Ergonomics for Preventing MSDs in the Age of AI

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Overview of the Talk

- ❑ Part 1: Surveillance and Etiology of Musculoskeletal Disorders (MSDs)
- ❑ Part 2: Ergonomic Assessment Methods
- ❑ Part 3: Future Ergonomic Risk Assessments
- ❑ Part 4: NORA MSD Research Agenda
- ❑ Part 5: Elements of Ergonomics Programs

Part 1
Surveillance and Etiology of Musculoskeletal Disorders (MSDs)

1/3	1/3	1st
Injury involving days from work	Workers' compensation cost	Burden of disease

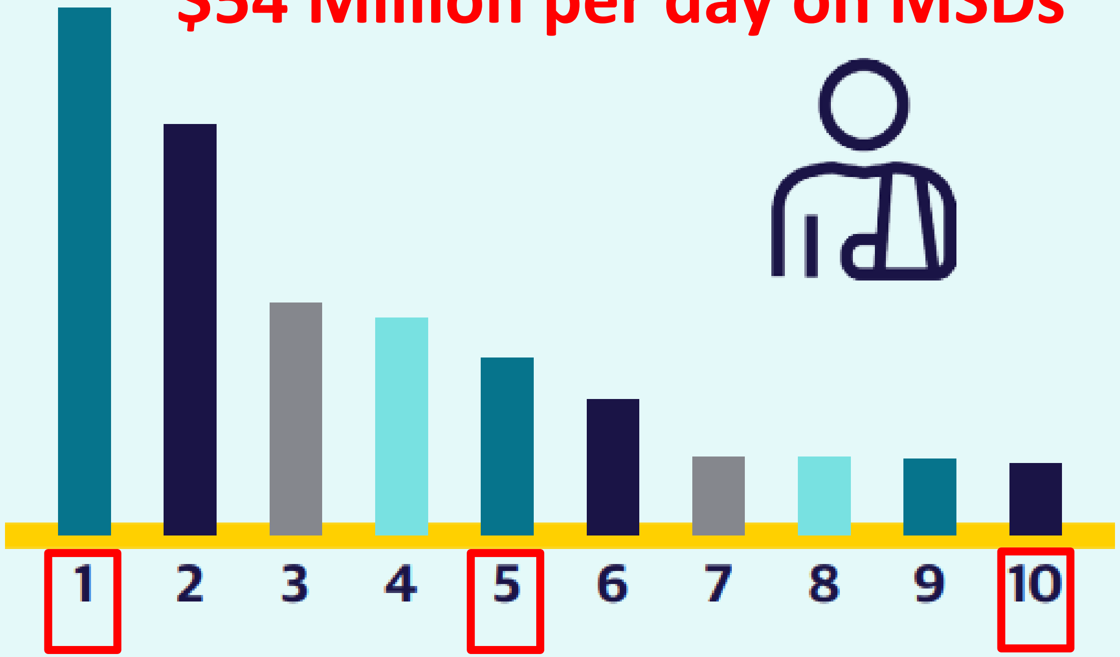
Graphic source: NIOSH

Workers' Compensation Cost for MSDs (1/3)

Total cost of the most disabling workplace injuries:
$58.61 billion

Cost of top 10 most disabling workplace injuries:
$52.28 billion

$54 Million per day on MSDs



	Cost billions	Percent total	
1.	$13.30	22.7%	**Overexertion involving outside sources** (handling object)
2.	$10.58	18.1%	**Falls on same level**
3.	$6.26	10.7%	**Falls to lower level**
4.	$5.61	9.6%	**Struck by object or equipment** (being hit by objects)
5.	$4.71	8.0%	**Other exertions or bodily reactions** (awkward postures)
6.	$3.16	5.4%	**Roadway incidents involving motorized land vehicle** (vehicle crashes)
7.	$2.52	4.3%	**Slip or trip without fall**
8.	$2.46	4.2%	**Struck against object or equipment** (colliding with objects)
9.	$2.01	3.4%	**Caught in or compressed by equipment or objects** (running equipment or machines)
10.	$1.66	2.8%	**Repetitive motions involving microtasks**

Source: Liberty Mutual Safety Index 2021.

Workers' Compensation Cost for MSDs (2/3)

The Workplace Safety Index: injury rankings by type, 2018 to 2023

Cause	2018	2019	2020	2021	2022	2023
Overexertion involving outside sources	1	1	1	1	1	1
Falls on same level	2	2	2	2	2	2
Falls to lower level	3	4	4	3	4	3
Struck by object or equipment	4	3	3	4	3	4
Other exertions or bodily reactions	5	5	5	5	5	5
Roadway incidents involving motorized land vehicle	6	6	6	6	6	7
Slip or trip without fall	7	7	7	7	7	9
Caught in or compressed by equipment or objects	8	8	10	9	8	8
Struck against object or equipment	9	10	9	8	9	
Repetitive motions involving microtasks	10	9	8	10		

Source: Liberty Mutual Safety Index 2023. Photo Credit: Purchased Getty Image.

Workers' Compensation Cost for MSDs (3/3)

Top 5 loss causes by industry

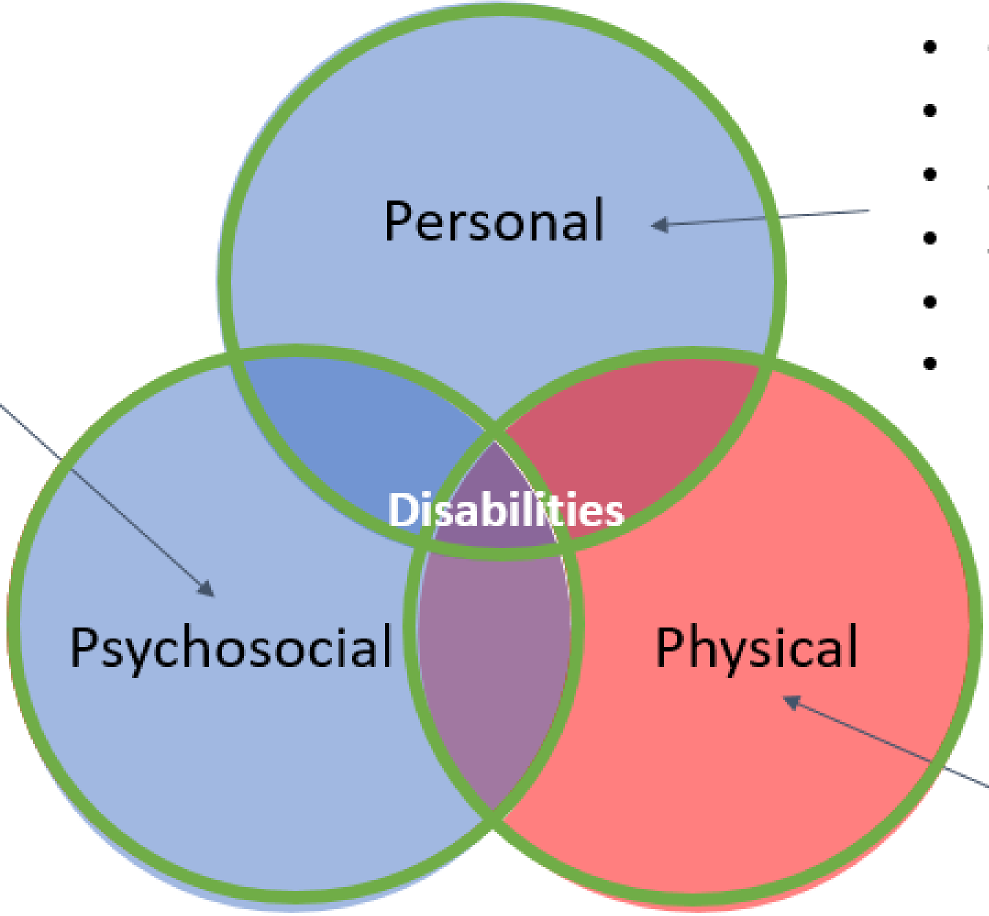
Industry	Loss cause ranking 1st	2nd	3rd	4th	5th	Total cost ($B)	Percentage of cost for over-exertions (MSDs)
	(Cost – $B; %)						
All industries	$12.84; 21.9%	$8.98; 15.3%	$6.09; 10.4%	$5.14; 8.8%	$3.67; 6.3%	$58.61	28.2%
Construction	$3.22; 28.2%	$2.09; 18.4%	$1.52; 13.3%	$1.00; 8.8%	$0.86; 7.6%	$11.40	25.9%
Manufacturing	$1.80; 21.6%	$1.20; 14.4%	$0.97; 11.7%	$0.82; 9.9%	$0.71; 8.5%	$8.32	21.6%
Professional & business services	$1.73; 21.5%	$1.56; 19.3%	$1.07; 13.3%	$0.60; 7.5%	$0.47; 5.9%	$8.08	19.3%
Retail	$1.64; 30.4%	$1.08; 20.1%	$0.55; 10.3%	$0.41; 7.7%	$0.36; 6.6%	$5.39	37.1%
Healthcare & social assistance	$1.54; 28.7%	$1.35; 25.1%	$0.50; 9.4%	$0.37; 6.8%	$0.29; 5.4%	$5.56	32.9%
Transport & warehousing	$1.37; 28.5%	$0.63; 13.2%	$0.46; 9.6%	$0.44; 9.1%	$0.40; 8.3%	$4.79	38.2%
Wholesale	$1.32; 31.5%	$0.53; 12.7%	$0.52; 12.4%	$0.34; 8.1%	$0.27; 6.4%	$4.19	37.9%
Leisure & hospitality	$1.22; 36.3%	$0.43; 12.9%	$0.28; 8.3%	$0.25; 7.4%	$0.24; 7.1%	$3.35	20.3%

