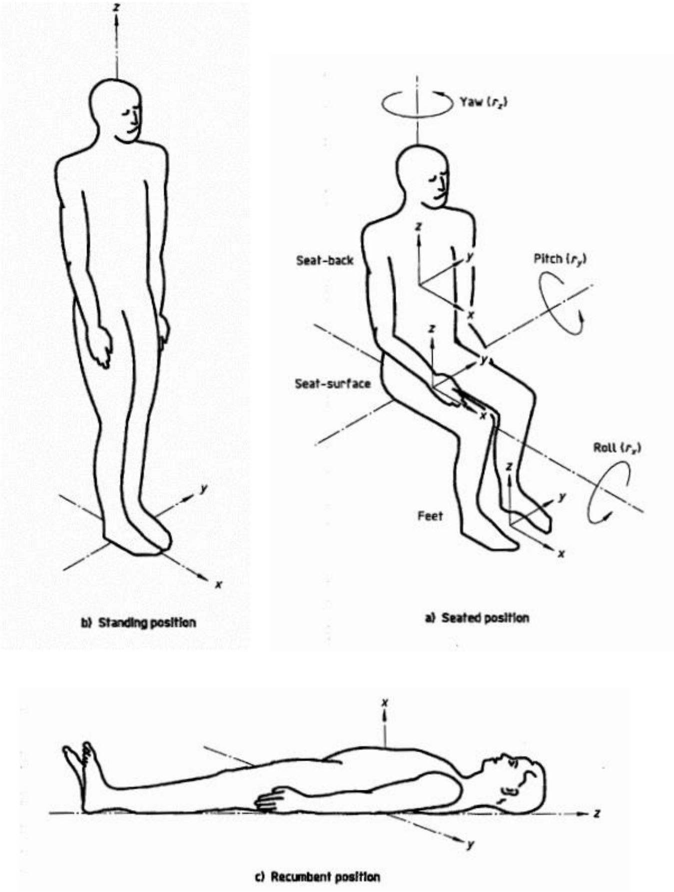
  [Cambridge Dictionary]

- "A state of the body is defined by two relationships which we separate-that of the body to the ground and that of the parts to each other. Thus, we have the upright or standing posture, the lying posture, the sitting posture, each with modifications according to the positions of the limbs and head."

  [Massion et al. (2004)]

- Configuration of the body segments at any given time

  - Thomas (1940)



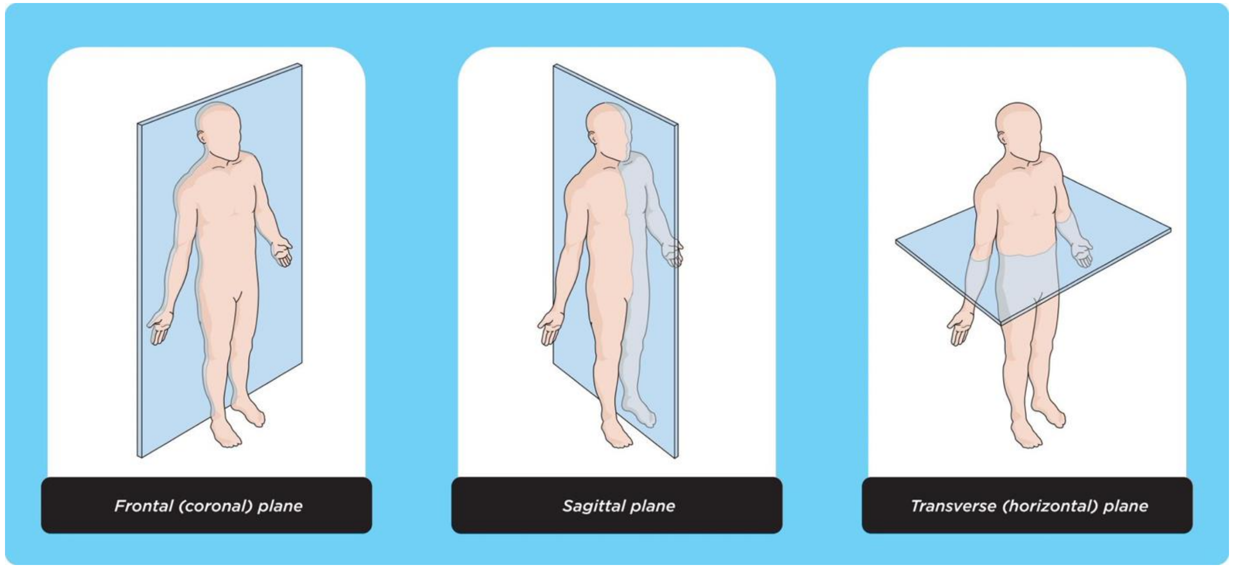
[ISO 2631-1:1997]

Anatomical Position and Body Planes

- Anatomical Position
  - Palms facing forward
  - Thumbs pointed away from body
  - Reference position to describe posture of hand and wrist

Planes of the Body

- Frontal (coronal) plane
  - ➢ Divides body into front and back
- Sagittal plane
  - ➢ Divides body into left and right
- Transverse (Horizontal) plane
  - ➢ Divides body into superior and inferior

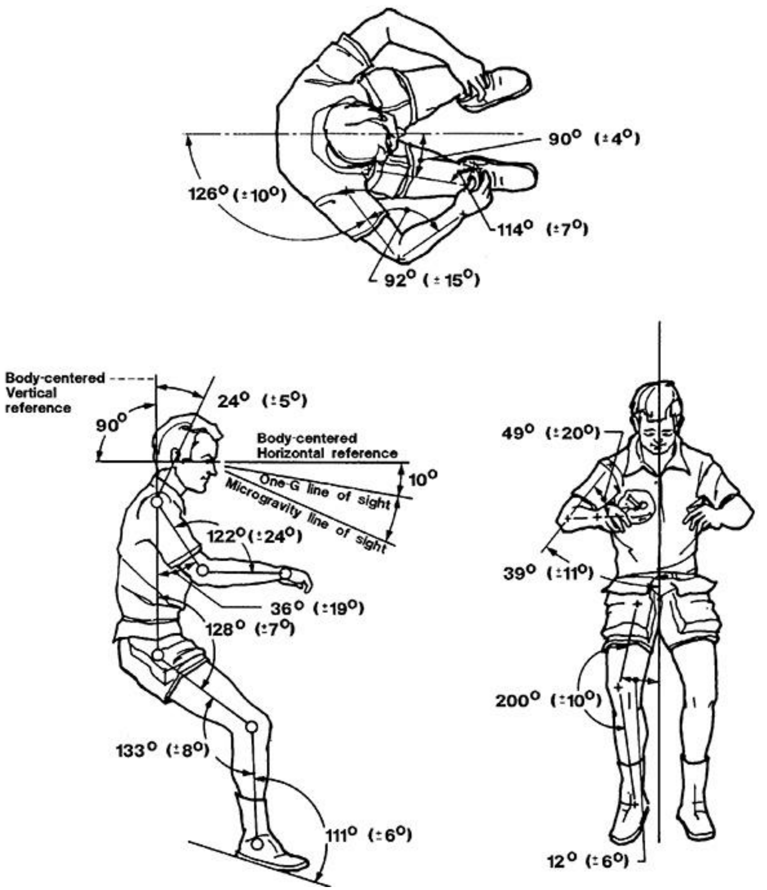


Neutral Posture - *Defined*

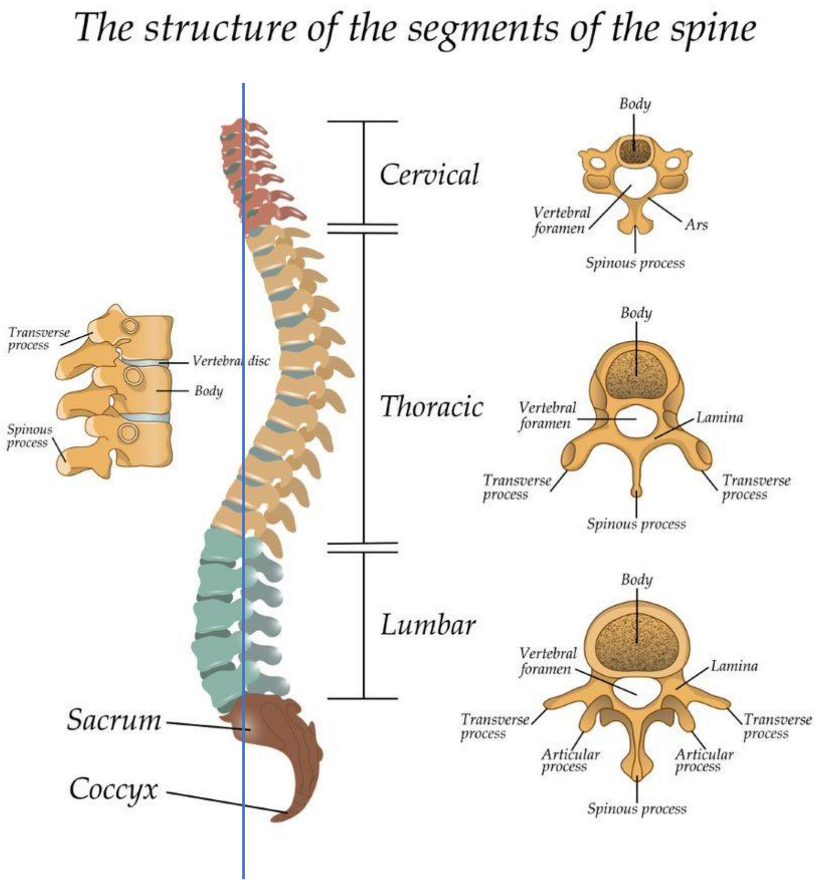
“The posture (i.e., body position) found in weightlessness where the muscle, tendon, and ligament systems acting over the joints are in total balance”

Congleton et al. (1985)

Neutral Posture - *Characterized*



[NASA Standards Inform Comfortable Car Seats | NASA Spinoff]



[Joseph Brence, 2013]

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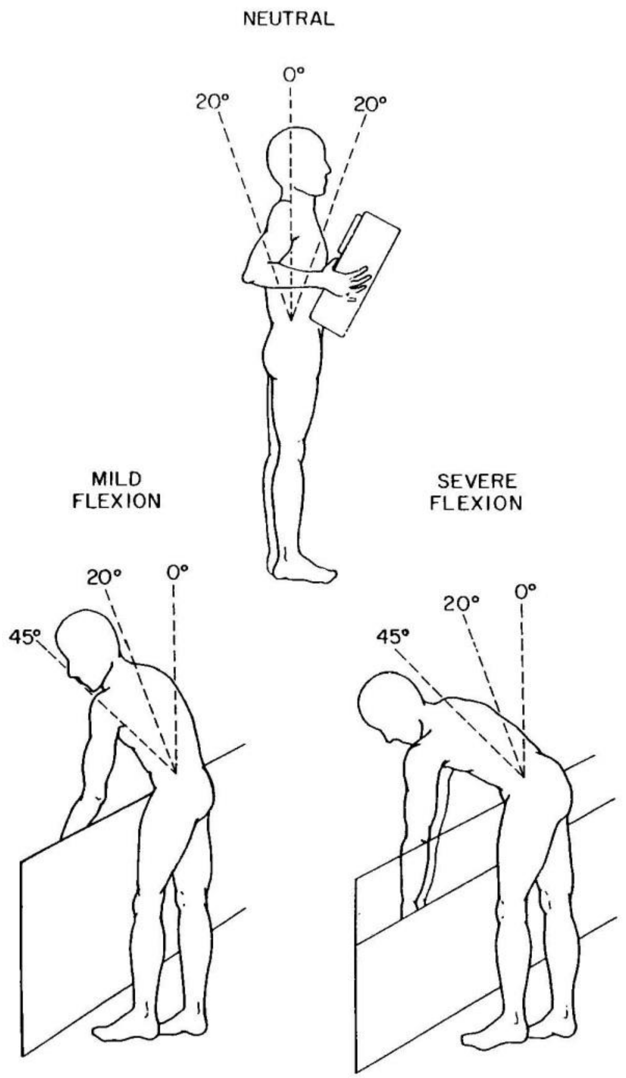
Non-neutral Postures *Defined*

Awkward (i.e., poor) Postures

- "Joint positions that are significant deviations from neutral"

Andrasfay et al. (2021)



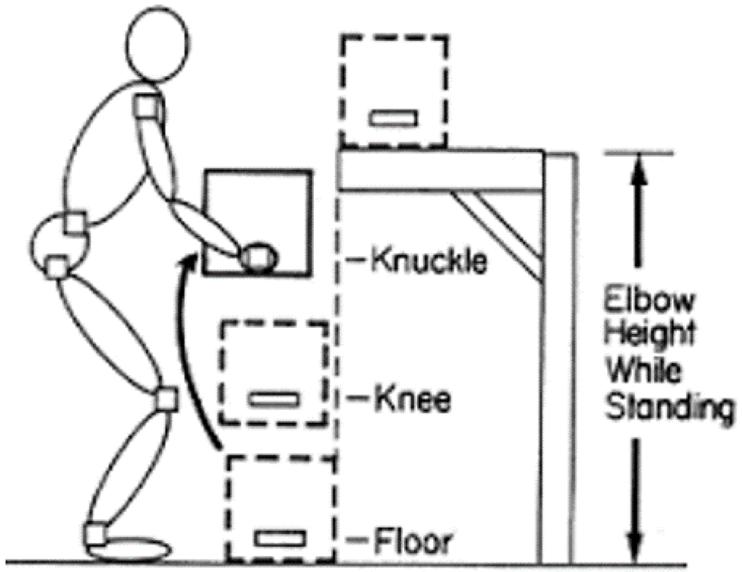
Punnet et al. (1991)

Question 3
Optimal Height for Lifting

Which vertical lifting height based on body part is considered optimal for lifting the maximum weight?

a) Elbow
b) Knuckle
c) Knee
d) Floor

Optimal Lifting Height (BEFORE)



Force Defined - WSBC

"Force refers to the effort a worker must exert on an object as part of a task.

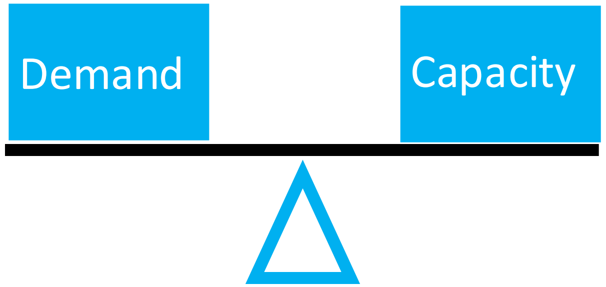
The greater the magnitude and/or intensity of the force, the greater the risk of developing an MSI.

Force can be present with tasks such as lifting, lowering, carrying, pushing, pulling, gripping, and pinching."

WorkSafeBC Guidelines, G4.49 Risk factors

Twitter, 2014

Demand vs. Capacity



MSI Risk Level	Demand vs. Capacity
Low	Demand < Capacity
Moderate	Demand = Capacity
High	Demand > Capacity

Internal Forces
Loading of the Body's Internal Structures

Compression force

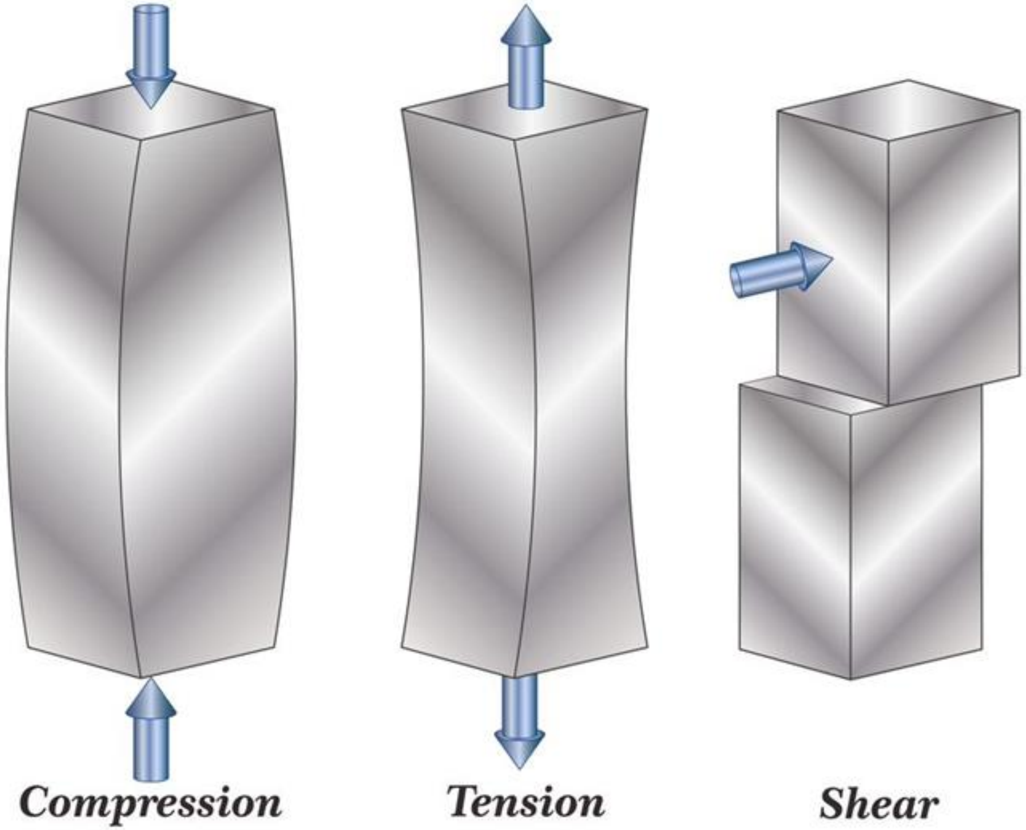
- A force that compresses or squeezes an object or material, pushing its particles or components closer together and causing it to shorten or become more compact

Tension force

- A force transmitted through a wire, rope, string, or similar thing when it is pulled from opposite ends that causes it to stretch or lengthen

Shear force

- A force that makes one surface of a substance move over another parallel surface