- Overexertion, outside sources
- Falls, same level
- Falls, to lower level
- Struck by object or equipment
- Other exertions or bodily reactions
- Caught in or compressed by equipment or objects
- Roadway incidents involving motorized land vehicle
- Intentional injury by person
- Exposure to other harmful substances

Source: Liberty Mutual Safety Index 2023

Multifactorial Cause of MSDs

- Job stress (demands/control)
- Poor supervisory/colleague support
- Job dissatisfaction
- Time pressure
- Work organization: shift work (Chen 2023), rapid work pace, monotonous task



- Genetics
- BMI
- Sex
- Smoking
- Depression
- Prior history of MSDs

37% of MSDs attributable to physical risk factors*

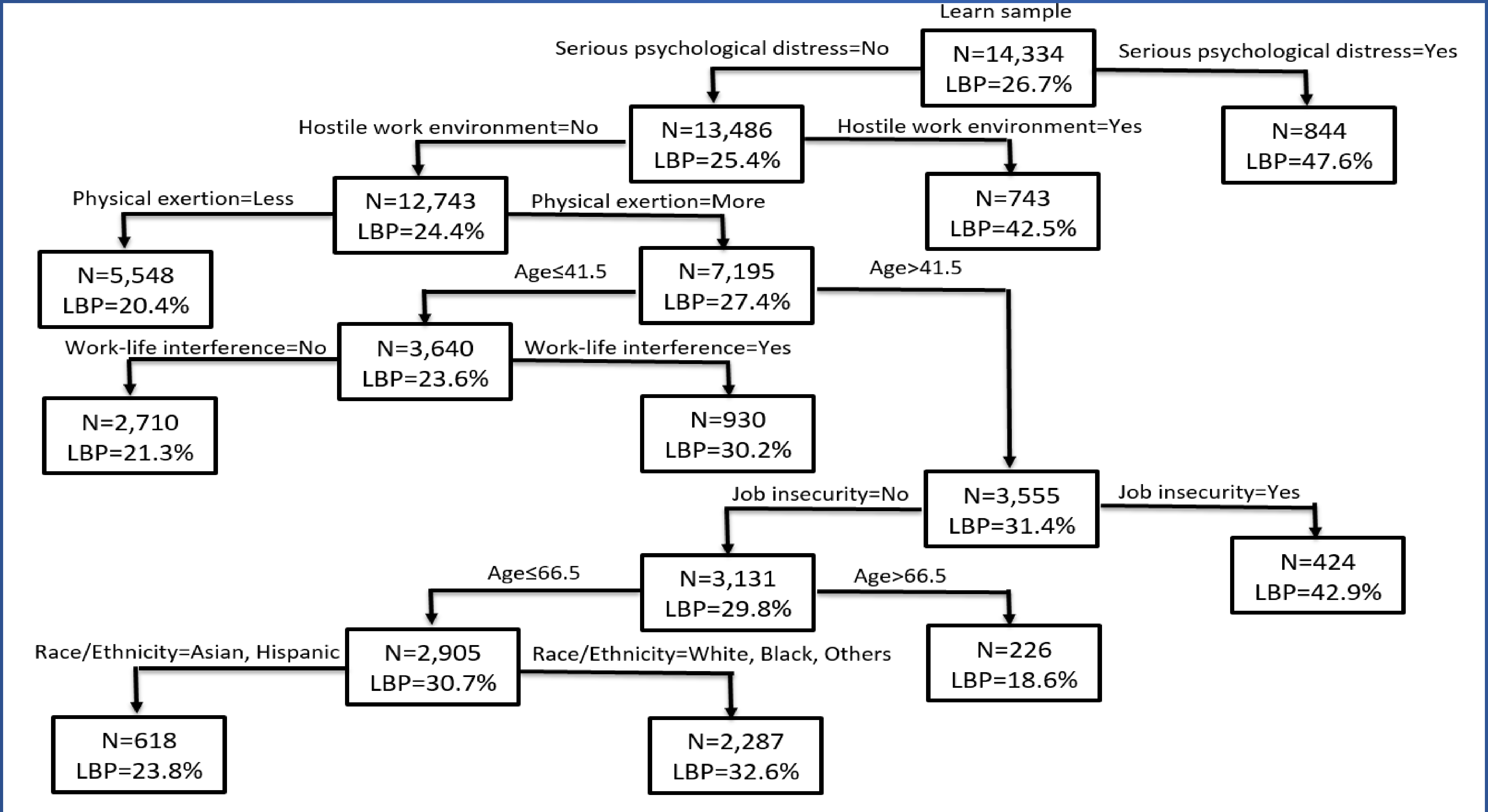
- Manual material handling
- Poor work posture
- Repetitive body motion
- Forceful movement

Work environment

Human-workplace system thinking (Total Worker Health™)

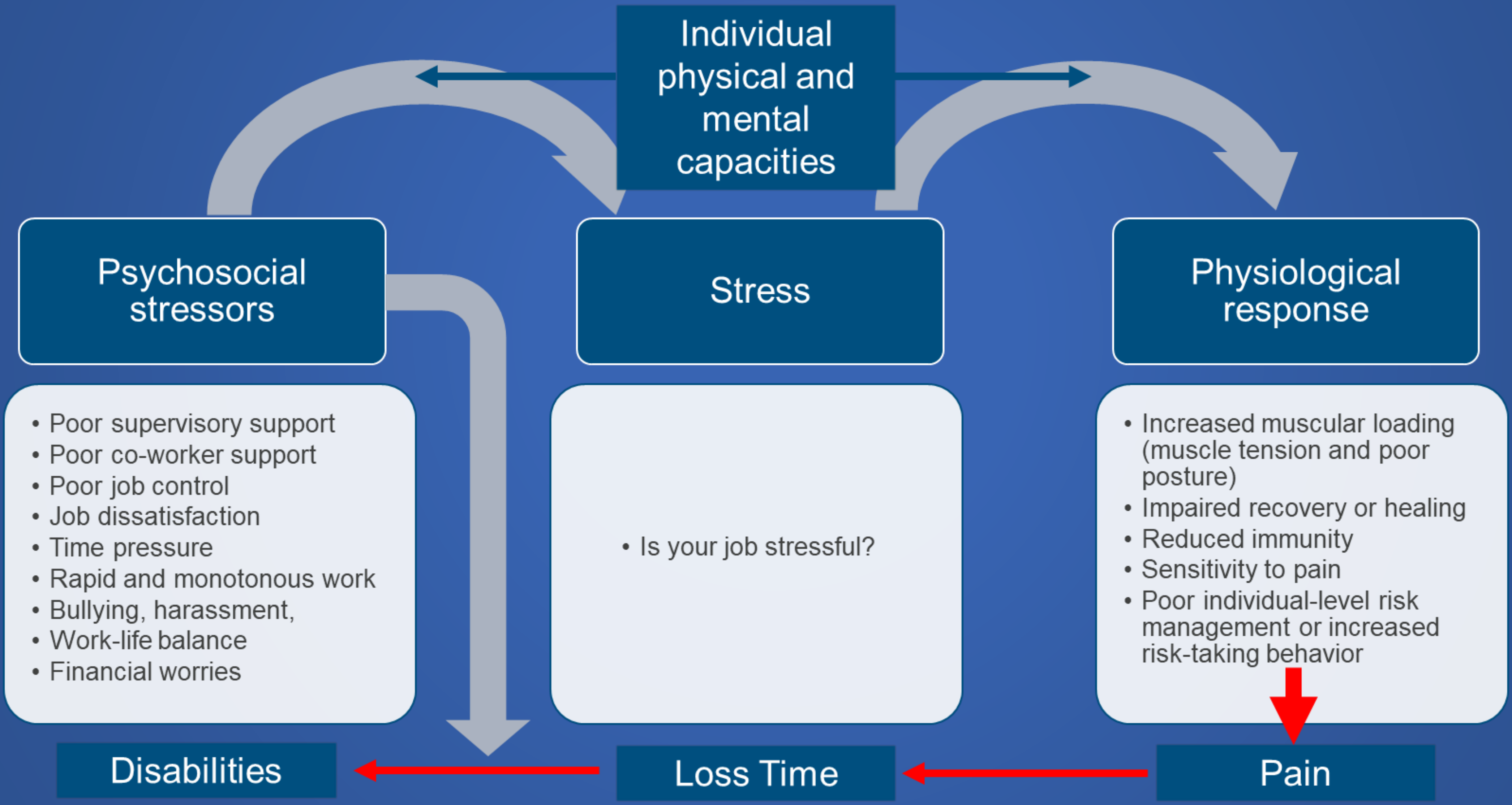
Source: *MSDs and the Workplace: Low Back and Upper Extremities*, National Academies, 2001; * Punnett et al., *AJIM* 48: 459-469, 2005