Measuring Forces
External Forces Acting on Body

- Weight scale
- Force gauge

Force = mass x acceleration

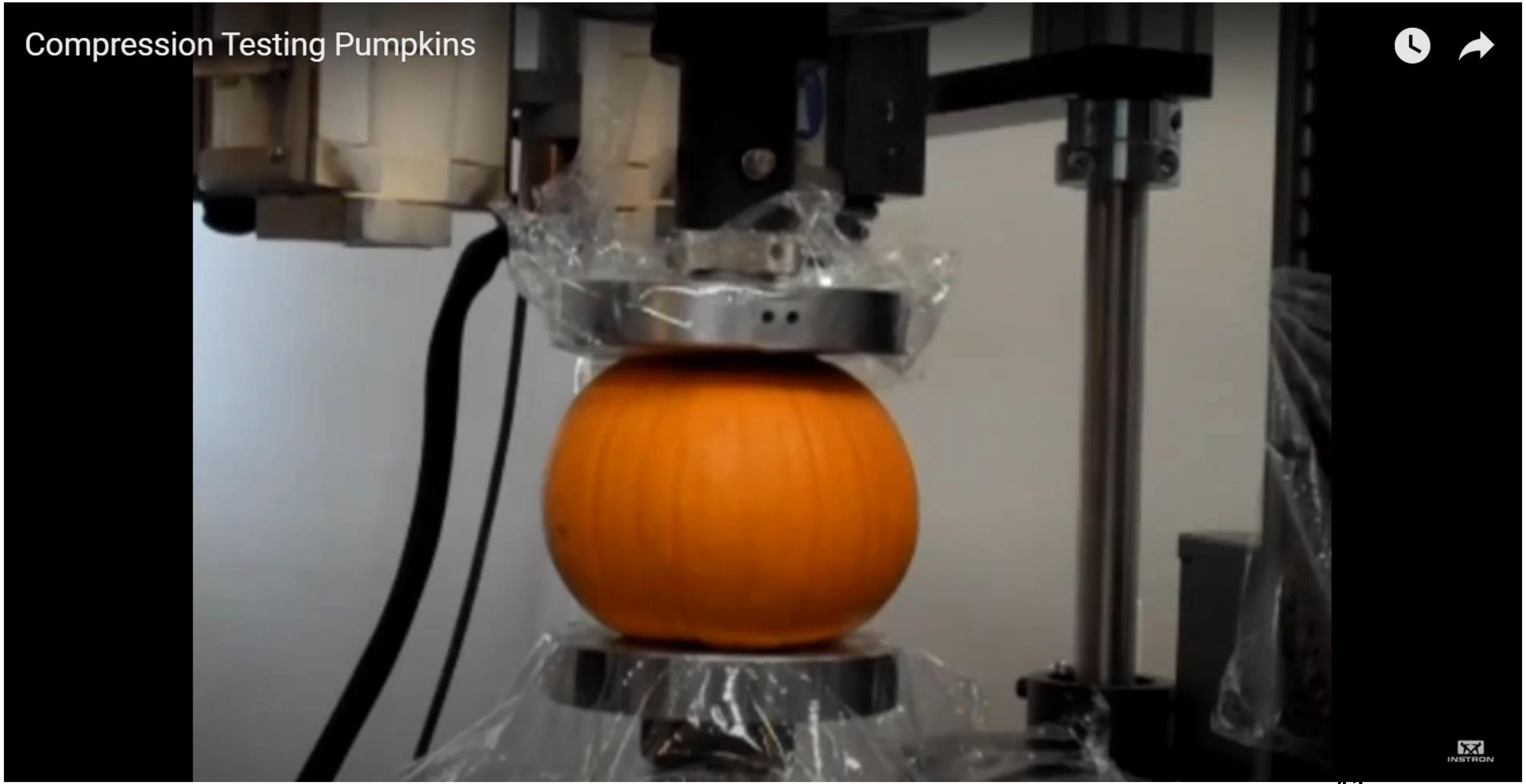
Units of Force → Newtons, Kg, Lbs

Quantifying Internal Forces/ Intensity

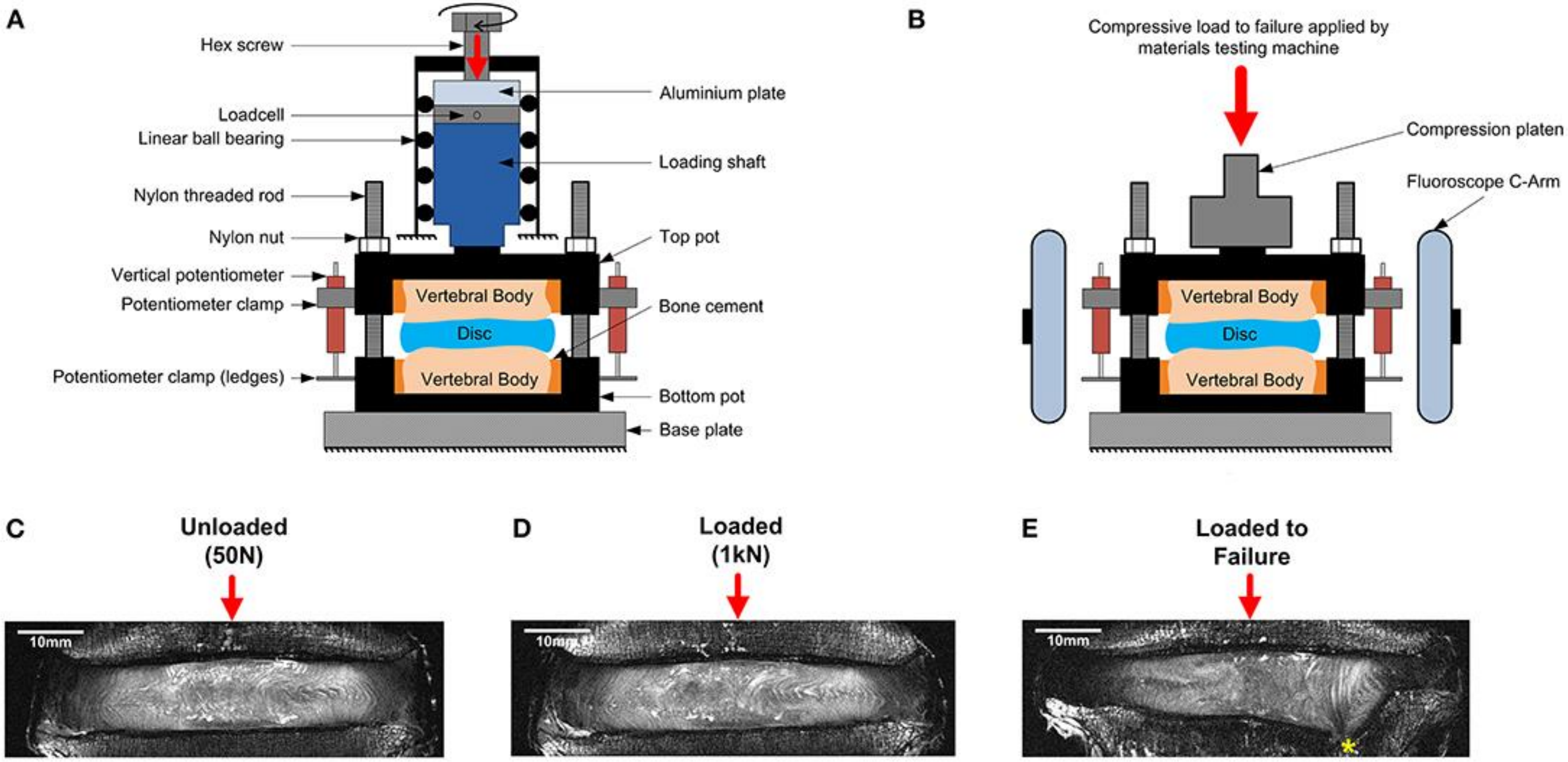
Methods for Determining or Estimating Intensity

Method	Reliability	Ethical Issues	Invasiveness
Implantable Sensor (In Vivo)	**Low/ Moderate**	**High**	**High**
Electromyography (fine wire/ indwelling)	Moderate/ High	Moderate/ High	High
Electromyography (surface)	Moderate/ High	Low	Low
Biomechanical model	**Moderate**	**Low**	**Low**
Psychophysics	**Moderate/ High**	**Low**	**Low**
Heart rate	**Moderate/ High**	**Low**	**Low**
Strength Model	Low - High	Low	Low

Compression Testing: Protect Your Pumpkin



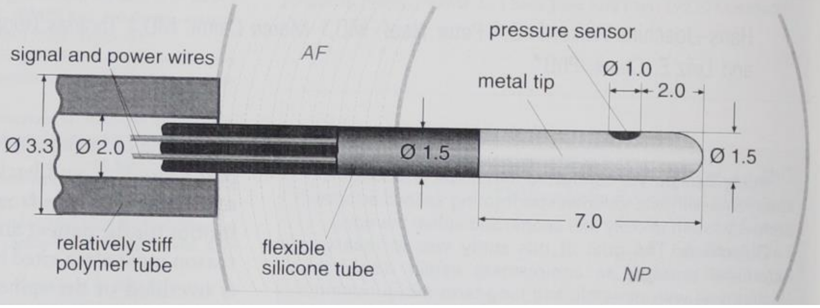
Measuring Capacity: Internal Forces – *In Vitro Biomechanical Loading*



[Tavana et al., 2020]

Measuring Internal Forces
In Vivo Biomechanical Loading

Figure 1. Schematic diagram of the total implantation system (all dimensions in millimeters). To prevent shifting of the transducer caused by the pressure in the nucleus acting at its tip, the transducer was guided through a relatively stiff polymer tube with an inner diameter of 2.0 mm and an outer diameter of 3.3 mm, which was then secured to the belt. Thus, the total implantation system was divided between a stiffer section beginning at the skin surface and extending to the disc, a pliant section within the anulus fibrosus, and finally, a metal tip within the nucleus.



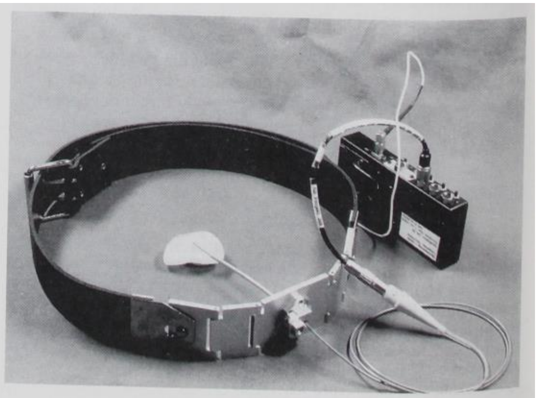


Figure 2. Spatial relation of implanted transducer, intervertebral disc and stabilization, and transmission belt.

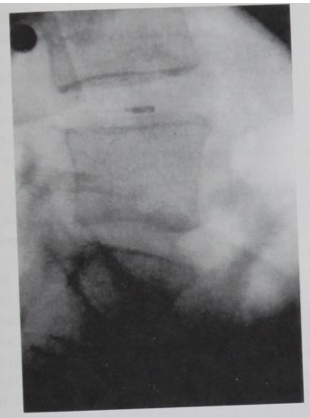


Figure 3. Radiograph with implanted pressure transducer approximately in the center of the L4–L5 nucleus pulposus.

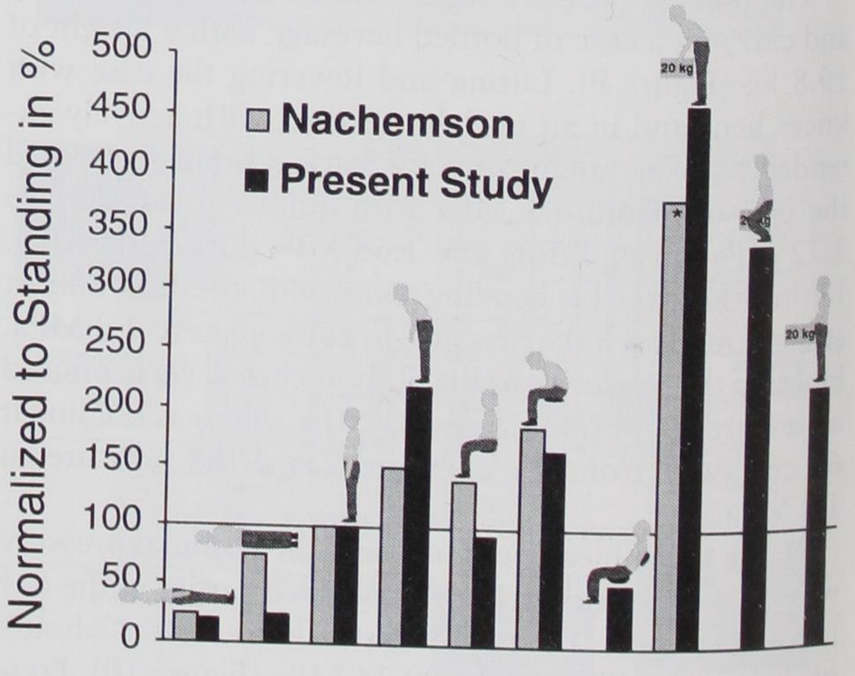
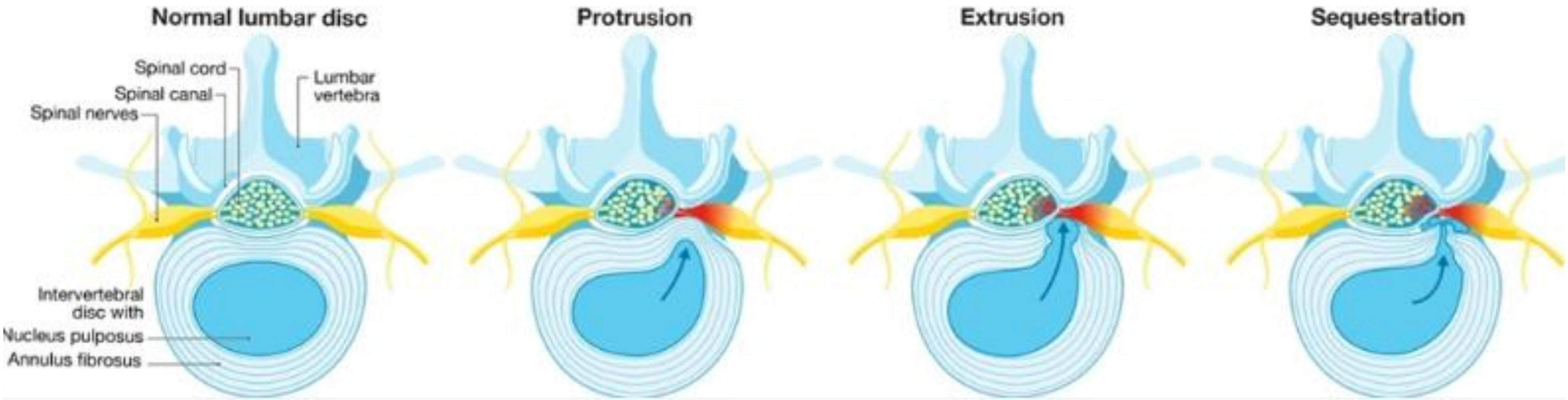


Figure 11. A comparison between data of Nachemson[17,19] and those of the current study (both for 70-kg individuals) regarding intradiscal pressure in common postures and activities, normalized to standing. Lifting weight = 20 kg in the current study; *lifting weight = 10 kg in Nachemson study.

Wilke et al., 1999

Mechanisms of Injury – 8X Mr. Olympia

Spinal Disc Health and Disease

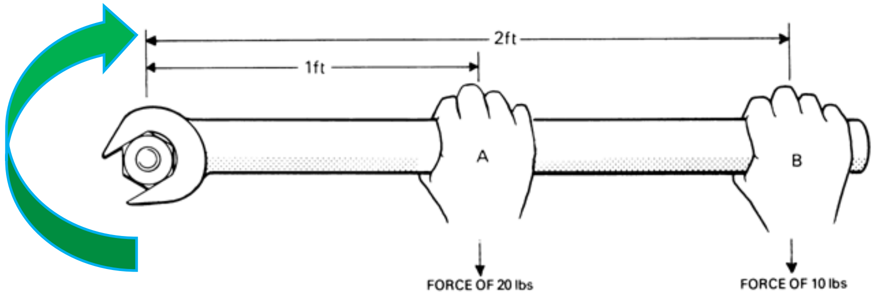


Workshop Activity 1
Static Endurance of Shoulder

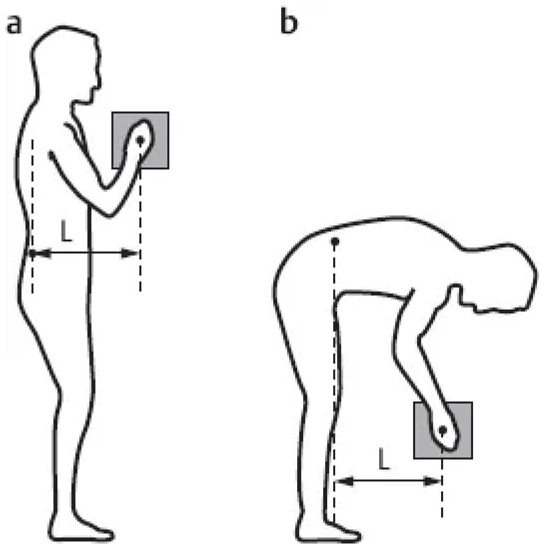
How Lever Arm Length Influences Injury Risk?

Common Levers

- Baseball bat
- Crowbar
- **Socket handle**

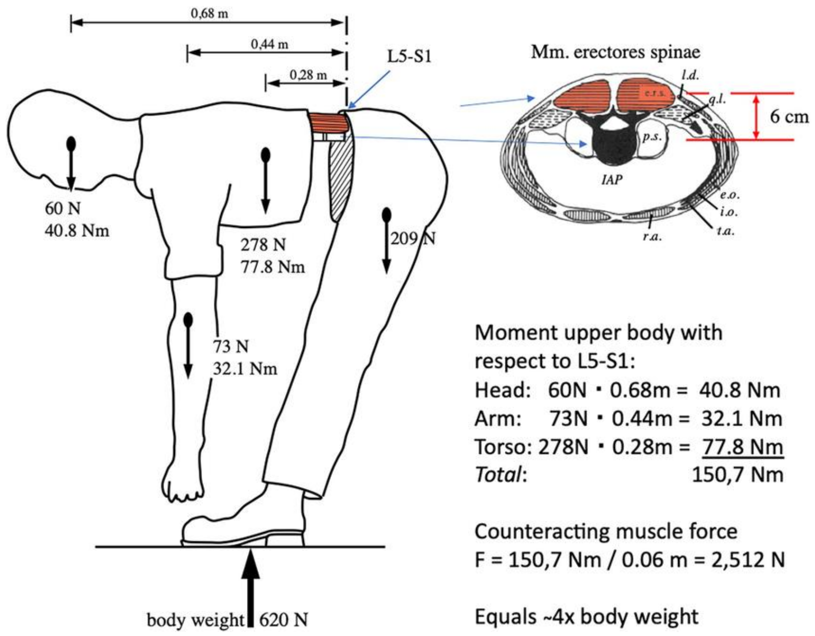


[Barbell Medicine]



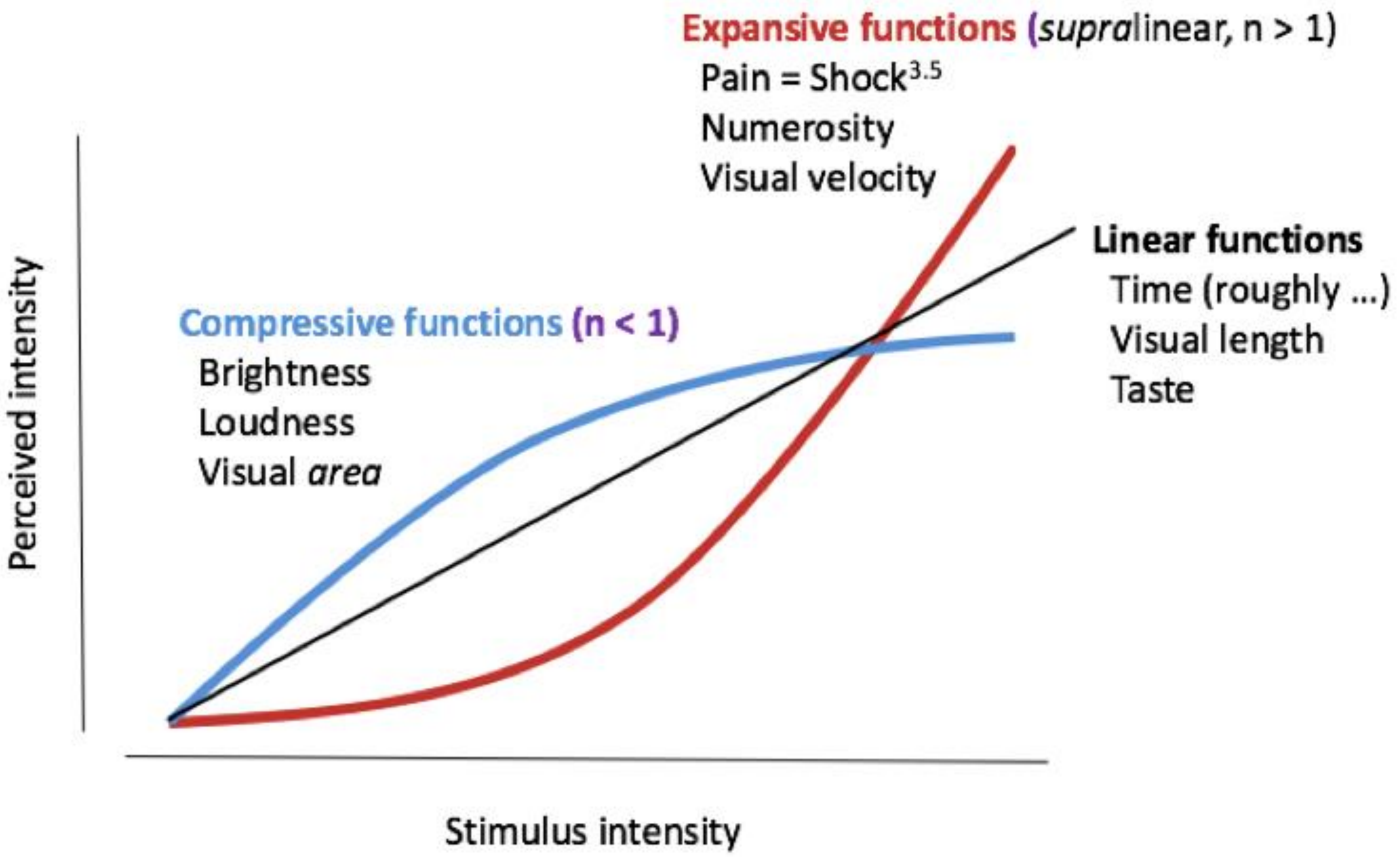
[Musculoskeletal Key]

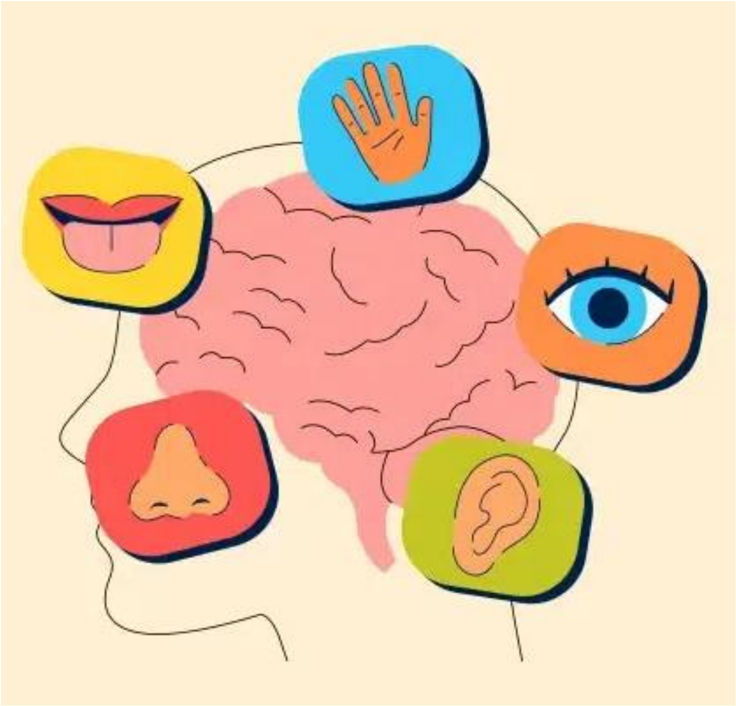
Mass of each body segment requires muscular effort to maintain the body's position



[Smith, 2020]

Psychophysics

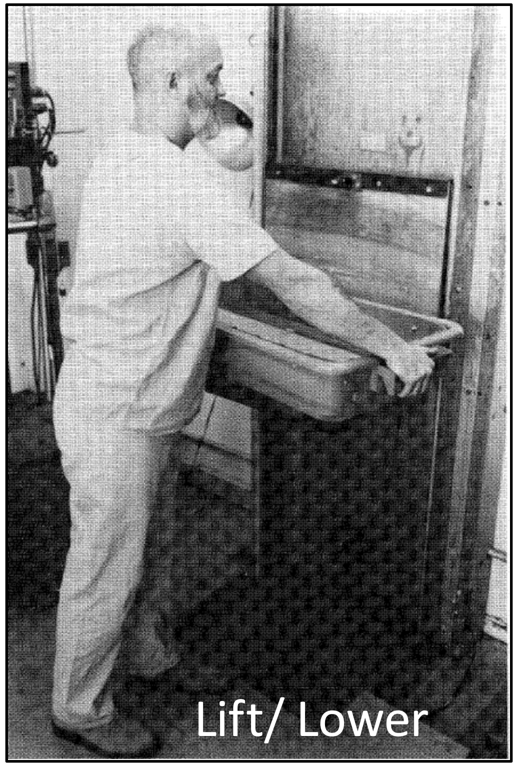


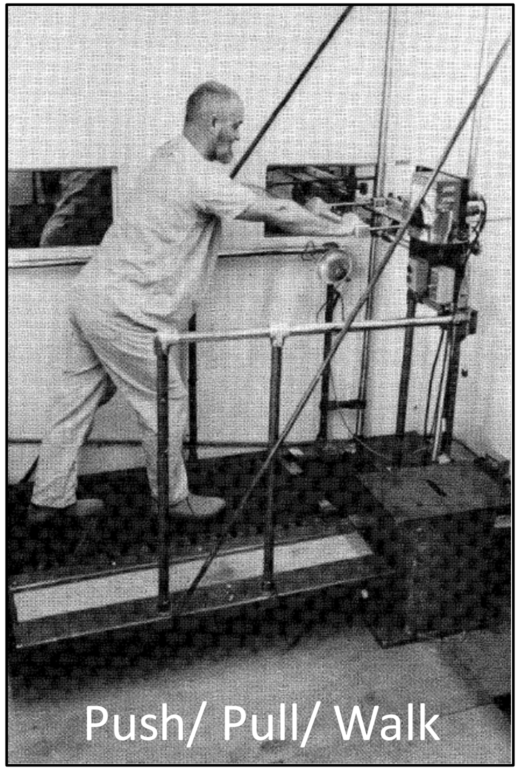


Estimating Intensity – Qualitative and Indirect: *Psychophysics*

Snook Tables & Liberty Mutual Manual Material Handling Equations (LM-MMH)

- Workers requested to self-adjust load or speed based on '**feelings of exertion**' during different MMH tasks:
  - Lifting
  - Lowering
  - Pushing
  - Pulling
  - Carrying
  - Walking





Snook, 1978

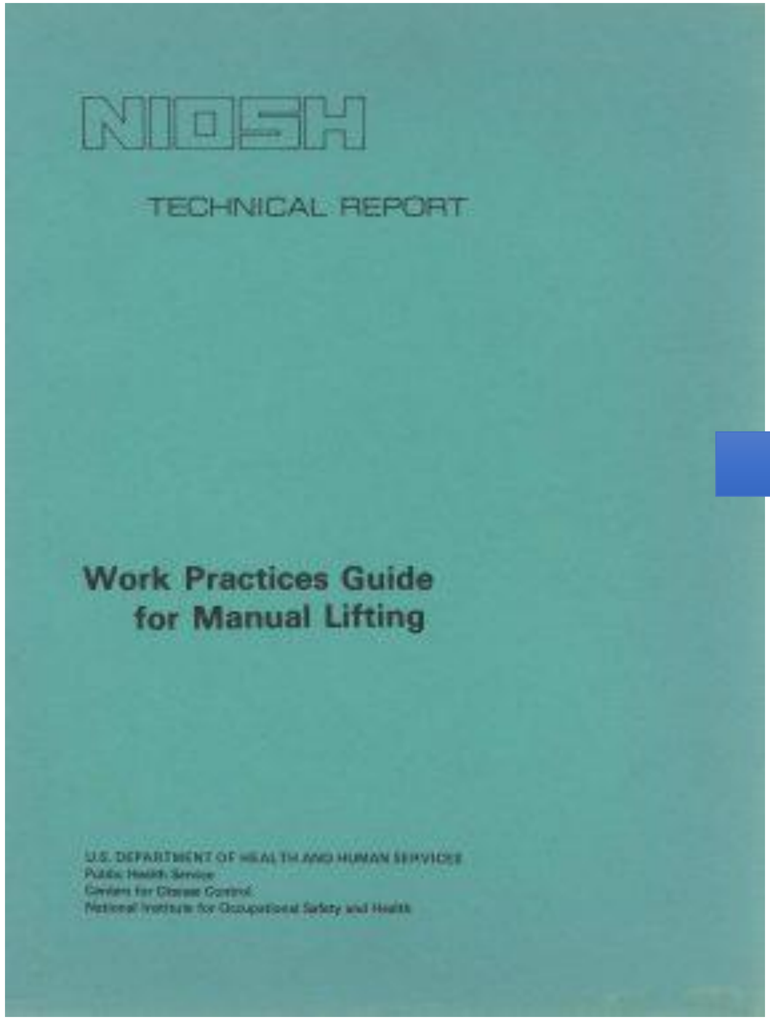
- Provides a good estimate of work intensity between 2 to 6 exertions per minute

Estimating Intensity – Quantitative and Indirect: *Heart Rate (HR)*

- Monitoring HR and Physiological Criteria
- Indirect data that corresponds with physiological criteria from the NIOSH lifting equation
- Provides a good estimation of physical work intensity for frequencies above 6 lifts per minute
- Provides an estimate of cognitive workload
  - Heart Rate Variability

Wahoo Fitness

NIOSH Lifting Equation - REVISED



ERGONOMICS, 1993, VOL. 36, NO. 7, 749–776

Rapid Communication

Revised NIOSH equation for the design and evaluation of manual lifting tasks

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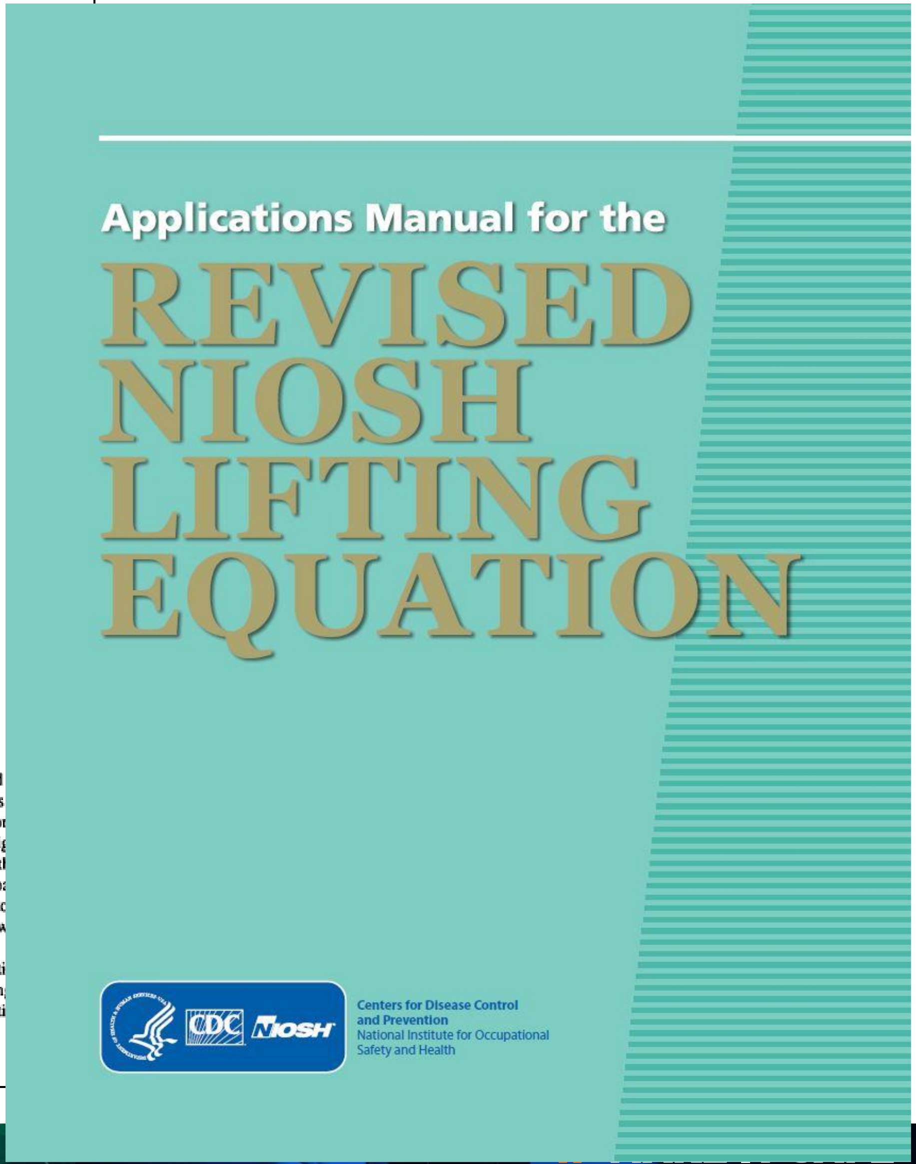
Keywords: Low back pain; Prevention and control;
Evaluation methodology; Lifting.

In 1985, the National Institute for Occupational Safety and Health (NIOSH) convened an *ad hoc* committee of experts who reviewed the current literature on lifting, recommend criteria for defining lifting capacity, and in 1991 developed a revised lifting equation. Subsequently, NIOSH developed the documentation for the equation and played a prominent role in recommending methods for interpreting the results of the equation. The 1991 equation reflects new findings and provides methods for evaluating asymmetrical lifting tasks, lifts of objects with less than optimal hand–container couplings, and also provides guidelines for a larger range of work durations and lifting frequencies than the 1981 equation. This paper provides the basis for selecting the three criteria (biomechanical, physiological, and psychophysical) that were used to define the 1991 equation, and describes the derivation of the individual components (Putz-Anderson and Waters 1991). The paper also describes the lifting index (LI), an index of relative physical stress, that can be used to identify hazardous lifting tasks. Although the 1991 equation has not been fully validated, the recommended weight limits derived from the revised equation are consistent with or lower than those generally reported in the literature. NIOSH believes that the revised 1991 lifting equation is more likely than the 1981 equation to protect most workers.

1. Introduction

The National Institute for Occupational Safety and Health (NIOSH) first developed equation in 1981 to assist safety and health practitioners evaluate lifting demands the sagittal plane (NIOSH 1981). The lifting equation was widely used by occupation health practitioners because it provided an empirical method for computing a weig limit for manual lifting. This limit proved useful for identifying certain lifting jobs th posed a risk to the musculoskeletal system for developing lifting-related low back pa (Liles and Mahajan 1985). Because the 1981 equation could only be applied to limited number of lifting tasks, namely sagittal lifting tasks, the 1981 equation w revised and expanded in 1991 to apply to a larger percentage of lifting tasks.

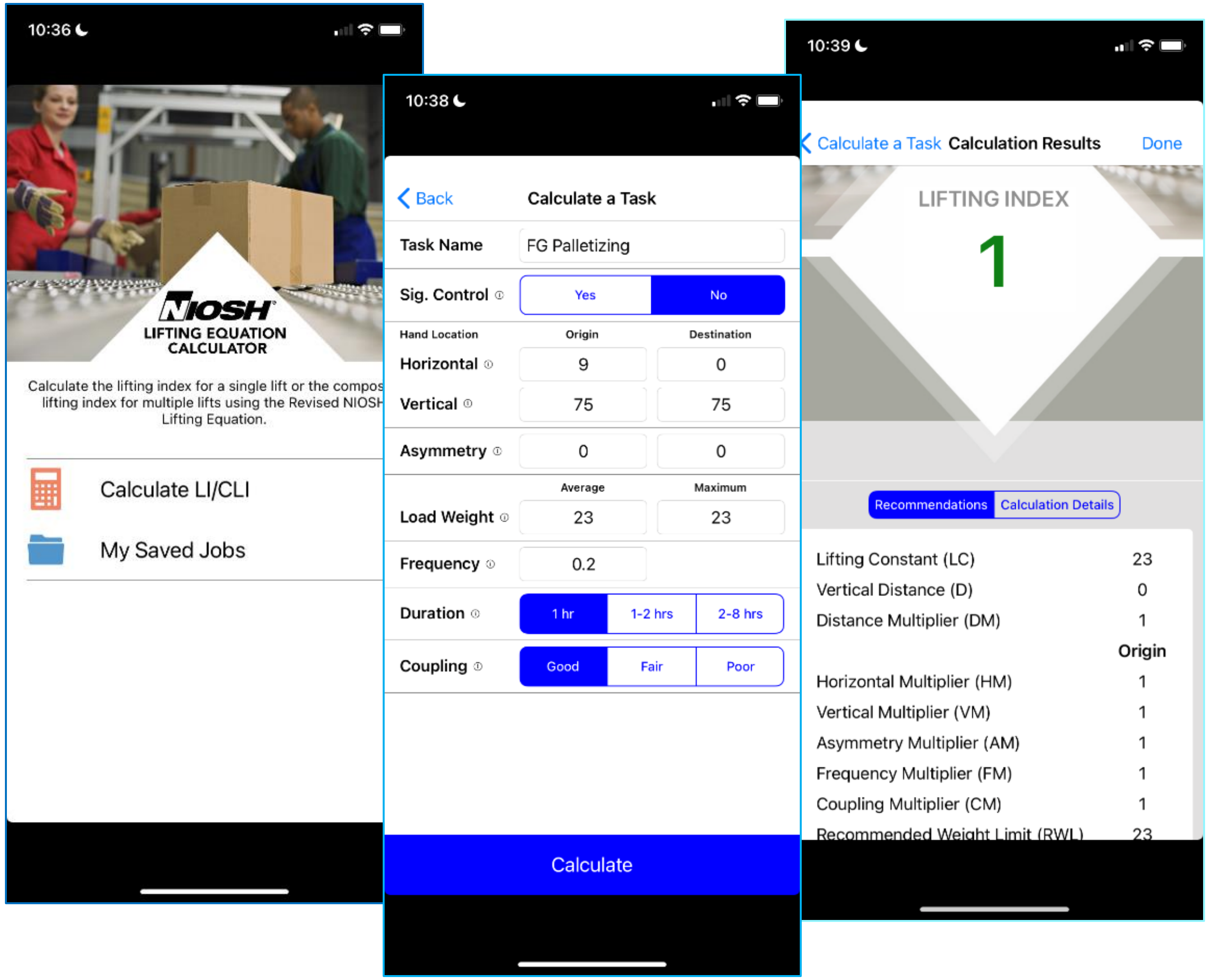
The 1991 lifting equation reflects new findings, provides methods for evaluati asymmetrical lifting tasks, objects with less than optimal hand–container couplin and offers new procedures for evaluating a larger range of work durations and lifti