Intricate Interactions of MSD Risk Factors



Source: Lu M, Yang, H and Luckhaupt S. Effect of sex and age on moderating the risk of work-related low back pain. Presented at the American Occupational Health Conference, Denver, Colorado, April 23-26, 2017. Data from paper by Haiou Yang, Scott Haldeman Ming-Lun Lu and Dean Baker: Low back pain prevalence and related workplace psychosocial risk factors: A study using data from 2010 NHIS. J of Manipulative Physiological Therapeutics. 39: 459-472 (2016).

Psychosocial Risk Pathways of MSDs



Graphic source: NIOSH

Part 2
Ergonomic Assessment Methods

1.0 Biomechanics and physiology → 2.0 Psychophysiology → 3.0 NLE and observational methods → 4.0 Automation of assessment methods

1960's | 1970's | 1990's | Today

2D and 3DSSPP (1970's), OWAS (1977), Snook Table (1978), NLE (1981), RULA (1993), RNLE (1993), PLIBEL (1995), Strain Index (1995), PATH (1996), ACGIH HAL (1997), OCRA (1998), QEC (1999), Washington State Ergo Checklist (2000), REBA (2000), ACGIH TLV for Lifting (2005), ACGIH for ULMF (2016), Kim (2017), LiFFT (2017), DUET (2018), etc.

Graphic source: NIOSH

Principles of Ergonomic Assessments

Force

Repetition

Posture

Graphic source: NIOSH

General Method Categorization

- Upper body (Hands/wrists, arms and shoulders)
- Low back
- Whole body

Photo credit: Purchased iStock photos

Photo credit: Purchased iStock photos

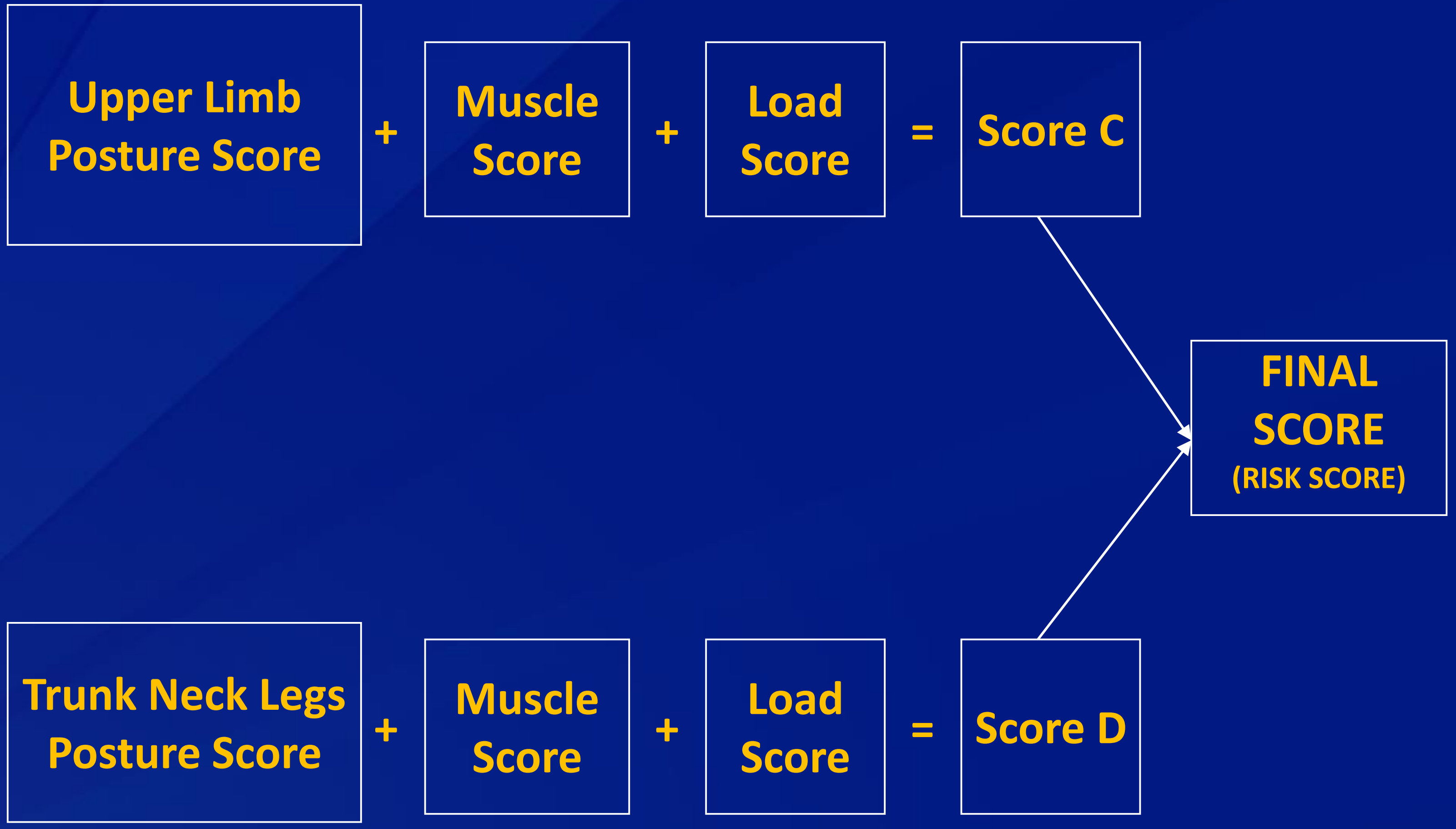
Upper Body Assessment Methods

- Rapid Upper Limb Assessment (RULA)
- Strain Index (SI)
- Hand Activity Level (HAL)