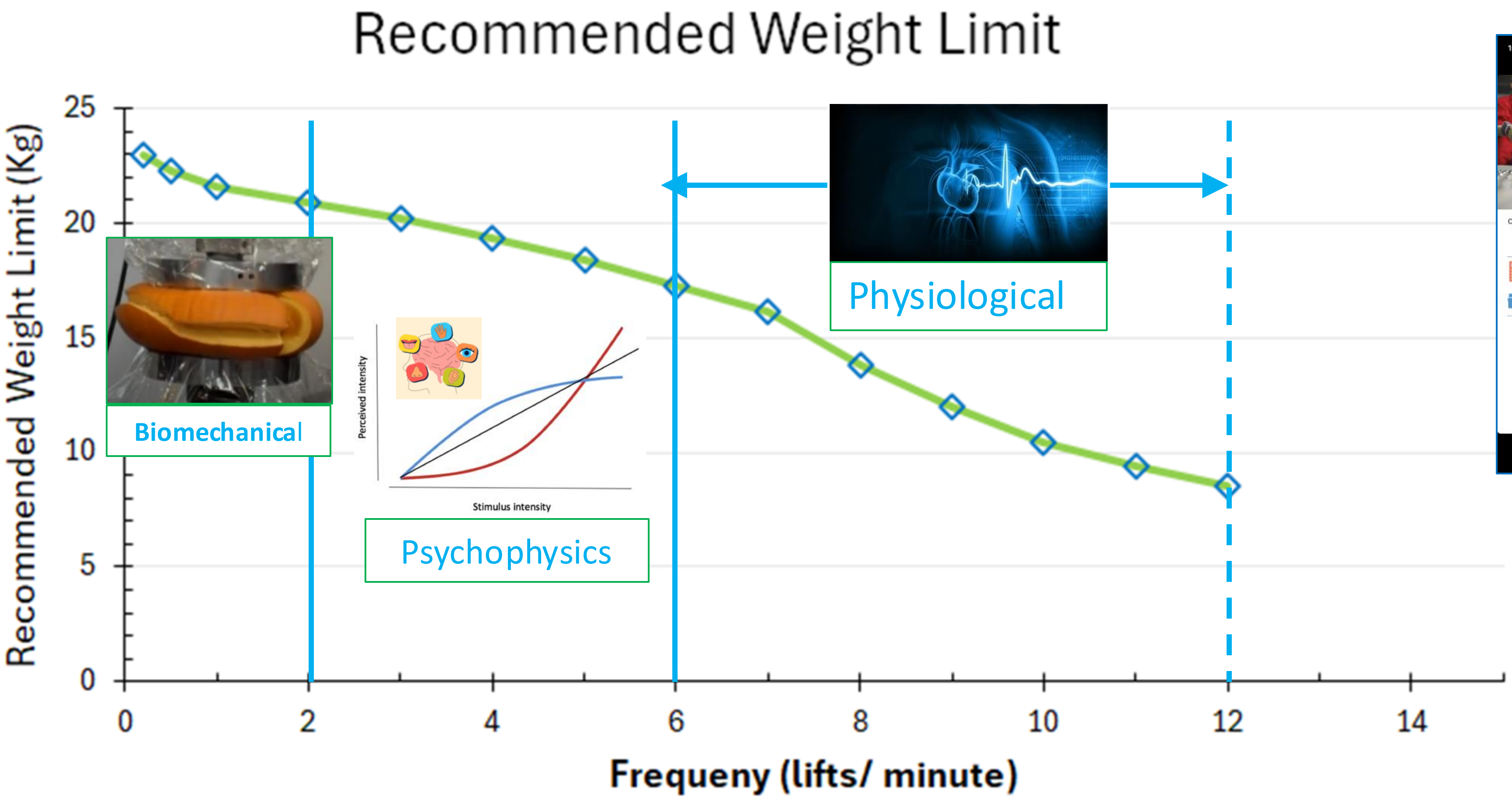
Workshop Activity 2 – Exploring RNLE Parameters

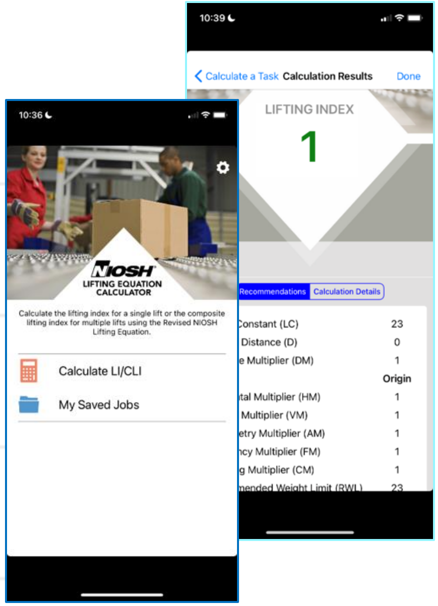
- Download NLE App
  - iPhone (Apple IOS) ONLY
- Change inputs and calculate RWL
- Change units from metric to imperial
- Explore descriptions of inputs
  - Lifting Index (LI)
  - Significant control vs. Horizontal Destination
  - …

NIOSH NLE Calculator



NIOSH Lifting Equation – Revised: *Recommended Weight Limit*





Revised NIOSH Lifting Equation (RNLE)

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

Multipliers

Load Constant

Recommended Weight Limit

National Institute of Occupational Health and Safety (NIOSH), 2022

Determining Capacity Relative to Demand

1. Measure and record the RNLE input parameters
2. Determine the parameter multipliers
3. Use a worksheet or calculator to determine the RWL and Lifting Index (LI)
4. Determine if the LI is greater than moderate or high risk

MSI Risk Level	Demand vs. Capacity	Lifting Index (LI)
	Demand << Capacity	LI < 1.0
Low	Demand < Capacity	1.0 < LI ≤ 1.5
Moderate	Demand = Capacity	1.5 < LI ≤ 2.0
High	Demand > Capacity	2.0 < LI ≤ 3.0

Fox et al. 2019

Worksheet for Recording RNLE

JOB ANALYSIS WORKSHEET

DEPARTMENT ______________________ JOB DESCRIPTION
JOB TITLE ______________________ ______________________
ANALYST'S NAME ______________________ ______________________
DATE ______________________ ______________________

STEP 1. Measure and record task variables

Object Weight (lbs.)		Hand Location (in.) Origin		Hand Location (in.) Destination		Vertical Distance (in.)	Asymmetry Angle (degrees) Origin	Asymmetry Angle (degrees) Destination	Frequency Rate Lifts/min.	Duration Hours	Object Coupling
L (avg.)	L (max.)	H	V	H	V	D	A	A	F		C

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

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

ORIGIN RWL = ☐ × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐

DESTINATION RWL = ☐ × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐

STEP 3. Compute the LIFTING INDEX

ORIGIN Lifting Index = Object Weight (L) / RWL = ________ = ☐

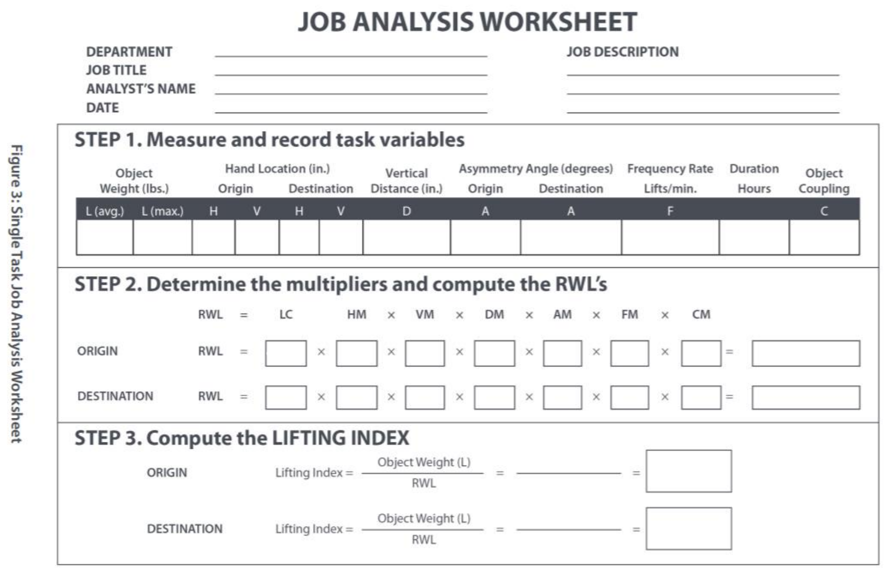
DESTINATION Lifting Index = Object Weight (L) / RWL = ________ = ☐

Figure 3: Single Task Job Analysis Worksheet

Workshop Activity 3
15 Minute Workshop Activity

Instructions

- In groups of 4, measure and record the following input parameters:
  - Horizontal
  - Vertical
  - Distance
  - Asymmetry



JOB ANALYSIS WORKSHEET

DEPARTMENT ____________
JOB TITLE ____________
ANALYST'S NAME ____________
DATE ____________

JOB DESCRIPTION ____________

STEP 1. Measure and record task variables

Object Weight (lbs.)		Hand Location (in.) Origin		Hand Location (in.) Destination		Vertical Distance (in.)	Asymmetry Angle (degrees) Origin	Asymmetry Angle (degrees) Destination	Frequency Rate Lifts/min.	Duration Hours	Object Coupling
L (avg.)	L (max.)	H	V	H	V	D	A	A	F		C

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

RWL = LC HM × VM × DM × AM × FM × CM

ORIGIN RWL = ☐ × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐

DESTINATION RWL = ☐ × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐

STEP 3. Compute the LIFTING INDEX

ORIGIN Lifting Index = $\frac{\text{Object Weight (L)}}{\text{RWL}}$ = ______ = ☐

DESTINATION Lifting Index = $\frac{\text{Object Weight (L)}}{\text{RWL}}$ = ______ = ☐

Figure 3: Single Task Job Analysis Worksheet

Load Constant (LC)

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

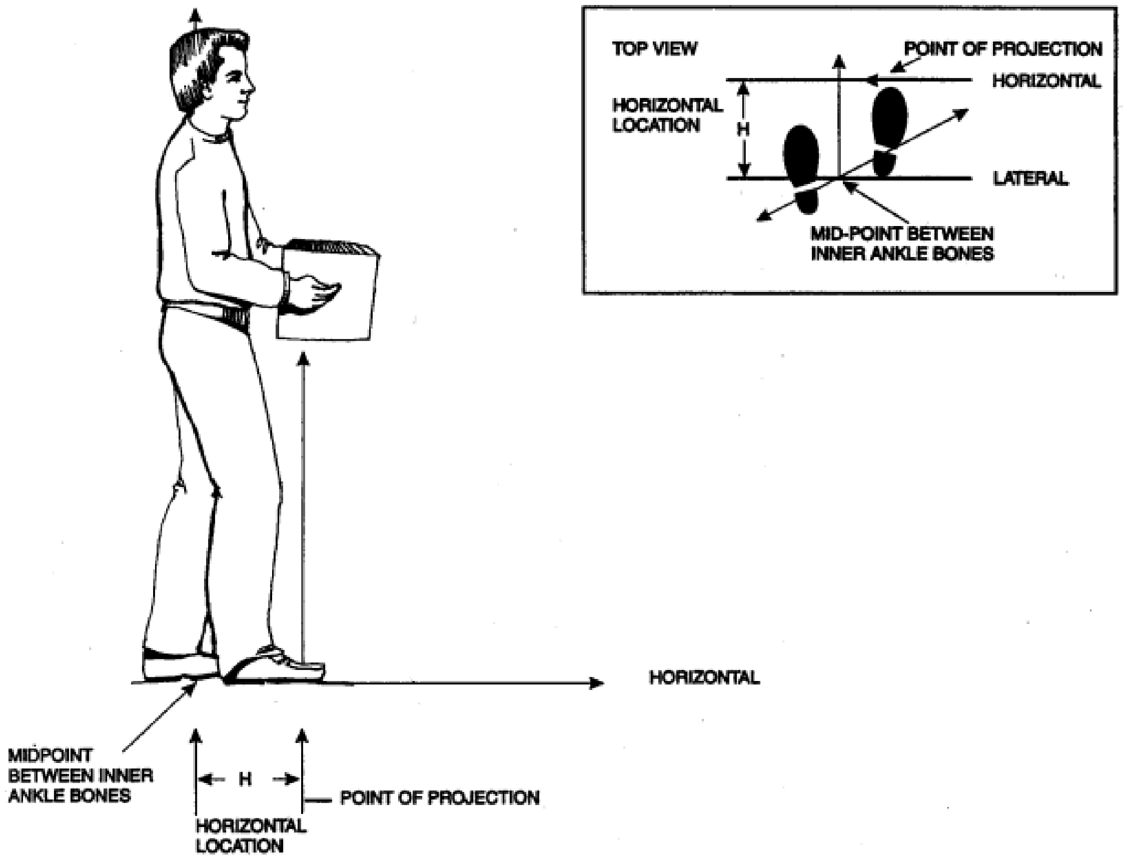
The load constant (23 kg or 50 lbs) refers to the maximum recommended weight for lifting at the standard lifting location under optimal conditions

- Acceptable to 75% of female workers and about 90% of male workers
- "Two out of every three low back injuries associated with heavy manual handling tasks can be prevented if the tasks are designed to fit at least 75% of the population"

Waters et al., 2003

Horizontal (H)

- Axial compression stress applied to spine is generally proportional to horizontal distance of load from spine
- As the load is moved horizontally from the spine, the amount of weigh a person is willing to lift decreases proportionately
- H is most sensitive parameter to measurement errors



Garg, 1995

Horizontal Multipliers (HM)

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

- Optimal H corresponds with body's center of mass projected through inner ankle bones
- A reduction coefficient defined as:
  - 10/H, for H measured in inches; and
  - 25/H, for H measured in centimeters
  - Min H ≤ 10 in (25 cm), set HM = 1.0
  - Max H = 25 in (63 cm), set HM = 0.4

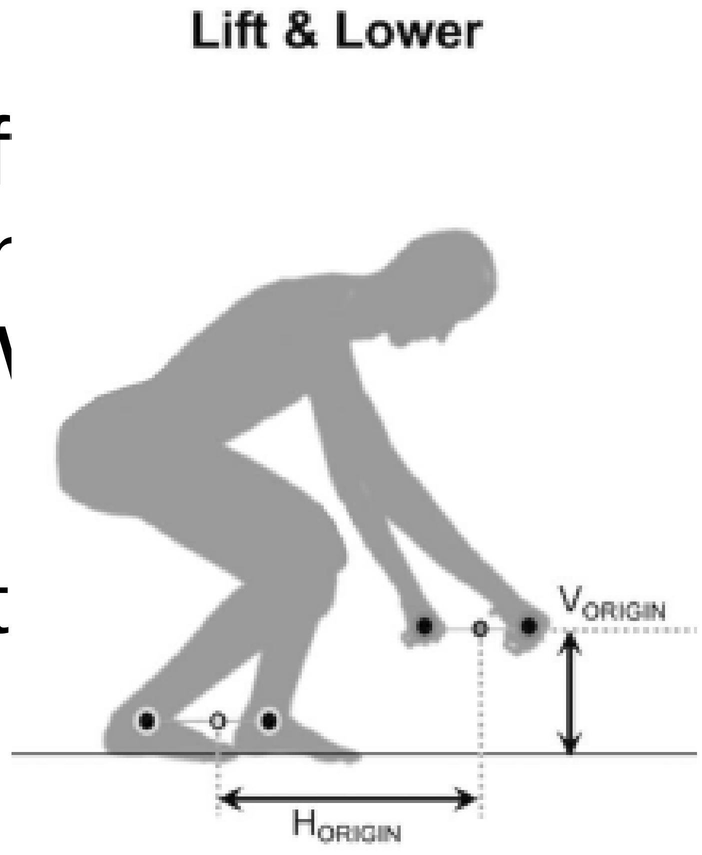
Horizontal Multiplier

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

Workshop Activity 4 and 5 – HM and VM Effects

To understand the independent ef
manipulating the Horizontal (H) ar
(V) Inputs on the Recommended \
(RWL)

- Use double-sided sheet in booklet

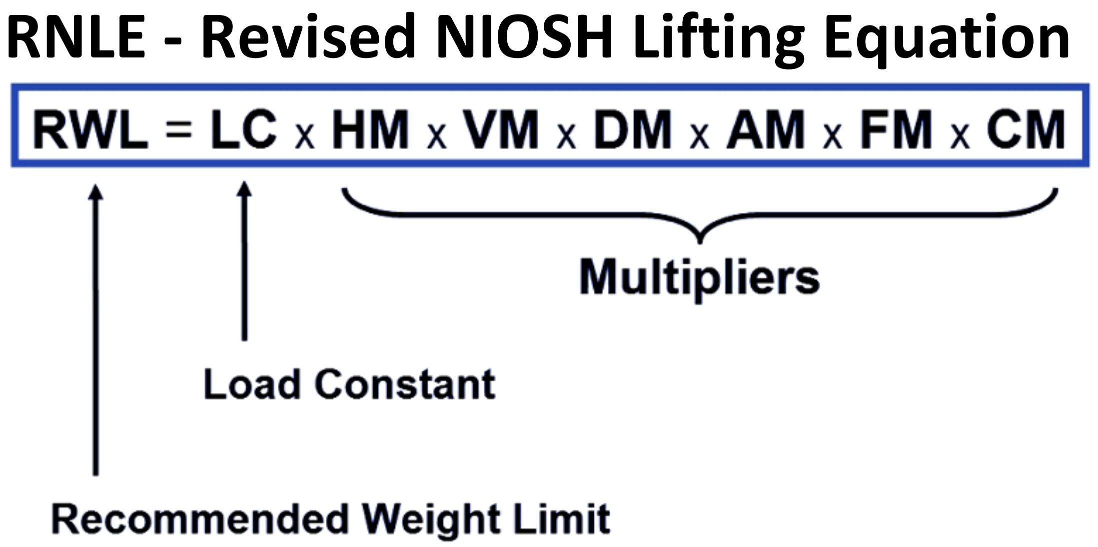


Potvin, 2021

Workshop Activity 4 – HM Effects on RWL

Instructions

- Use spreadsheet to complet



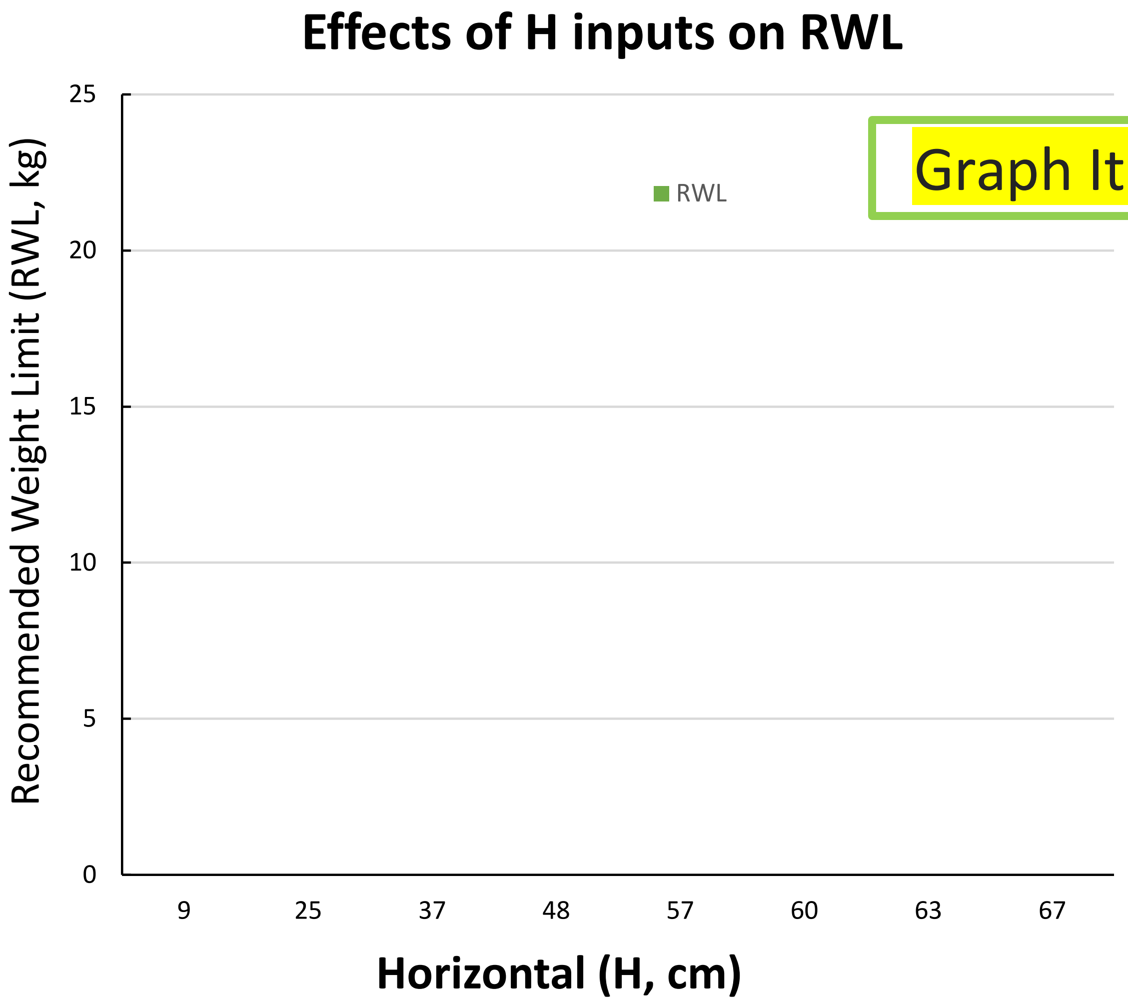
RNLE INPUTS						
Load	H	V	D	A≥	F V ≥ 75 cm for ≤ 1 h	C V ≥ 75 cm
23	25	75	25	0	0.2	Good
3						
LC	HM	VM	DM	AM	FM	CM
23	1.00	1.00	1.00	1.00	1.00	1.00

RWL = 23.0 kg

Workshop Activity 4 – Effects of HM on RWL

H inputs and outputs

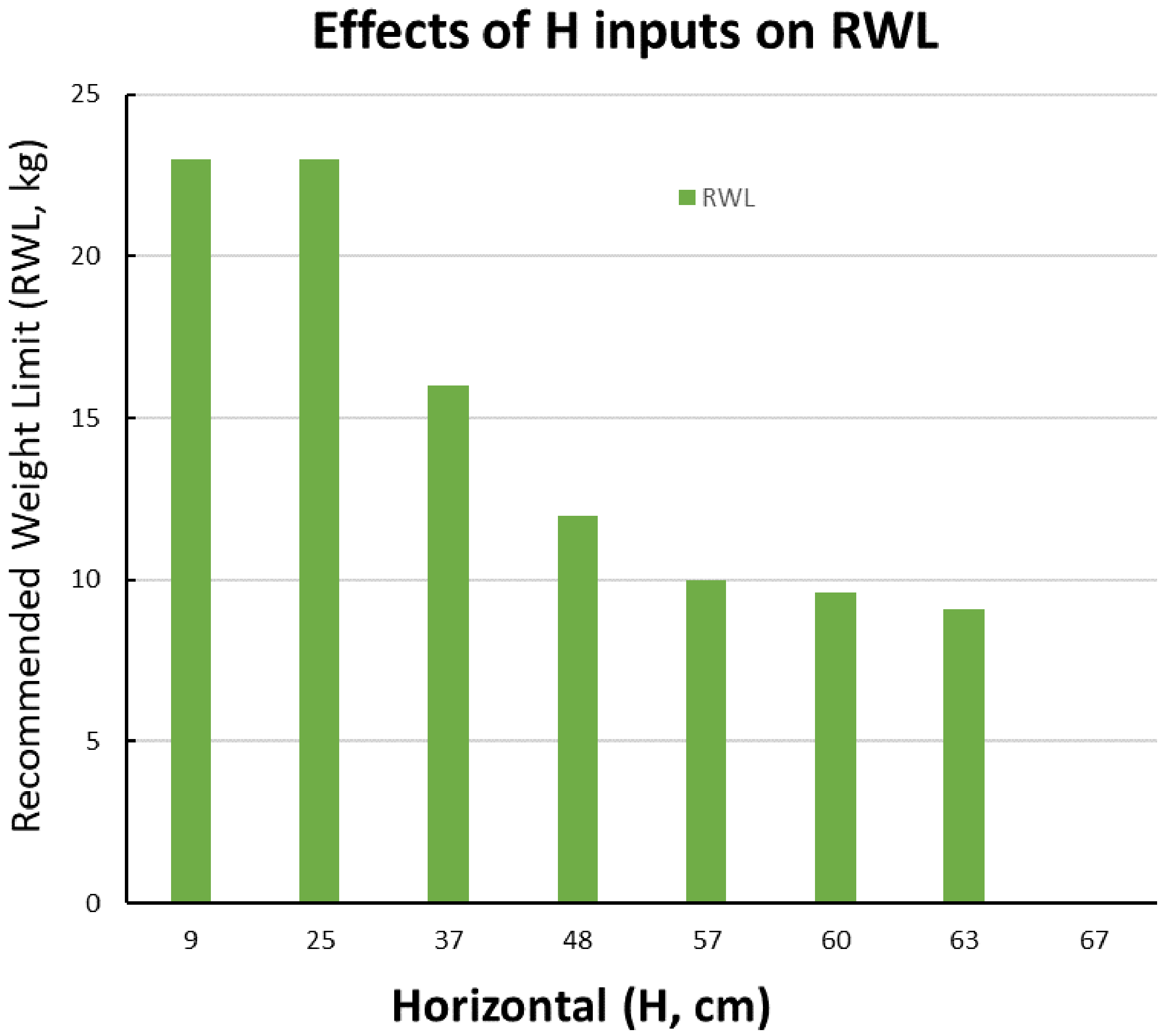
H_{input} (cm)	HM	RWL (kg)
9		
25		
37		
48		
57		
60		
63		
67		



Graph It !!

MAKE IT SAFE

Workshop Activity 4 – Effects of HM on RWL



H_{input} (cm)	HM	RWL (kg)
9	1.0	23.0
25	1.0	23.0
37	0.68	15.5
48	0.52	12.0
57	0.44	10.1
60	0.42	9.6
63	0.40	9.1
67	n/a	0.0

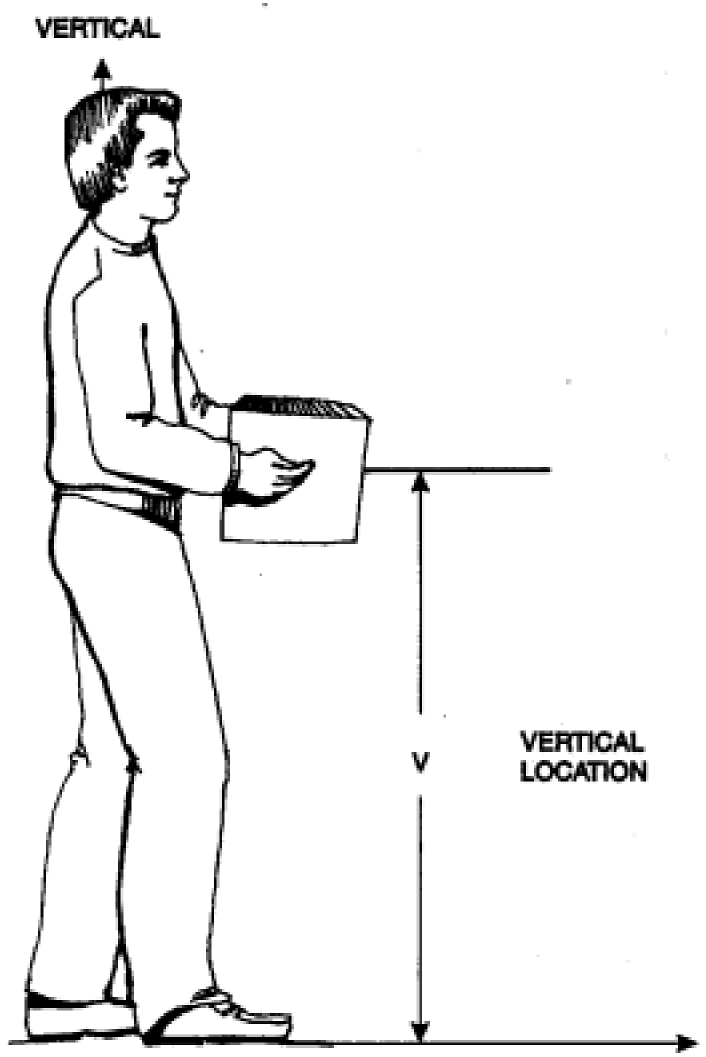
Vertical (V)

Minimum **V**ertical Input

$$V_{min} = 0 \text{ cm } (0 \text{ in})$$

Maximum **V**ertical Input

$$V_{max} = 175 \text{ cm } (70 \text{ in})$$



Garg, 1995

Vertical Multiplier (VM)

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

- Optimal V is 75 cm (30”) above floor level, which ‘knuckle height’ for a worker of average height
- VM = 1.0 → “Optimal V”, when V = 30 inches (75 cm)
    - V = 0 inches (0 cm), VM = 0.78
    - V = 70 inches (175 cm), VM = 0.7
    - V > 70 inches, VM = 0
- A reduction coefficient defined as:
    - VM_m = 1-(.003 |V-75|) for *Metric* (i.e., cm)

Vertical Multiplier

V (in)	VM	V (cm)	VM
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

Workshop Activity 5 – VM Effects on RWL

Instructions

- Use spreadsheet to complete this exercise

RNLE - Revised NIOSH Lifting Equation

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

Multipliers

Load Constant

Recommended Weight Limit

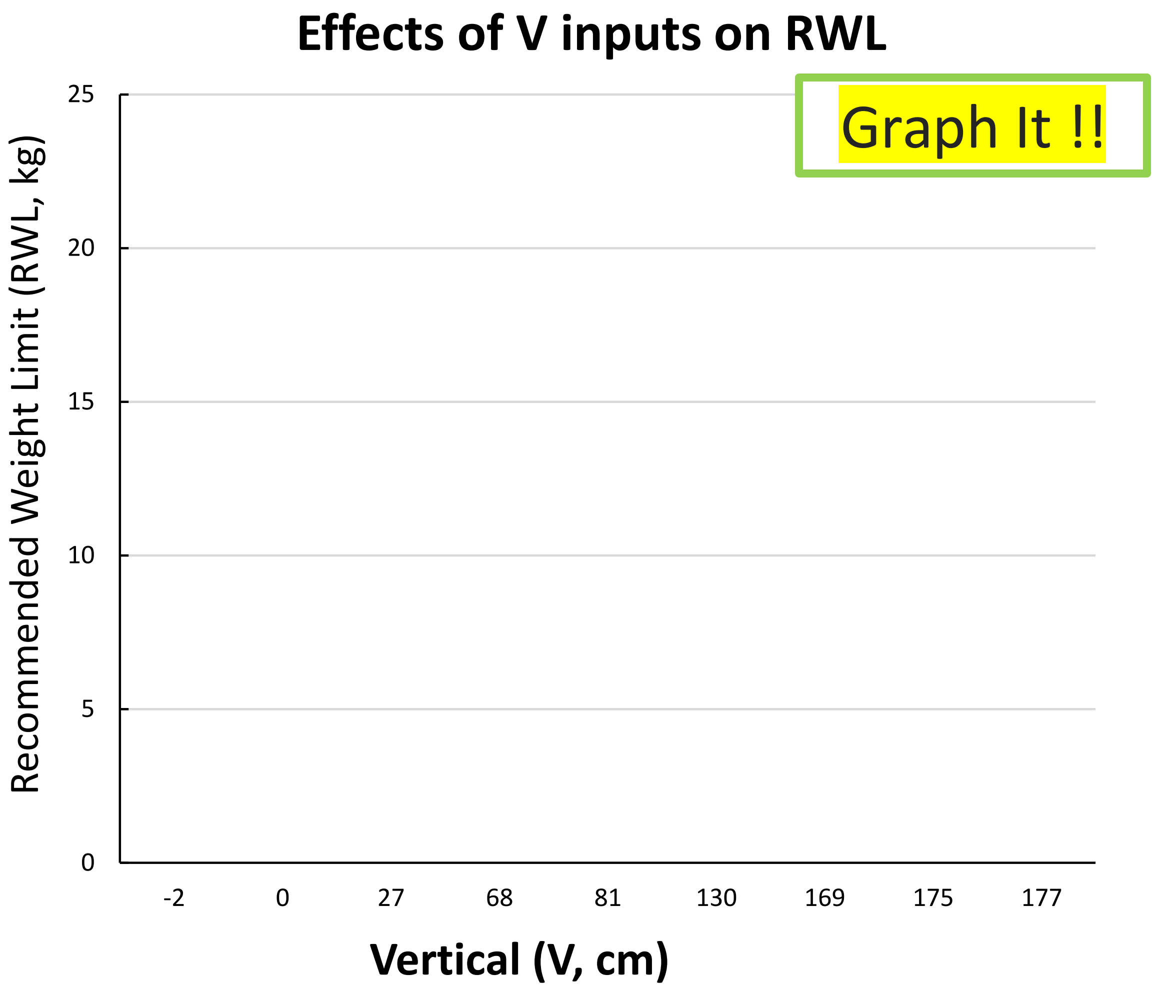
RNLE INPUTS						
Load	H	V	D	A≥	F V ≥ 75 cm for ≤ 1 h	C V ≥ 75 cm
23	25	75	25	0	0.2	Good
3						
LC	HM	VM	DM	AM	FM	CM
23	1.00	1.00	1.00	1.00	1.00	1.00

RWL = 23.0 kg

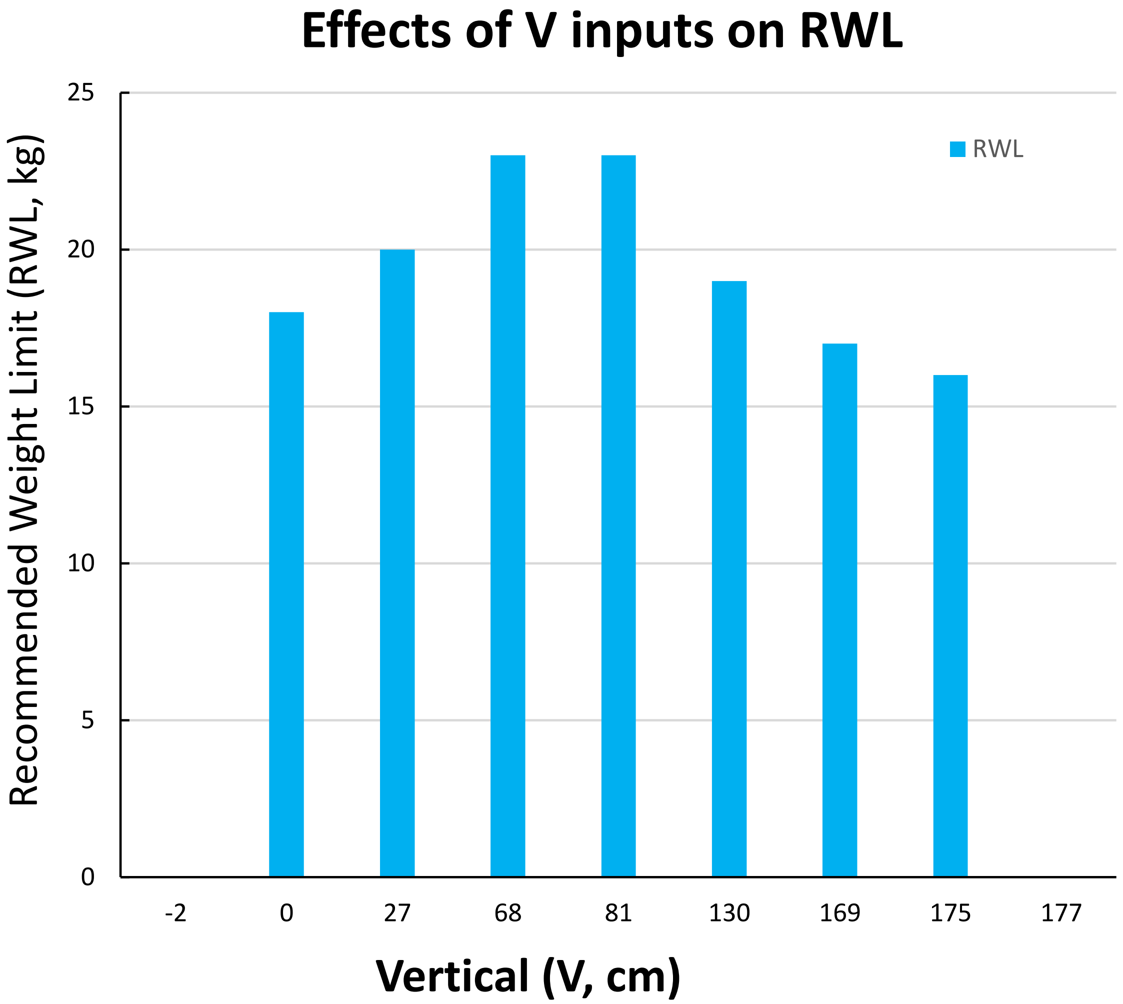
Workshop Activity 5 – Effects of VM on RWL