RULA

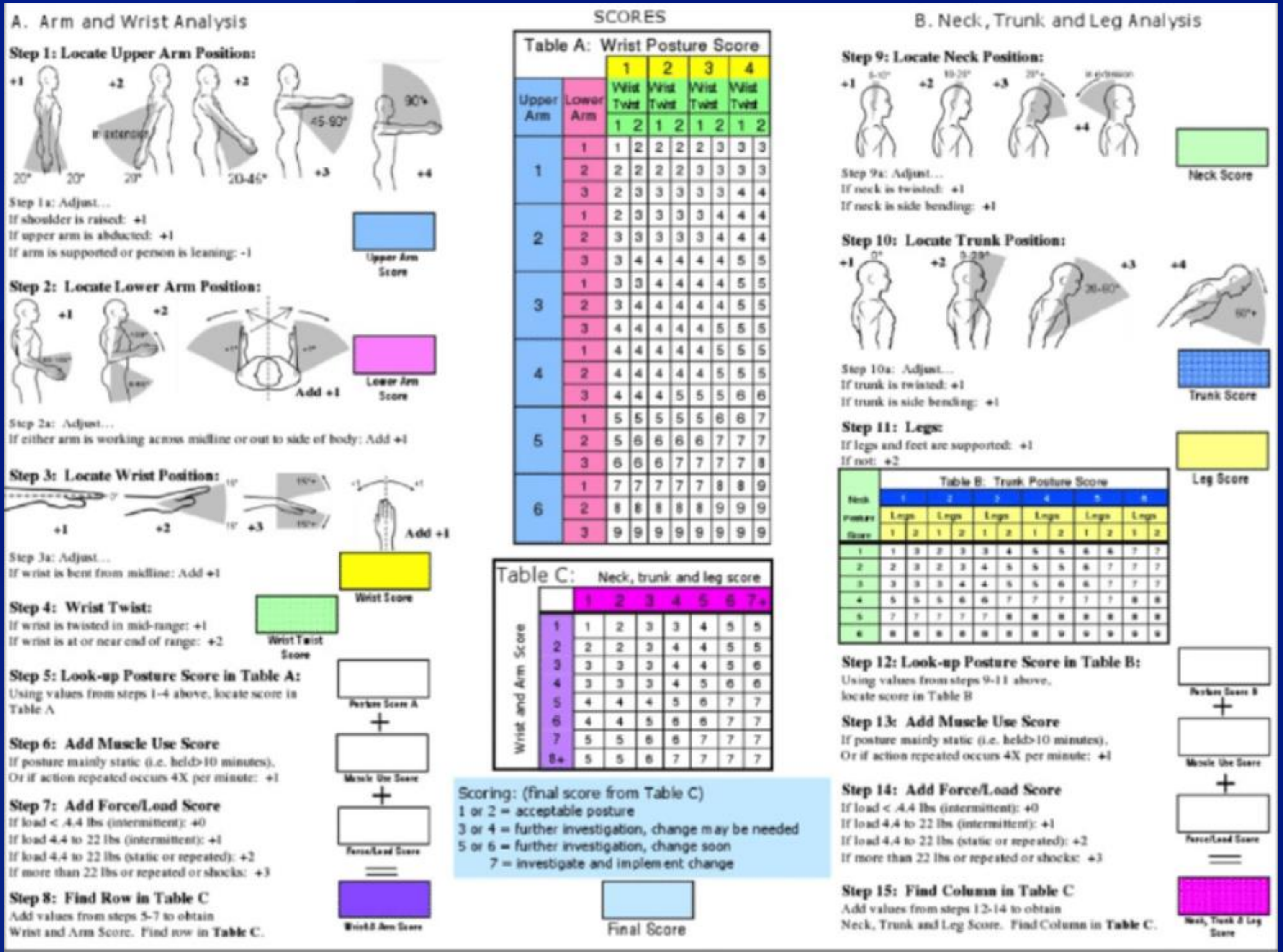
- Tool used to detect work postures or risk factors that may need to modified.
- Results in a risk score between 1-7, where higher scores signify a greater risk.

Procedural overview of RULA



Scoring System and Action Levels

- Action Level 1: Score of 1-2
  - posture is acceptable if it is not maintained for long durations.
- Action Level 2: Score of 3-4
  - changes may be needed soon.
- Action Level 3: Score of 5-6
  - changes are needed as soon as possible
- Action Level 4: Score of 7
  - changes should be made immediately.



Strain Index

Risk Factor	Rating criterion	Observation	Multiplier
Intensity of Exertion (IE)	Light	Barely noticeable	1.0
	Somewhat Hard	Noticeable or definite effort	3.0
	Hard	Obvious effort	6.0
	Very Hard	Substantial effort	9.0
	Near Maximal	Uses shoulder or trunk force	13.0
Duration of Exertion - % of job cycle (DE)	< 10 %	Time performing the effort X 100 / total cycle time	0.5
	10 - 29 %		1.0
	30 - 49 %		1.5
	50 - 79 %		2.0
	> 80 %		3.0
Efforts per Minute (EM)	< 4	actual # of efforts observed / total observation time in minutes	0.5
	4 - 8		1.0
	9 - 14		1.5
	15 - 19		2.0
	> 20		3.0
Hand/Wrist Posture (HP)	Very Good	Perfectly Neutral	1.0
	Good	Near Neutral	1.0
	Fair	Non-Neutral	1.5
	Bad	Marked Deviation	2.0
	Very Bad	Near Extreme	3.0
Speed of Work (SW)	Very Slow	Extremely slow paced	1.0
	Slow	"taking one's own time"	1.0
	Fair	Normal speed of motion	1.0
	Fast	Rushed, but able to keep up	1.5
	Very Fast	Rushed and barely/unable to keep up	2.0
Duration- hrs per Day (DD)	< 1	# of hours per day the worker performs the job (assuming 5 day work week)	0.25
	1 - 2		0.5
	2 - 4		0.75
	4 - 8		1.0
	> 8		1.5

- **SI equation**

  SI = IE x DE x EM x HP x SW x DD

- **SI Scores**
  - ≤ 3 are probably safe.
  - 3 - 5 are uncertain.
  - 5 - 7 have some risk.
  - ≥ 7 are probably hazardous.

HAL

- Combination of HAL and Peak Hand Force (also called Maximum Voluntary Contraction (MVC)) values which nearly all workers may be exposed to without adverse health effects
- Based on epidemiological, psychophysical and biomechanical studies and is meant for “mono-task” jobs performed for 4 or more hours per day.
- Related to exertion frequency and duty cycle (% of work cycle where force is greater than 5% of maximum).