V inputs and outputs

V_{input} (cm)	VM	RWL(kg)
-2		
0		
27		
68		
81		
130		
169		
175		
177		



Workshop Activity 4 – Effects of VM on RWL

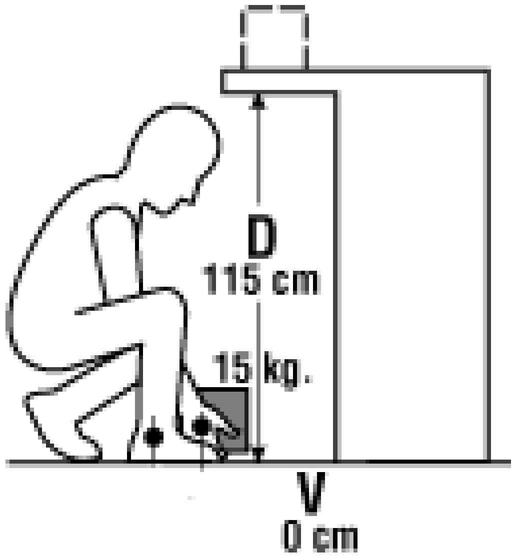


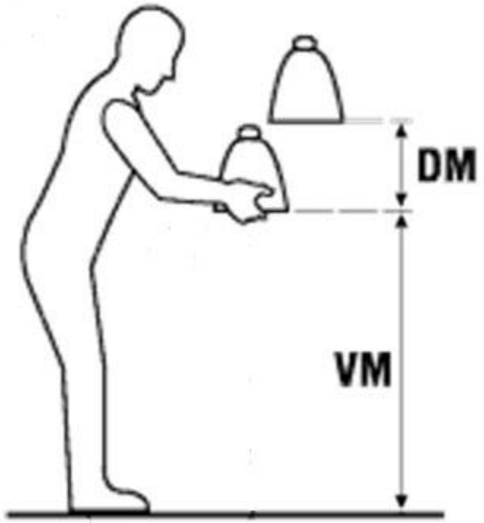
$V_{input\ (cm)}$	VM	RWL(kg)
-2	n/a	0
0	0.78	17.8
27	0.86	19.7
68	0.98	22.5
81	0.98	22.6
130	0.84	19.2
169	0.72	16.5
175	0.70	16.1
177	n/a	0

Distance (D) – Vertical Travel Distance

Vertical Travel Distance variable (D) is defined as:

- Vertical distance travelled of the hands between the origin a destination of the lift
  - D_{Min} = 10” (25 cm)
  - D_{Max} = 70” (175 cm)
- Lifting, D:
  - V_D - V_O (V at the destination minus V at the origin)
- Lowering, D:
  - V_O - V_D (V at the origin minus V at the destination)





Distance Multiplier (DM)

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

- $DM_m = 0.82 + (4.5/D)$, for D measured in cm

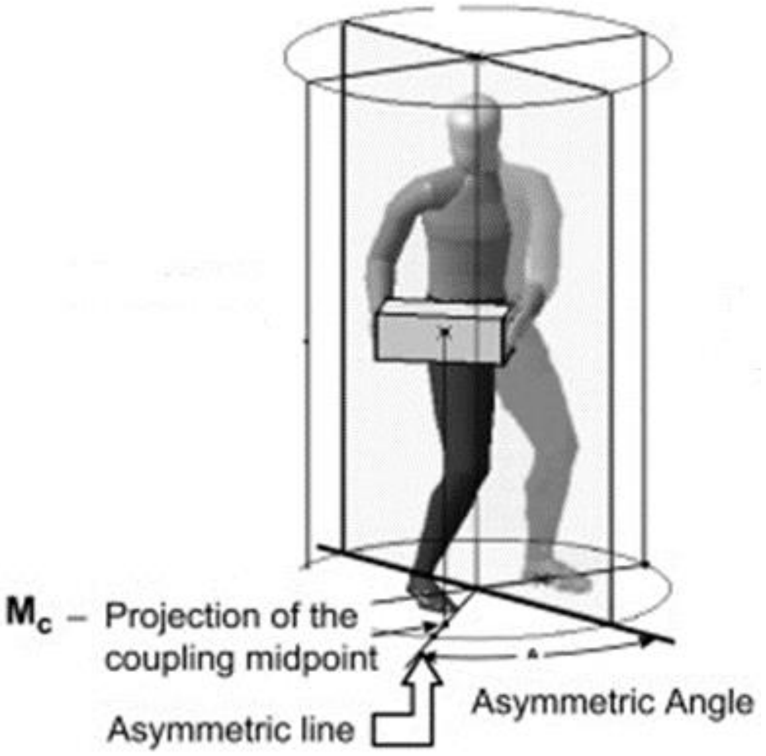
- DM Restrictions
  - DM = 1.0, when D ≤ 10 inches (25 cm)
  - DM = 0.85, when D = 70 inches (175 cm)
  - DM = 0, when D > 70 inches (175 cm)

Distance Multiplier

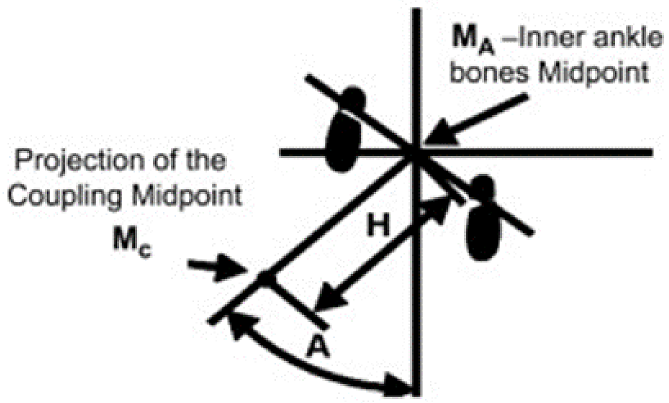
D (in)	DM	D (cm)	DM
<=10	1.00	<=25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

(A) - Asymmetry Angle

- Asymmetry refers to a lift that begins or ends outside the mid-sagittal plane as shown
- Axial twist of the spine is a substantial contributor to the development of low back pain
- $A_{min} = 0°$
- $A_{max} = 135°$



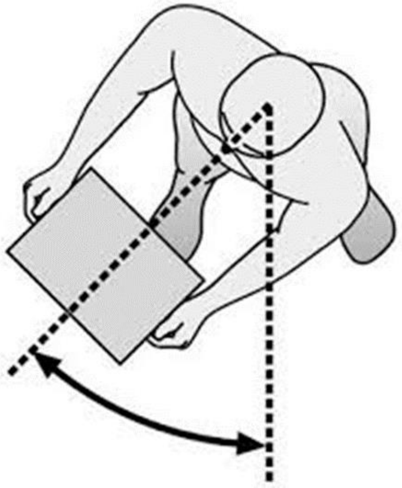
TOP VIEW

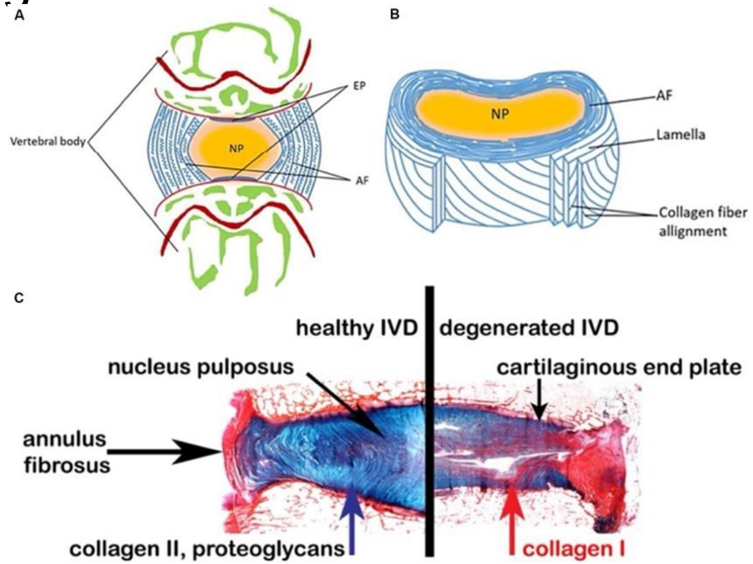


Asymmetry Multiplier (AM)

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

- AM = 1-(.0032A)
  - A_{min} = 0 ° → AM = 1.0
  - A_{max} = 135° → AM = 0.57
  - AM = 0, when Angle > 135°





Asymmetric Multiplier

A (deg)	AM
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

Task Variables and Multipliers

The RWL is defined by the following equation:

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

Where:

		Metric	U.S. Customary
Load Constant	LC	23kg	51lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1 – (.003|V-75|)	1 – (.0075|V-30|)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1 – (.0032A)	1 – (.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

Force Requirements: *Manual Material Handling Assessment Tools*

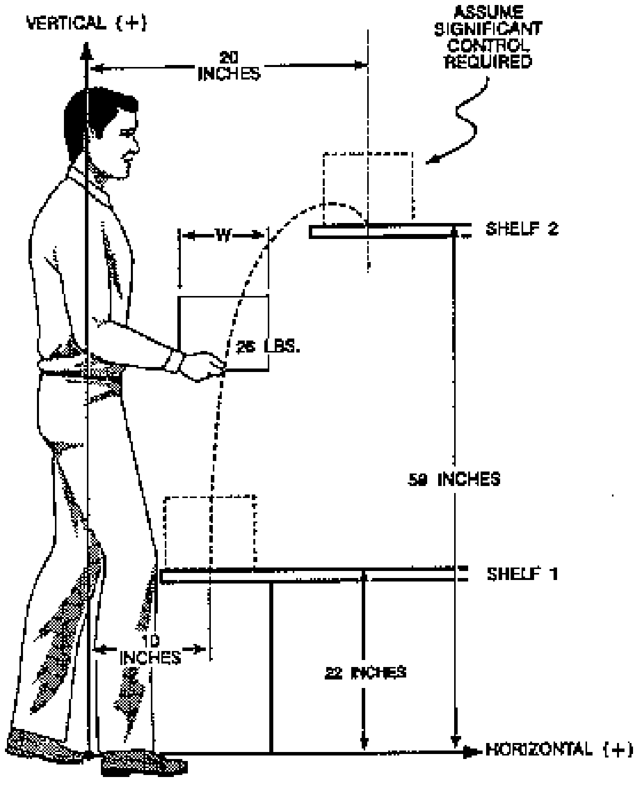
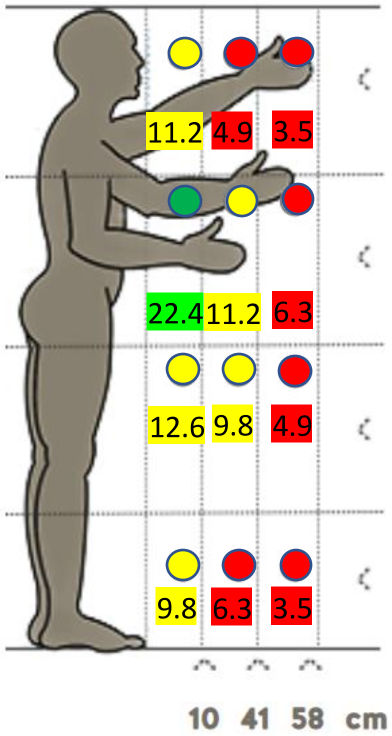
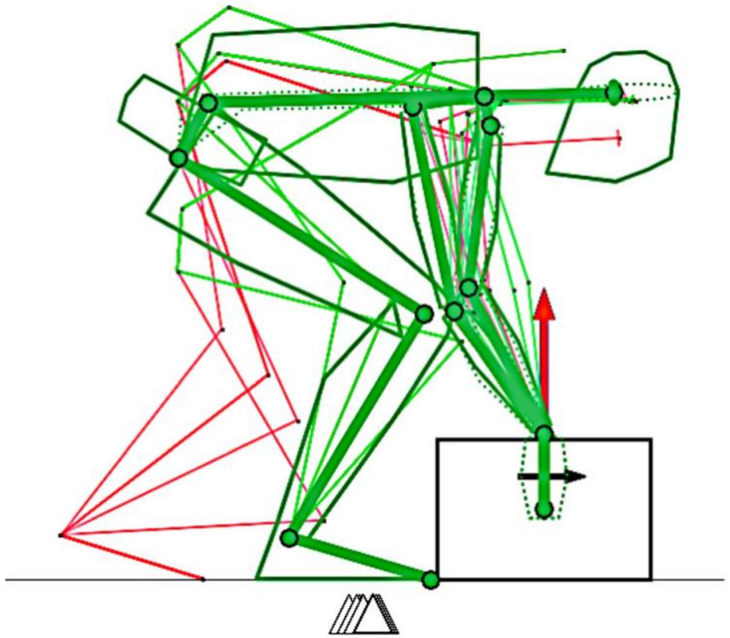


Figure 13 Package Inspection, Example 4





NIOSH Lifting Equation, 1994

WSBC Lift/Lower Calculator

Work(s) Ergo

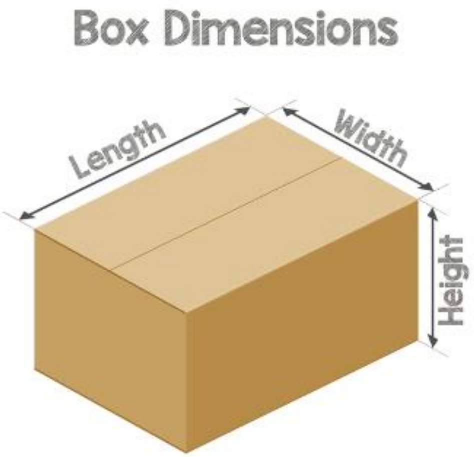
Question 2 - Again

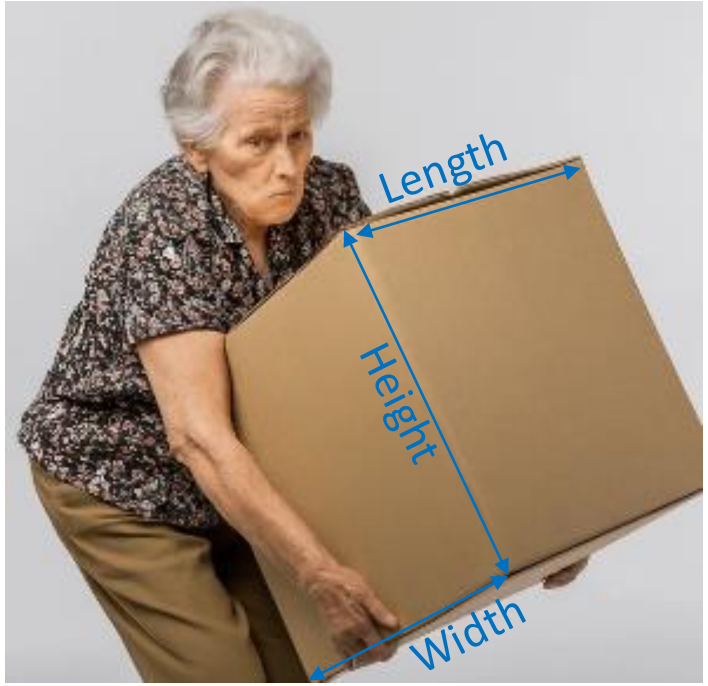
Box Dimensions Most Associated with MSI risk

Box dimension most frequently linked with lower back injury risk (AFTER)

While lifting, which box dimension is most frequently associated with injury risk to the back and spine?

A) Length
B) Width
C) Height
D) None of the above





Hierarchy of Controls – ‘MIS 2023’

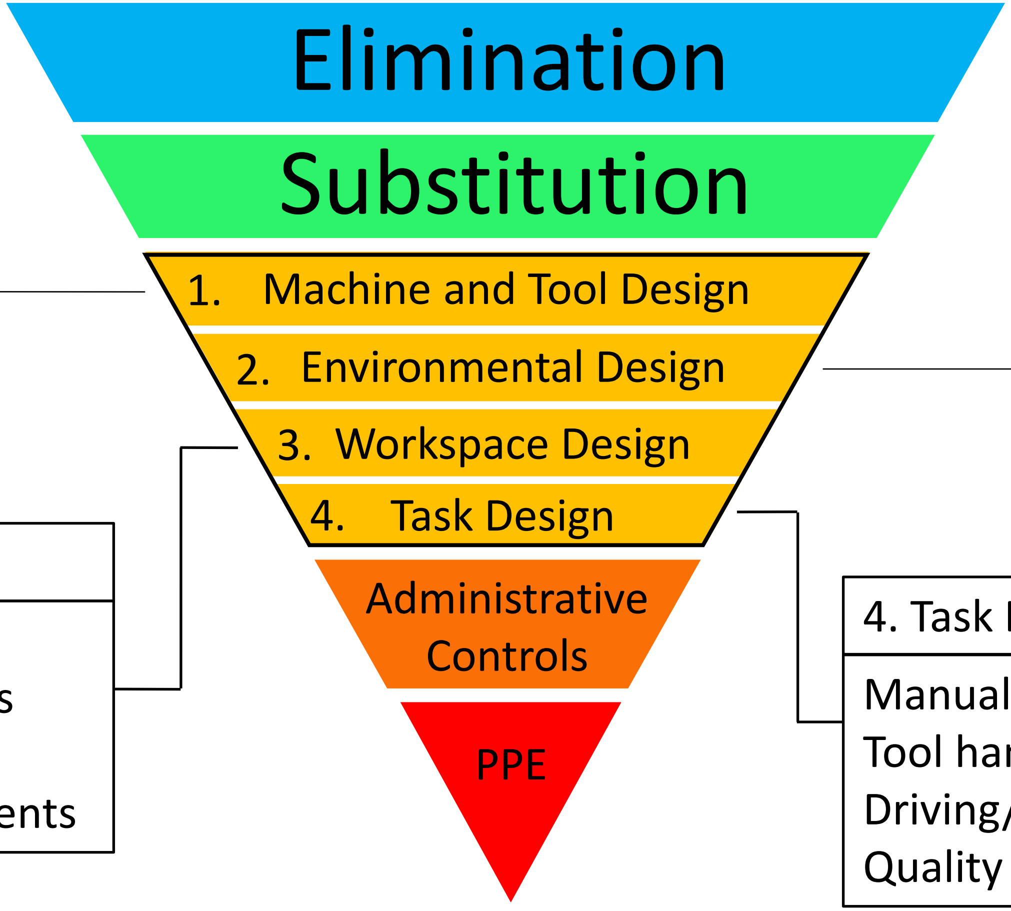
MSI Prevention and Engineering Controls

1. Machine and Tool Design

- Anthropometric requirements
- Biomechanical requirements
- Cognitive requirements
- Psychomotor requirements
- Perceptual requirements

3. Workstation Design

- Mobility requirements
- Workstation height requirements
- Workstation reach requirements
- Workstation clearance requirements



Derouin, 2023

2. Environmental Design

- Temperature controls
- Lighting controls
- Vibration controls
- Noise controls

4. Task Design

- Manual handling tasks
- Tool handling tasks
- Driving/ equipment operation tasks
- Quality control tasks

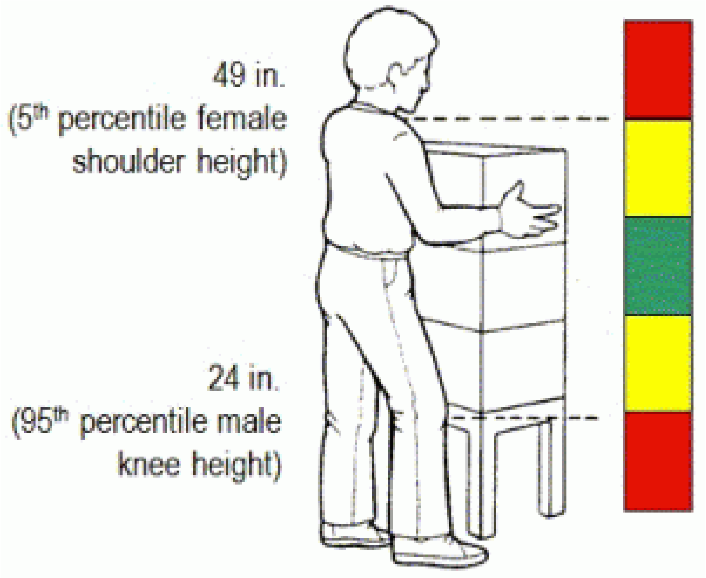
Protect Your Pumpkin → Preserve Your Pulp

Why Protect Your Pumpkin?

- Low back pain (LBP) is the most common musculoskeletal problem, globally
  - Affects your mobility
  - Affect your ability to earn wages
  - Affects your quality of sleep
  - ↑ Reliance on prescription medication → ↓Mental Health → ↑Drug Dependency
- LBP is the leading cause of disability pension
- Globally, LBP is the leading global cause of Years Lived with Disability

Closing Thoughts (1)
Minimize Loading on the Spine

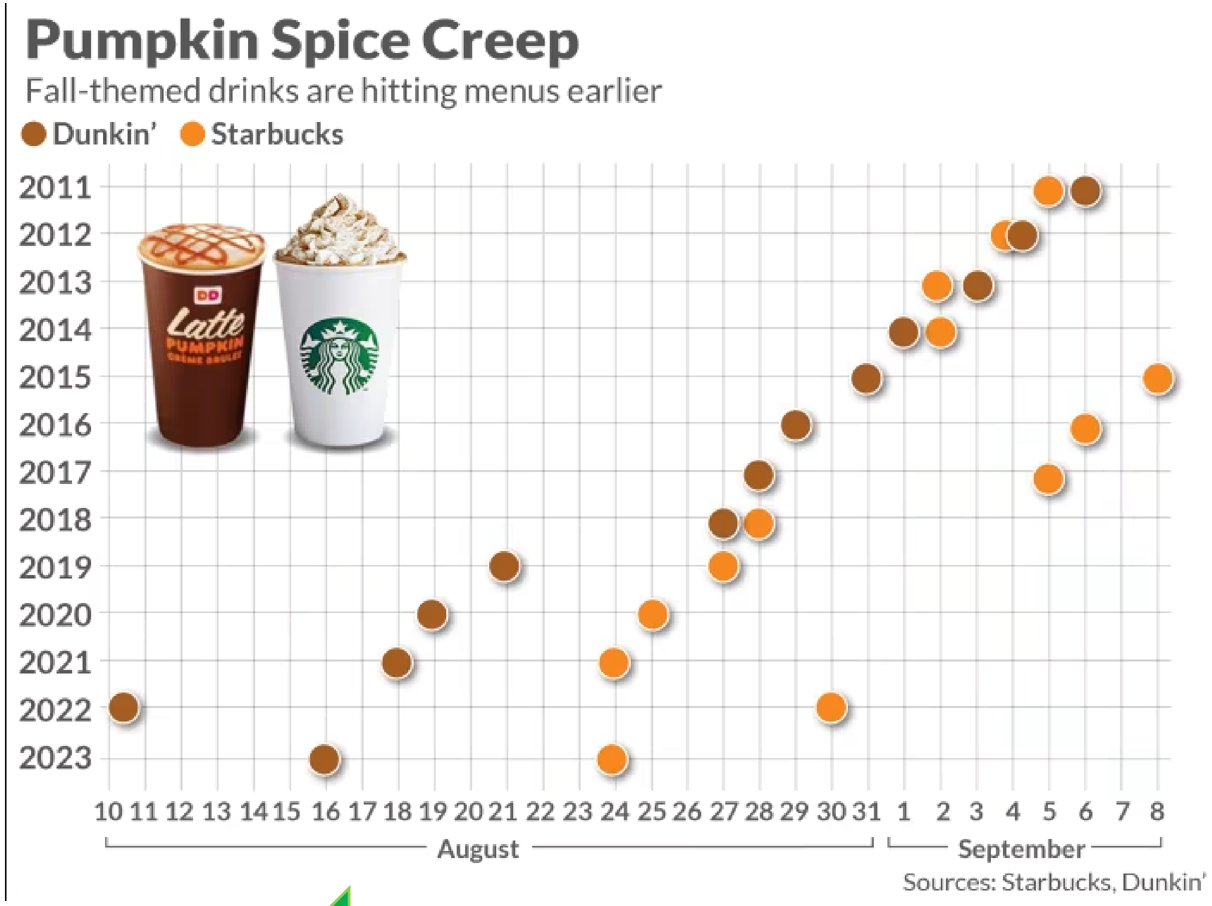
- Complete a lifting self-assessment before attempting the lift
- Remove any barriers to minimize the horizontal distance
- Keep the load as close to your body as possible
- Eliminate twisting motions while lifting
- Raise object to knuckle height
- Install a lift assist or aid
- Ask for help



ErgoWeb, MacLeod, 2013

Closing Thoughts (2)

Advance Forward Your Spending On Engineering Controls



Peter Horne, The Fabricator, 2022

Remember – Protect Your Pumpkin

Help when you need it

Your Alliance Safety Advisors

» Aaron Derouin

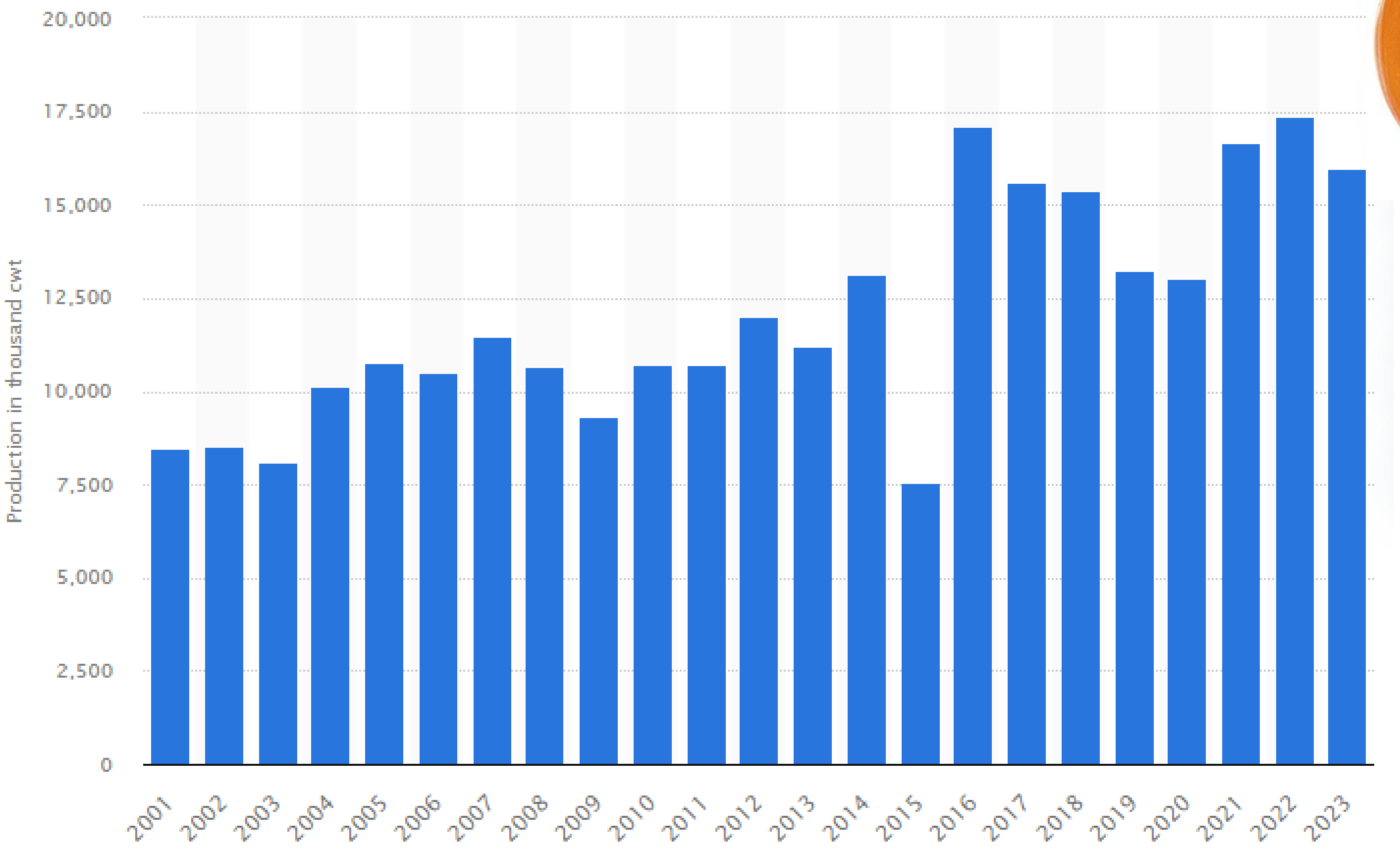
safetyalliancebc.ca

604-795-9595

manufacturing@safetyalliancebc.ca

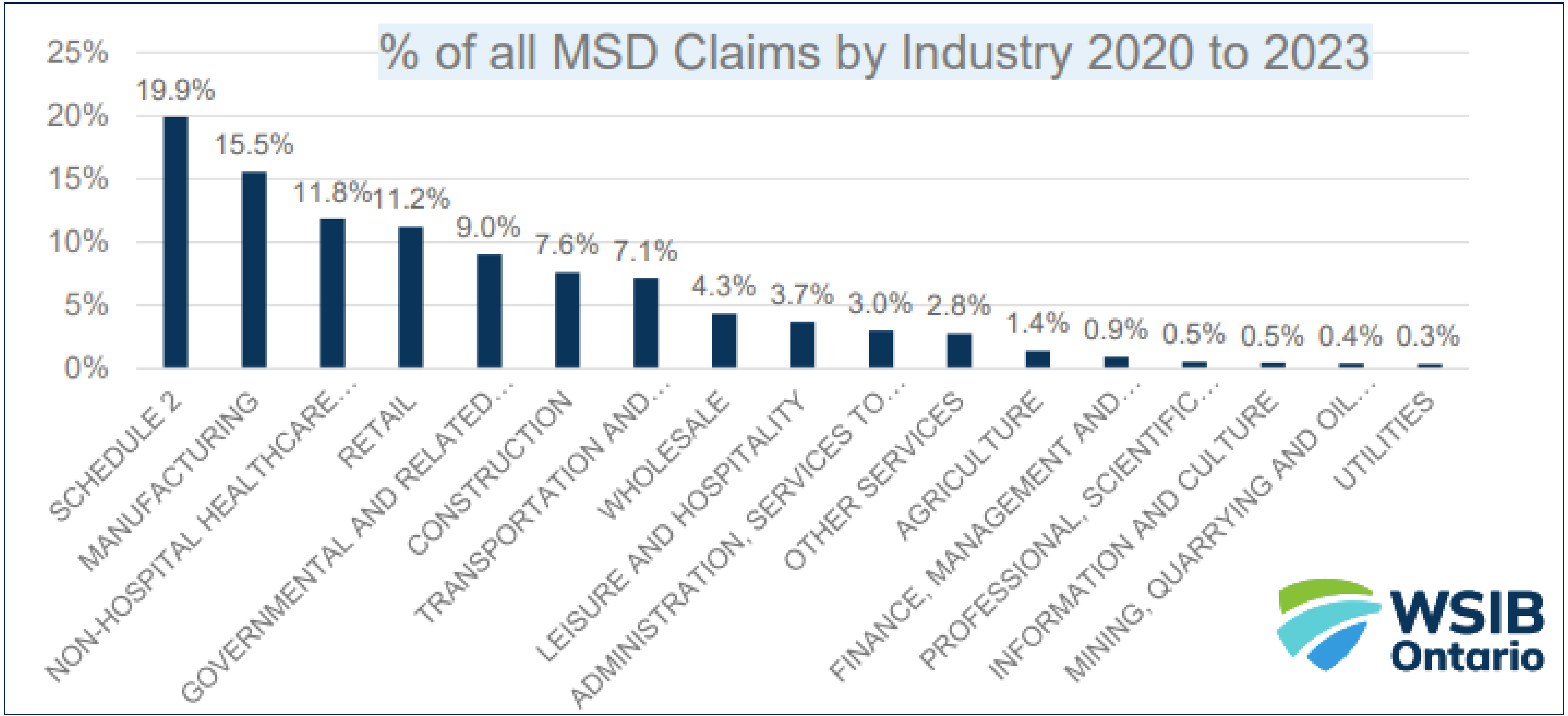
Supplementary Slides …

U.S. Pumpkin Production (2001 to 2023) 1,000 cwt



[Statista]

Workers Safety Insurance Board – Ontario: *Industry Sectors and MSD Claims*



Workers Safety Insurance Board – Ontario: *ER-MSD Claim Volume*

Claim Volume – Claim Details: Event and Source

- Overexertion events (lifting, pushing, pulling, throwing, carrying, turning) have accounted for about 53% of A-LT ER-MSD claims for injury/illness Years 2012 to 2023.
- Bodily reaction events (bending, climbing, reaching, twisting, running, etc.) make up approximately 37%.
- Although the counts are small and fluctuate easily, Repetitive motion, and Static posture and sustained viewing events show a slight increase from 2012 to 2023.

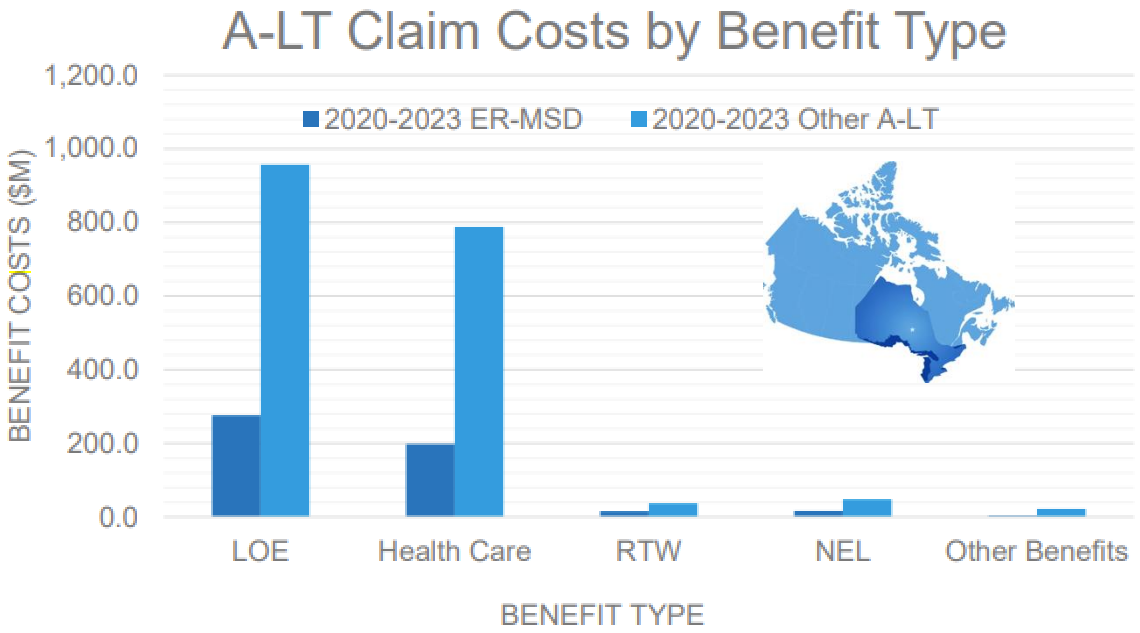
Event Category	% of ER-MSD Claims		
	2012	2017	2023
Overexertion	49.5	53.5	53.4
Bodily reaction	22.9	23.7	20.7
Bodily reaction and exertion	17.1	12.0	13.9
Repetitive motion	9.9	10.0	11.1
Static posture and sustained viewing	0.2	0.5	0.5
Rubbed or abraded by friction, pressure or jarred by vibration	0.3	0.3	0.4
Total ERMSD Claims	100.0	100.0	100.0

- The top Source of Injury/Illness, Persons (bodily motion or condition), accounts for 46% of ER-MSD claims from 2012-2023. This is followed by Containers, boxes, barrels, packages at 20%, and Parts and materials at about 9%.
- Source of Injury categories have fluctuated but not shifted noticeably during the review period.

Source: WSIB Enterprise Information Warehouse, WSIB DataHub as of March 31 following the Injury/Illness Year

WSIB Ontario

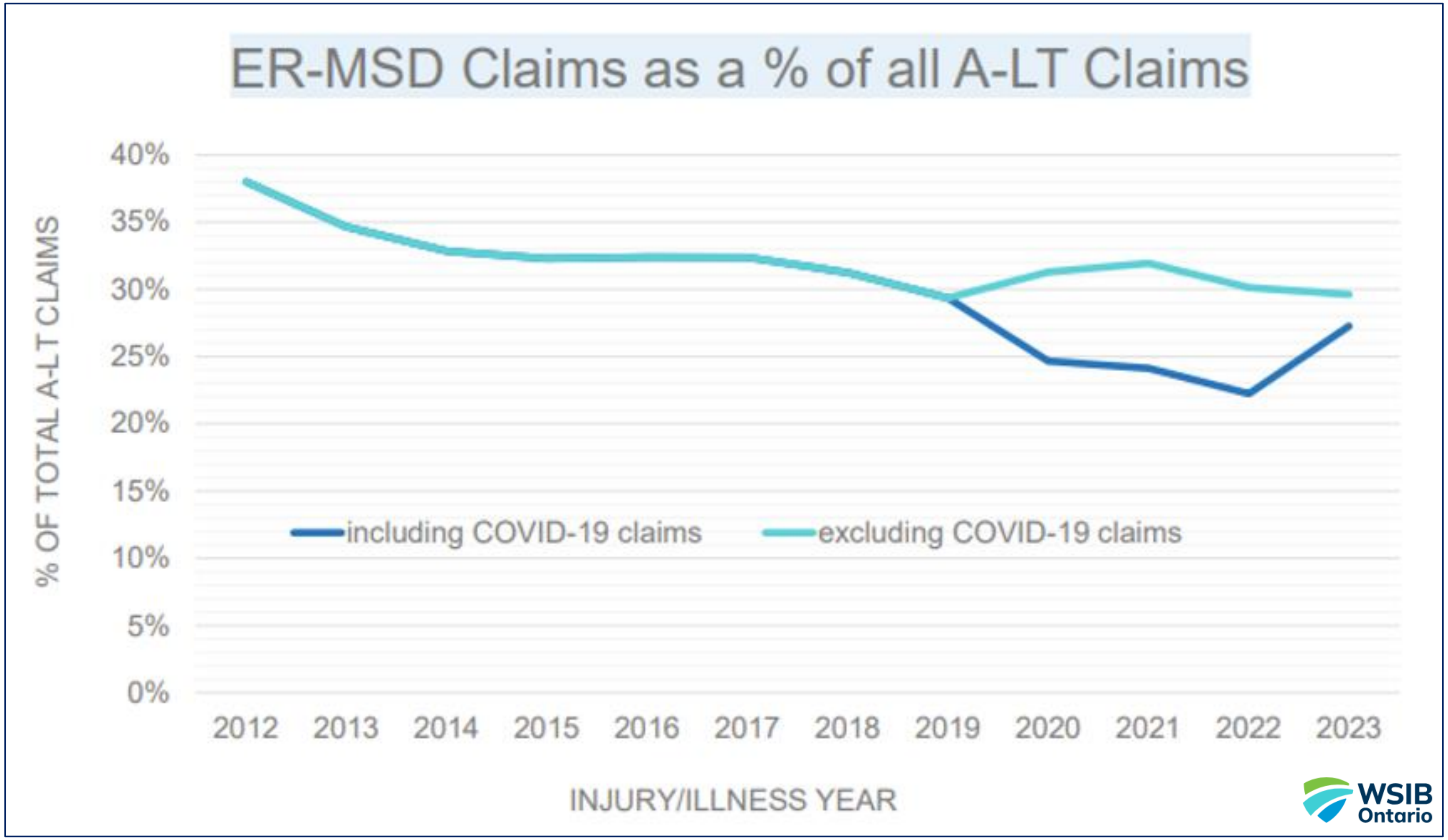
Workers Safety Insurance Board – Ontario
Ergonomic Related (ER) MSD Costs and %Cost