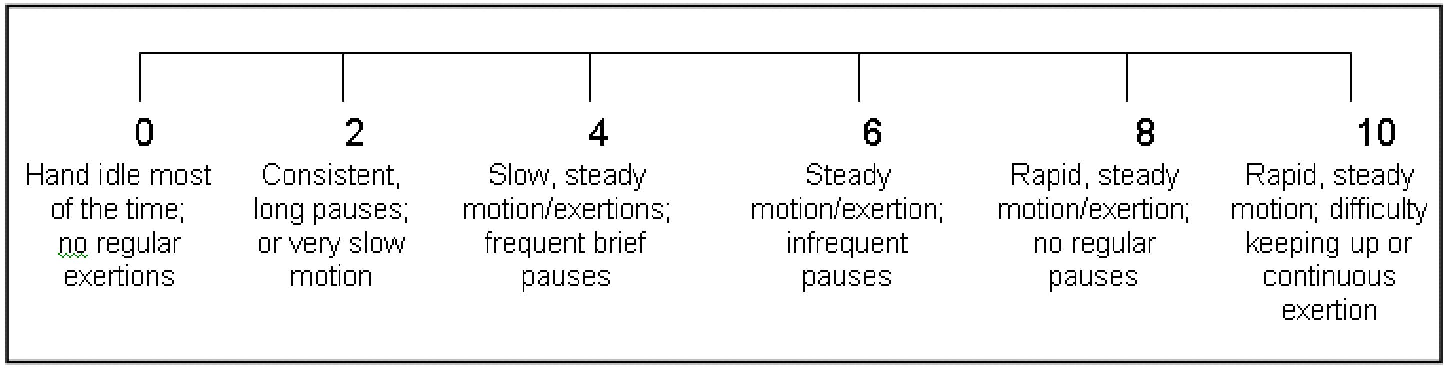
Risk Scoring System of HAL

Table 1: HAL (0 to 10) based on Frequency of Exertion and Duty cycle*

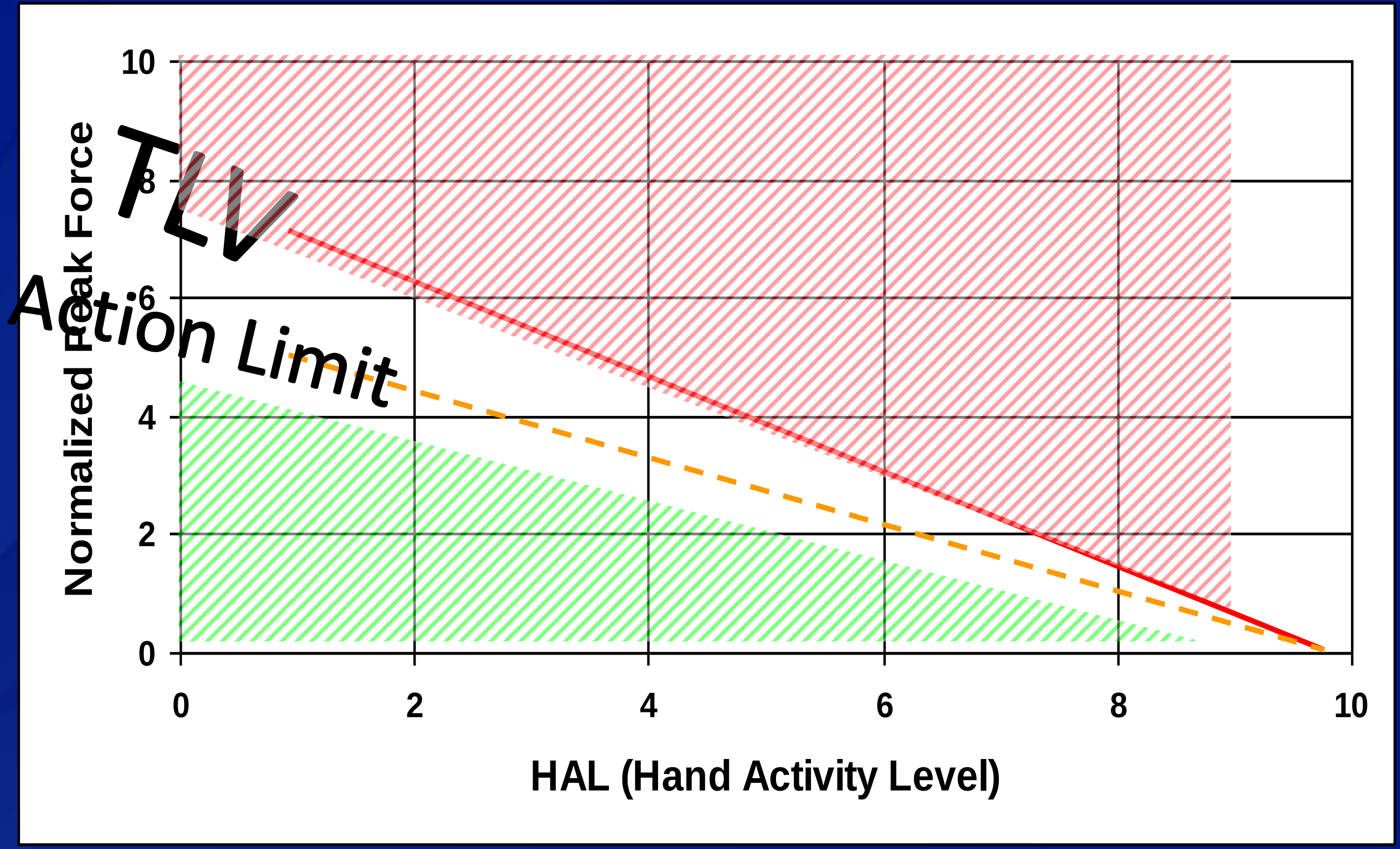
		Duty Cycle (%)				
Frequency (Exertion/sec)	Period (Sec/exertion)	0-20	20-40	40-60	60-80	80-100
0.125	8	1	1	---	---	---
0.25	4	2	2	3	---	---
0.5	2	3	4	5	5	6
1	1	4	5	5	6	7
2	0.5	---	5	6	7	8

* Use the HAL Rating scale to obtain HAL values outside those listed in the above table.

Figure 2: Hand Activity Level Rating Scale used by trained observers



HAL Threshold Limit Value (TLV) Graph

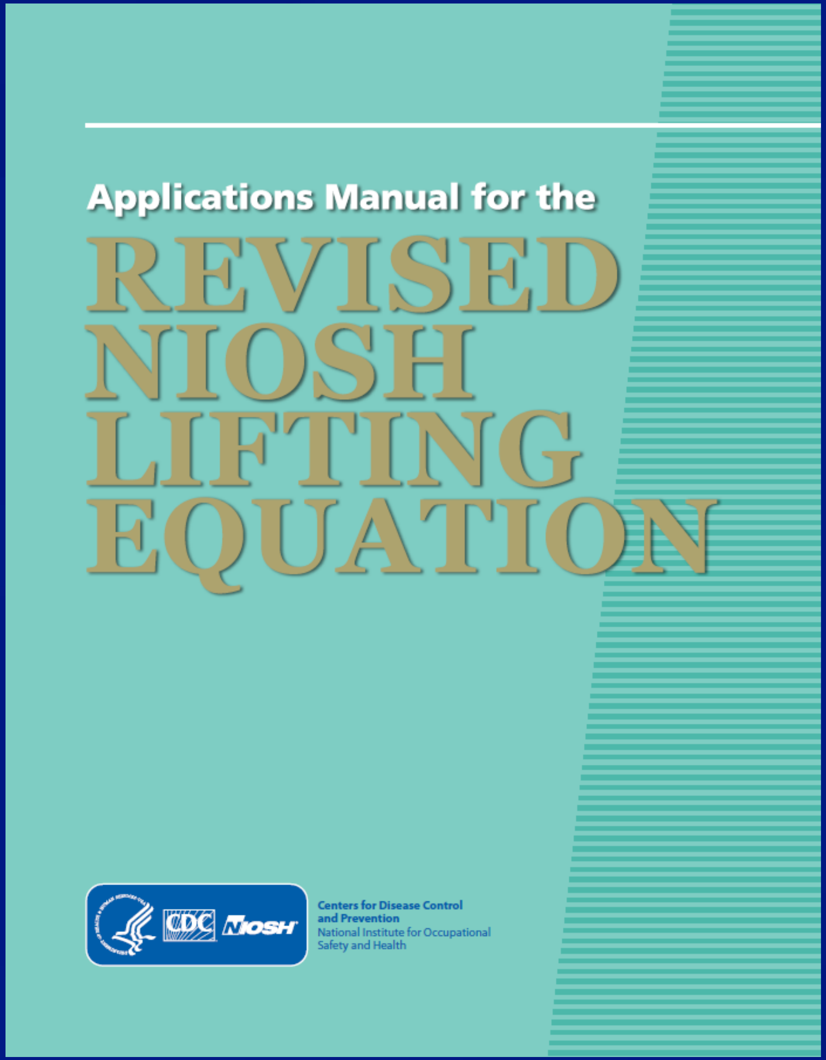


Low Back Assessment Methods

- NIOSH Lifting Equation
- ACGIH Lifting TLVs
- Push-Pull Force Limits
- 3DSSPP
- Equipment based methods (e.g. OSU lumbar motion monitor = Conity)

NIOSH Lifting Equation (NLE)

- First published by NIOSH in 1981
- Revised and published in 1991: Revised NLE or RNLE
- Official NIOSH applications manual for RNLE was published in 1994
- RNLE is used for assessing two-handed lifting tasks
- Two main outcome variables of the RNLE
  - Recommended weight limit (RWL)
  - Lifting Index (LI)



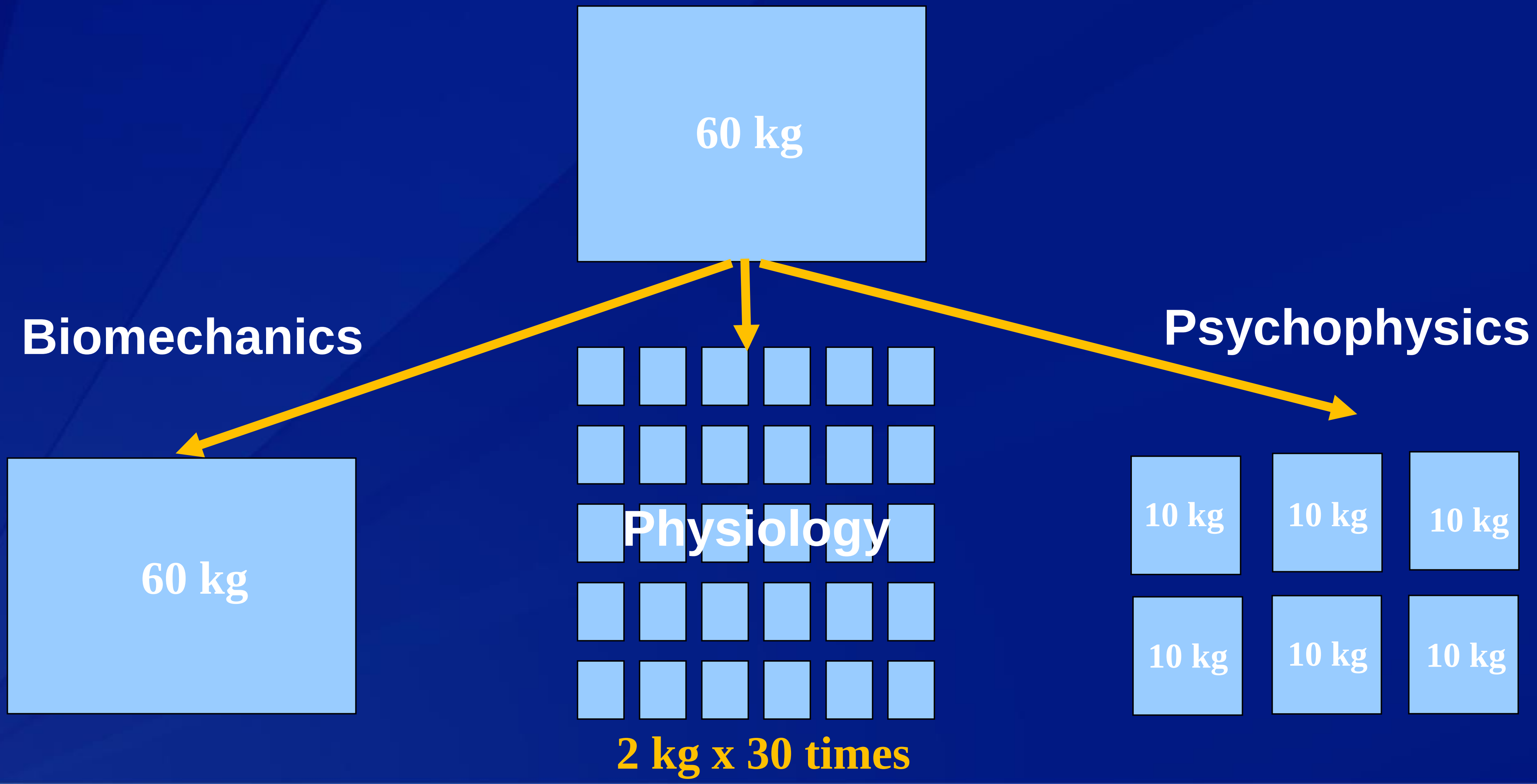
Recommended Weight Limit (RWL)