Benefit Type	Total Claim Costs ($M)				
	2016-2019 ER-MSD	2020-2023 ER-MSD	2020-2023 Other A-LT	2020-2023 Total	2020-2023 ER-MSD as % of Total
LOE	382.5	276.0	956.9	1,232.8	22%
Health Care	202.4	197.9	788.3	986.3	20%
RTW	32.7	15.9	36.8	52.7	30%
NEL	24.2	16.2	47.6	63.9	25%
Other Benefits	9.2	3.0	22.0	25.0	12%
Total	**651.1**	**509.0**	**1,851.7**	**2,360.7**	**22%**

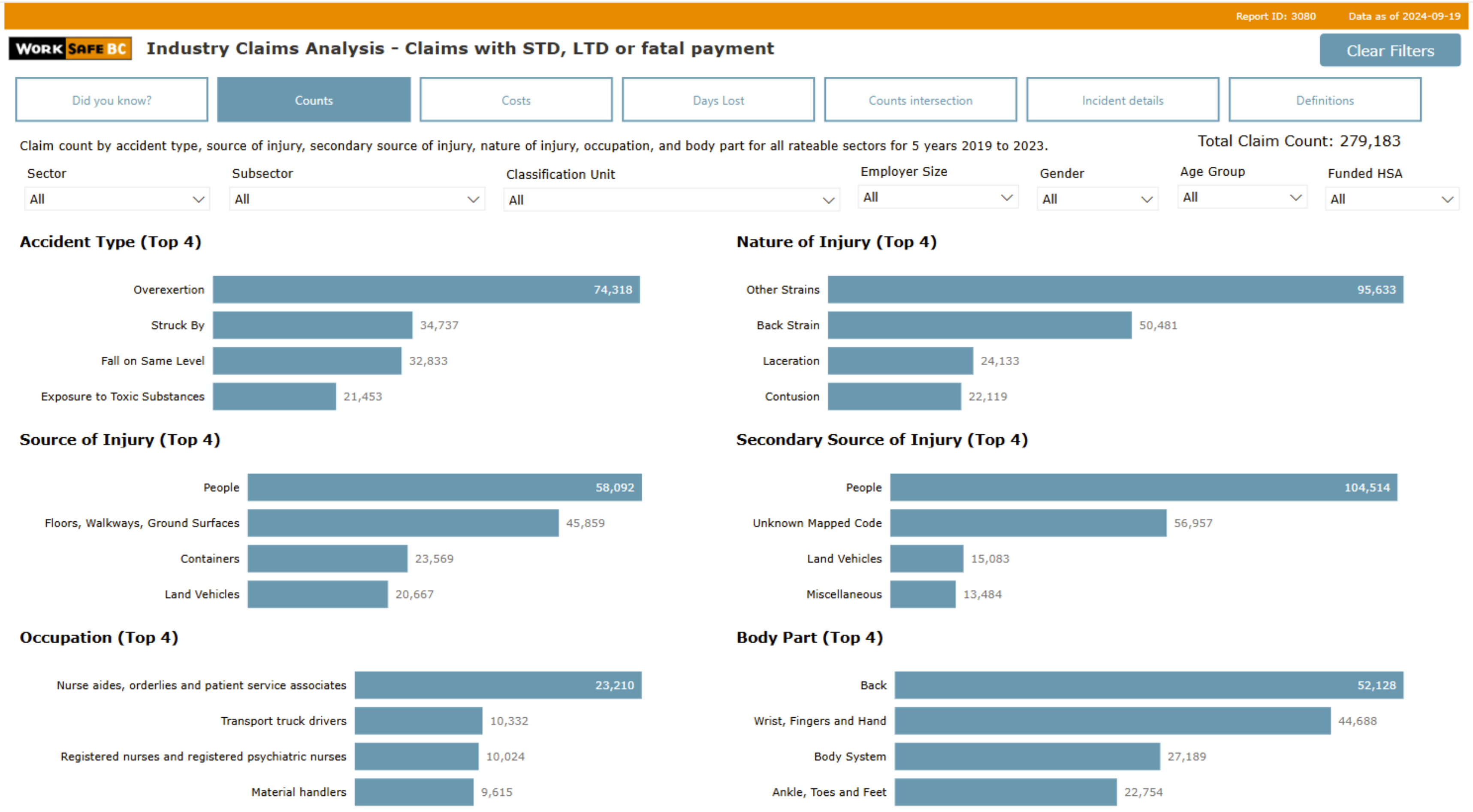
WSIB Ontario

Workers Safety Insurance Board – Ontario
ER-MSDs as a Percent of All Claims

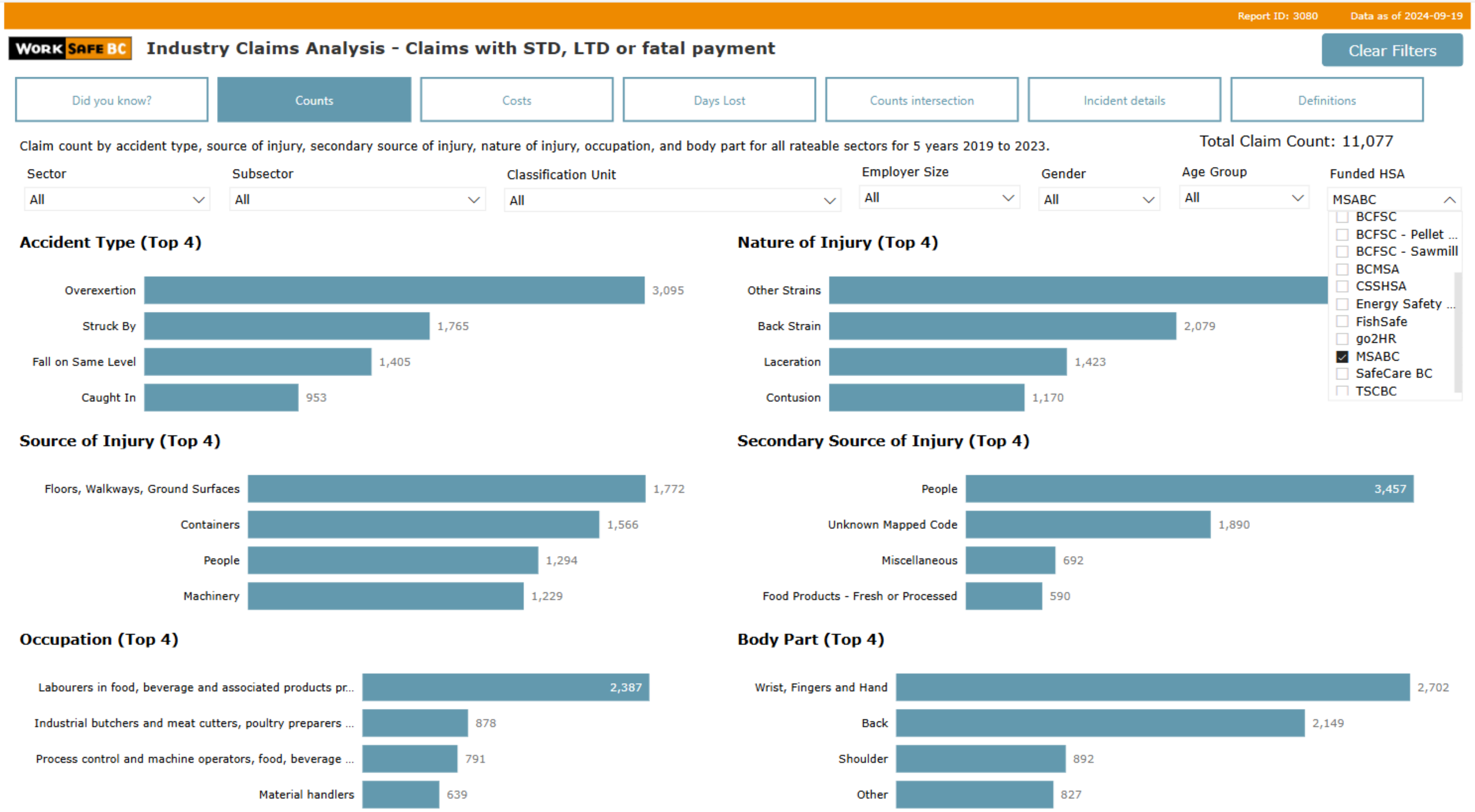


WorkSafe BC – Overexertion Statistics

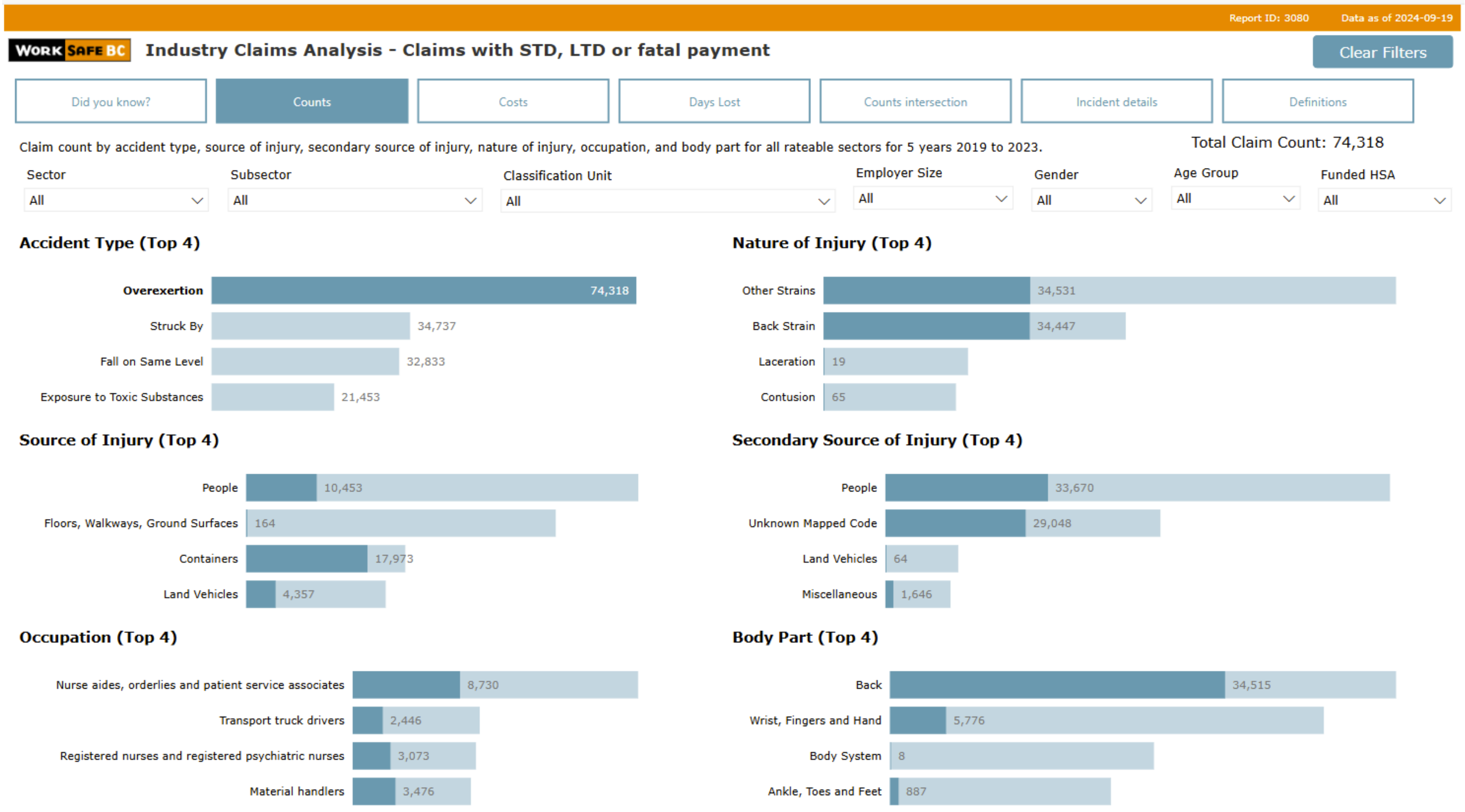
Counts - General



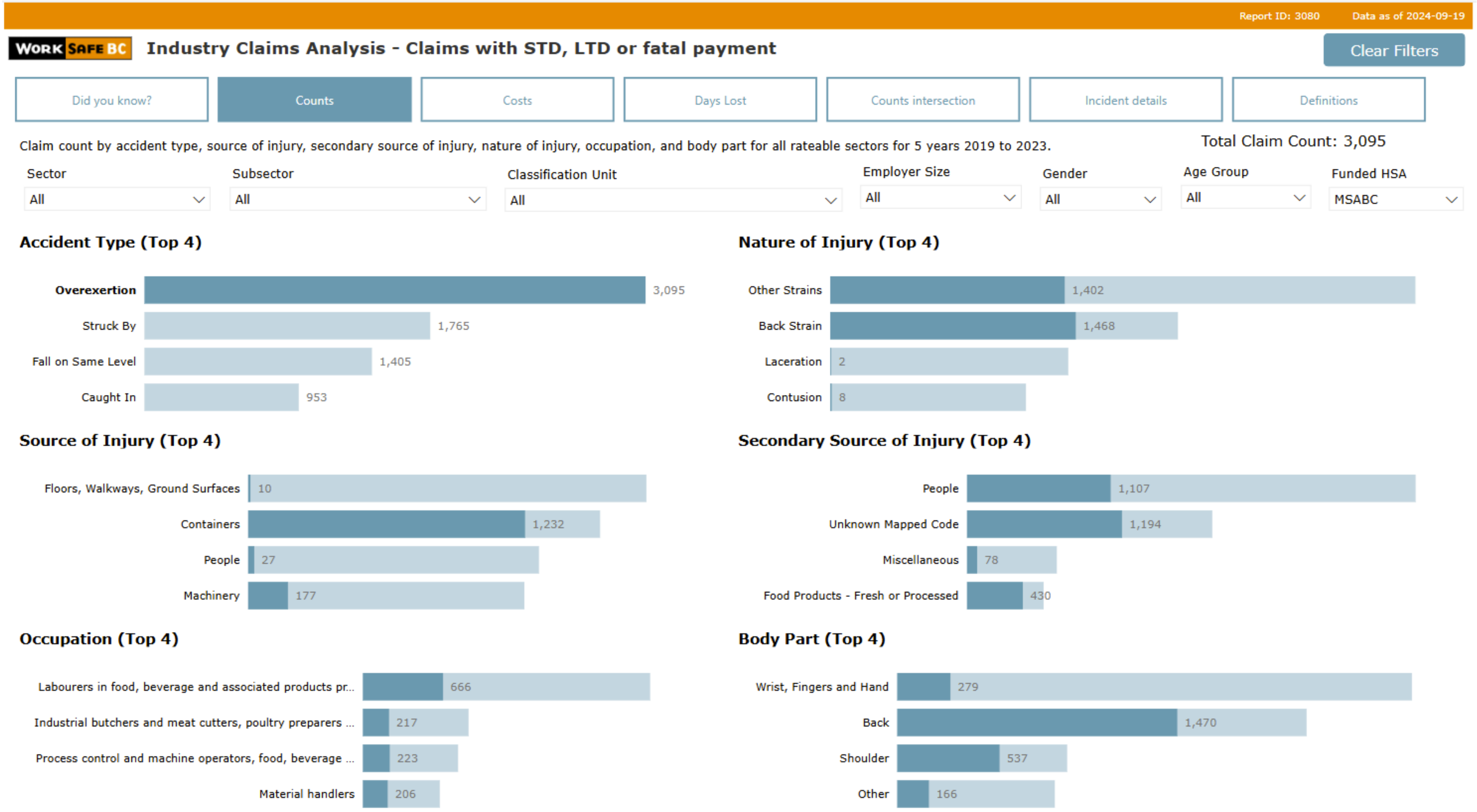
WorkSafe BC – Overexertion Statistic Counts – *Manufacturing (MSABC)*



WorkSafe BC – Overexertion Statistics General -> Back is Top Body Part



WorkSafe BC – Overexertion Statistics MSABC -> Back is Top Body Part



Frequency (F)

- Lifting frequency (F) range
  - 0.2 lifts/min up to 15 lifts/ min
- Frequency is adjusted for Vertical (V) location of hands
  - V ≤ 30 inches (75 cm)
  - V ≥ 30 inches (75 cm)
- Lifting above the maximum frequency results in a RWL of 0.0, regardless of duration

Frequency Multiplier (FM)

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

- FM values are dependent on:
- Work duration
- Vertical (V) relative to optimal height
  - V < 75cm
  - V ≥ 75 cm

Frequency multiplier (*FM*).

Frequency lifts/min	Work duration					
	≤ 1 h		≤ 2 h		≤ 8 h	
	V < 75	*V* ≥ 75	*V* < 75	*V* ≥ 75	*V* < 75	*V* ≥ 75
0·2	1·00	1·00	0·95	0·95	0·85	0·85
0·5	0·97	0·97	0·92	0·92	0·81	0·81
1	0·94	0·94	0·88	0·88	0·75	0·75
2	0·91	0·91	0·84	0·84	0·65	0·65
3	0·88	0·88	0·79	0·79	0·55	0·55
4	0·84	0·84	0·72	0·72	0·45	0·45
5	0·80	0·80	0·60	0·60	0·35	0·35
6	0·75	0·75	0·50	0·50	0·27	0·27
7	0·70	0·70	0·42	0·42	0·22	0·22
8	0·60	0·60	0·35	0·35	0·18	0·18
9	0·52	0·52	0·30	0·30	0·00	0·15
10	0·45	0·45	0·26	0·26	0·00	0·13
11	0·41	0·41	0·00	0·23	0·00	0·00
12	0·37	0·37	0·00	0·21	0·00	0·00
13	0·00	0·34	0·00	0·00	0·00	0·00
14	0·00	0·31	0·00	0·00	0·00	0·00
15	0·00	0·28	0·00	0·00	0·00	0·00
>15	0·00	0·00	0·00	0·00	0·00	0·00

Note:
‡ values of *V* are in cm; 75 cm = 30 in.

Waters et al., 1994

Coupling (C)

- Coupling refers to the ‘Hand-Load Interface’
- Quality of the grasp or handhold for the object being lifted or lowered

Coupling Multipliers (CM)

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

- Coupling Classification:
  - Quality of the grasp interface between the worker’s hands and the object
    - Good
    - Fair
    - Poor
  - Coupling Multiplier
    - A reduction coefficient based on:
      - Coupling Classification
      - Vertical Location of the lift

Coupling Multipliers (CM)

Table 7: Coupling Multiplier

Coupling Type	Coupling Multiplier	
	V<30 inches (75 cm)	V≥30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Decision Tree for Coupling Quality