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

Where:

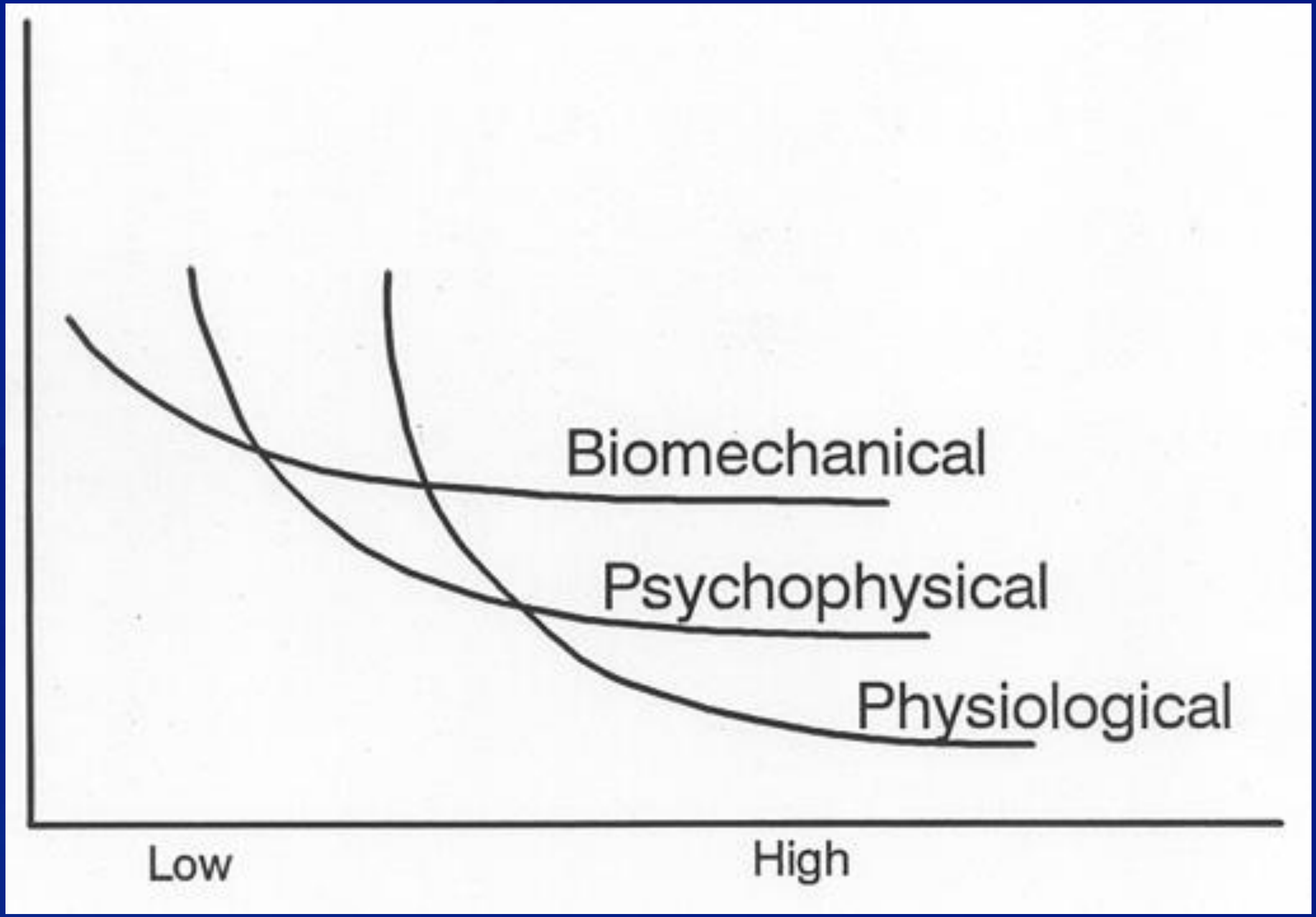
		Metric	U.S. Customary
Load Constant	LC	23kg	51lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1– (.003|V-75|)	1– (.0075|V-30|)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1– (.0032A)	1– (.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling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

Hybrid Approach to Designing RNLE



Criteria for Acceptable Lifting

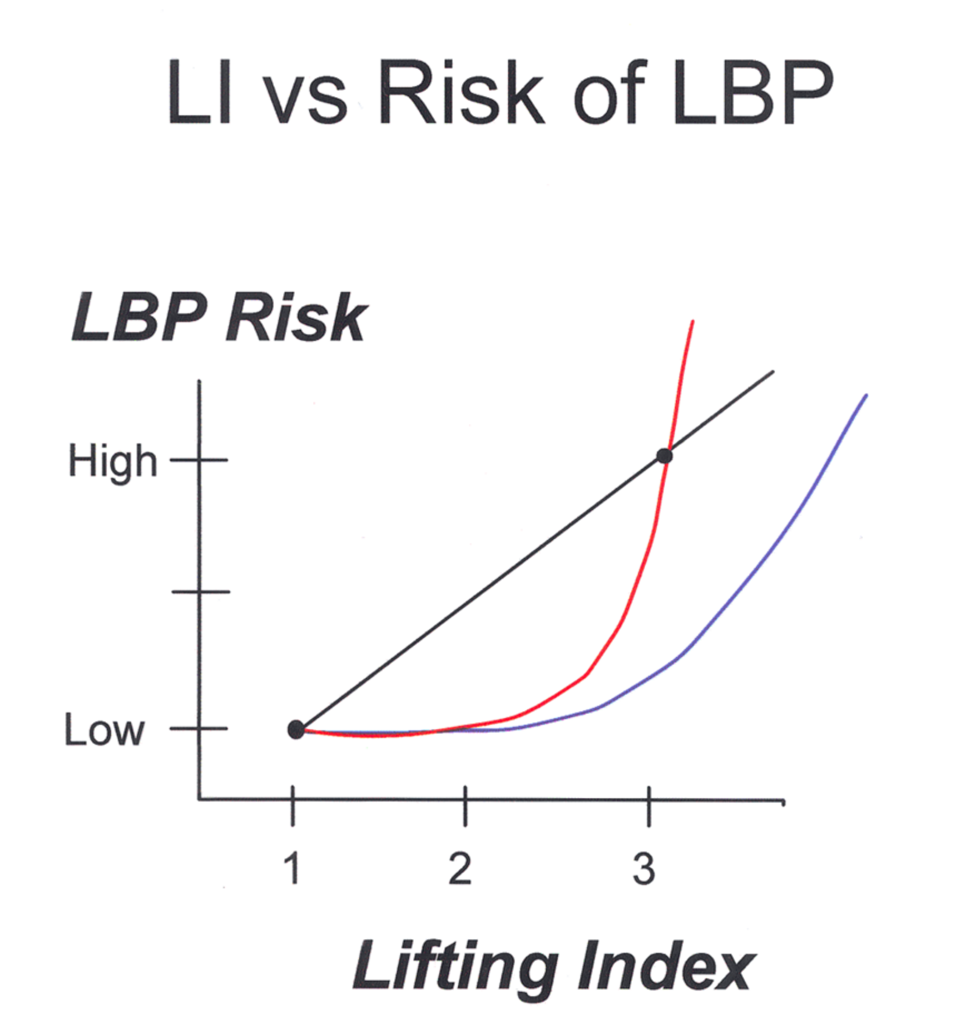
Acceptable Weight



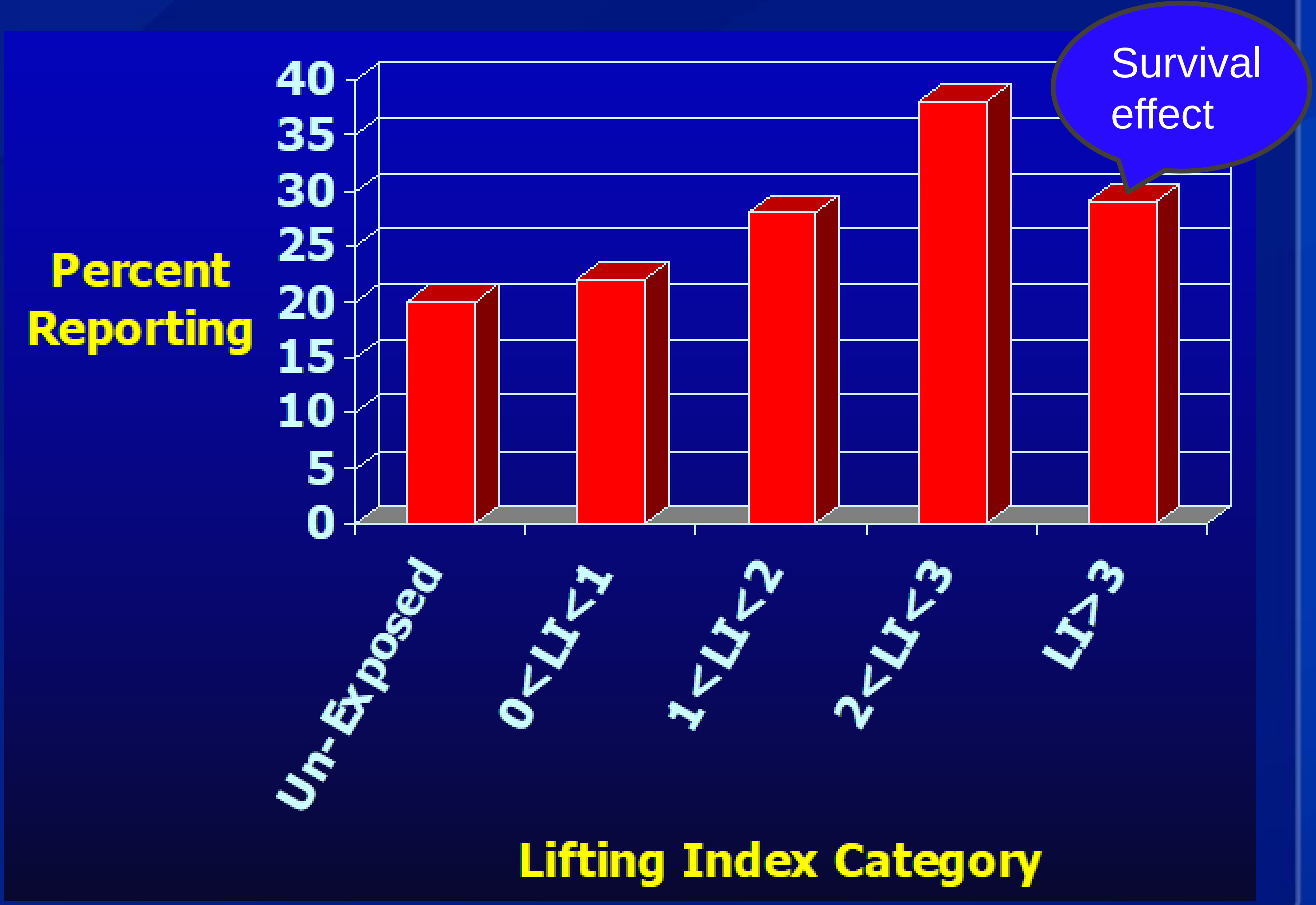
Lifting Frequency

Source: hypothetical curves by NIOSH

Risk of Low Back Pain (LBP)



Source: hypothetical curves by NIOSH



Source: Water and Lu et al., 1999, 2011

ISO 11228 Ergonomics Standard Part 1: Lifting, Lowering and Carrying

Table D.1 — Interpretation of LI (m_A/RML) values

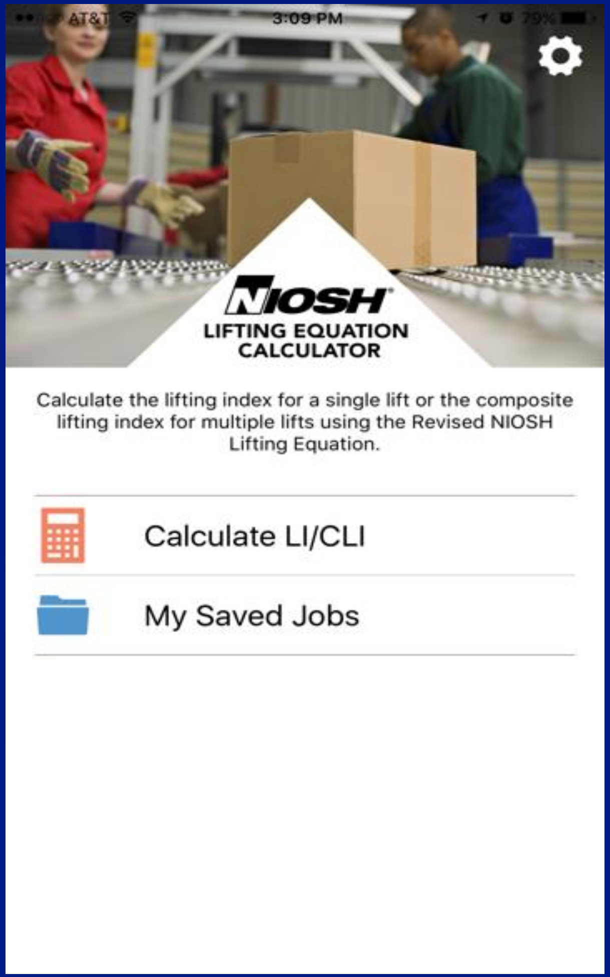
LI value	Exposure level/risk implication	Recommended actions[a]
LI ≤ 1,0	Very low	None in general for the healthy working population.
1,0 < LI ≤ 1,5	Low	In particular pay attention to low frequency/high load conditions and to extreme or static postures. Include all factors in redesigning tasks or workstations and consider efforts to lower the LI values < 1,0.
1,5 < LI ≤ 2,0	Moderate	Redesign tasks and workplaces according to priorities to reduce the LI, followed by analysis of results to confirm effectiveness.
2,0 < LI ≤ 3,0	High	Changes to the task to reduce the LI are a high priority.

[a] To be used in conjunction with considerations outlined in the Introduction and Annex A regarding general use of ergonomics principles and approaches that should be used at all workplaces.

Source: ISO Standard 11228-1 (2021)

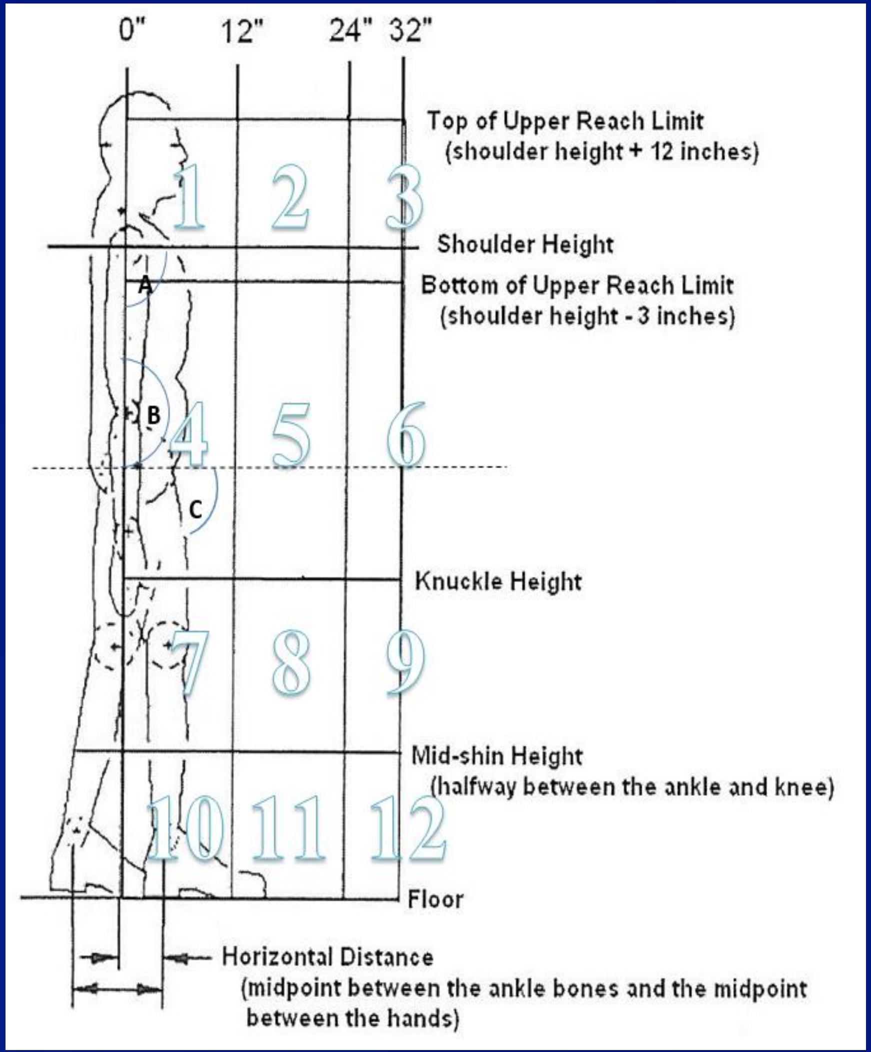
NIOSH Mobile App (NLE Calc) for RNLE

- Official and free mobile app for RNLE
- The first app capable of calculating composite lifting index for multi0task lifting jobs
- Provides calculation details and recommendations



ACGIH TLV for Lifting (1/3)

- American Conference of Government al Industrial Hygienists (ACGIH) TLV for lifting
- More limitations than the RNLE (i.e., no task asymmetry)
- "Simplified" version of RNLE
- Tables for different work duration and lifting frequency



ACGIH TLV for Lifting (2/3)

TABLE 1. TLVs' for Infrequent Lifting:
• •2 Hours per Day with • •60 Lifts per Hour
OR
• •2 Hours per Day with • •12 Lifts per Hour

Vertical Height of Hands	**Horizontal Distance of Hands from Body[A]**		
	Close: • 12 inches (30 cm)	**Intermediate: 12-24 inches (30-60 cm)**	**Extended:[B] 25-32 inches (60-80 cm)**
Reach Limit:[C]	35 lbs (16 kg)	15 lbs (7 kg)	No known safe limit for repetitive lifting[D]
Shoulder Area: 12″ above to 3″ below shoulder	35 lbs (16 kg)	15 lbs (7 kg)	No known safe limit for repetitive lifting[D]
Torso Area: Below shoulder to knuckle height[E]	70 lbs (32 kg)	35 lbs (16 kg)	20 lbs (9 kg)
Knee Area: Knuckle to middle of shin height[E]	40 lbs (18 kg)	30 lbs (14 kg)	15 lbs (7 kg)
Ankle Area: Middle of shin height to floor	30 lbs (14 kg)	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]

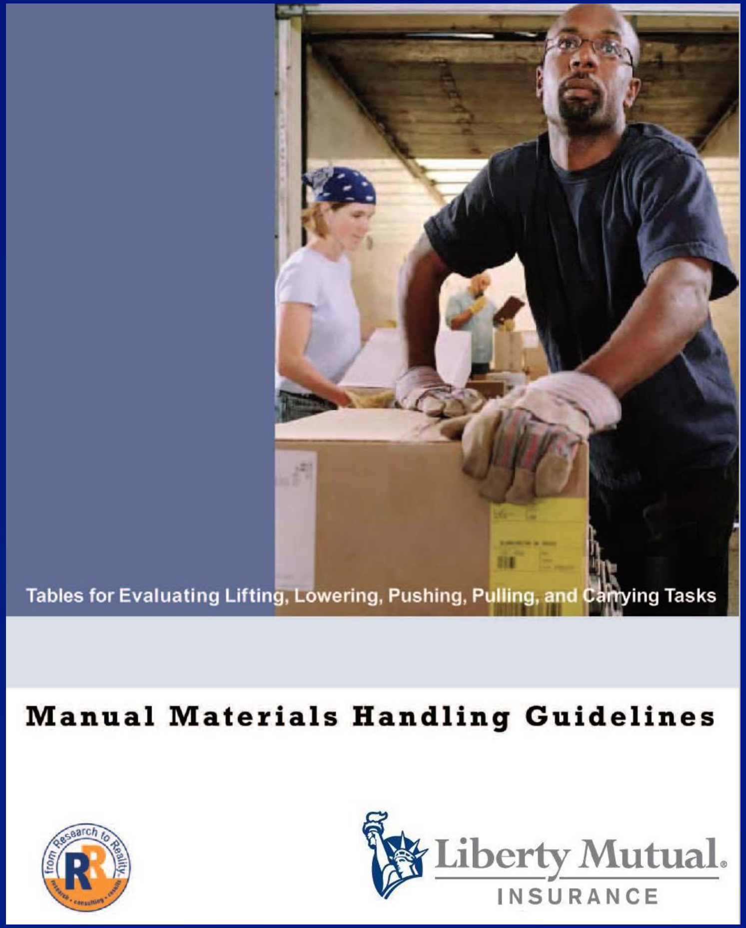
ACGIH TLV for Lifting (3/3)

TABLE 3. TLVs˙ for Frequent, Long Duration Lifting:
• •2 Hours per Day with • •30and • •360 Lifts per Hour

Vertical Height of Hands	**Horizontal Distance of Hands from Body**[A]		
	Close: • 12 inches (30 cm)	**Intermediate: 12-24 inches (30-60 cm)**	**Extended:**[B] **25-32 inches (60-80 cm)**
Reach Limit:[C]	25 lbs (11 kg)	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]
Shoulder Area: 12″ above to 3″ below shoulder	25 lbs (11 kg)	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]
Torso Area: Below shoulder to knuckle height[E]	30 lbs (14 kg)	20 lbs (9 kg)	10 lbs (5 kg)
Knee Area: Knuckle to middle of shin height[E]	20 lbs (9 kg)	15 lbs (7 kg)	5 lbs (2 kg)
Ankle Area: Middle of shin height to floor	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]

Push, Pull, Carry Force Limits (1/2)

- Maximal acceptable force limits (MAFs) for males and females in comfortable work conditions
- All the data are psychophysically determined, which the people are willing to accept if they were to perform the push or pull activities as a part of their normal 8 hour job



Push, Pull and Carry Force Limits (2/2)

INITIAL FORCES

INITIAL PUSHING FORCE (POUNDS)	HAND HEIGHT (INCHES) - MALES	MALE 30s	MALE 1m	MALE 5m	MALE 30m	MALE 8h	HAND HEIGHT (INCHES) - FEMALES	FEMALE 30s	FEMALE 1m	FEMALE 5m	FEMALE 30m	FEMALE 8h
130	57	-	-	-	-	25	53	-	-	-	-	-
	37	-	-	13	14	36	35	-	-	-	-	-
	25	-	-	-	-	22	22	-	-	-	-	-
127	57	-	-	-	-	28	53	-	-	-	-	-
	37	-	-	15	16	39	35	-	-	-	-	-
	25	-	-	-	-	25	22	-	-	-	-	-
124	57	-	-	-	11	31	53	-	-	-	-	-
	37	-	12	18	19	42	35	-	-	-	-	-
	25	-	-	-	-	29	22	-	-	-	-	-
121	57	-	-	12	13	35	53	-	-	-	-	-
	37	-	14	20	21	46	35	-	-	-	-	-
	25	-	-	-	11	32	22	-	-	-	-	-
118	57	-	-	15	16	38	53	-	-	-	-	-
	37	-	17	23	25	49	35	-	-	-	-	-
	25	-	-	13	13	35	25	-	-	-	-	-
115	57	-	12	17	18	42	53	-	-	-	-	-
	37	11	19	27	28	52	35	-	-	-	-	-
	25	-	-	15	16	39	22	-	-	-	-	-
112	57	-	14	20	21	46	53	-	-	-	-	-
	37	13	23	30	31	56	35	-	-	-	-	-
	25	-	12	18	19	43	22	-	-	-	-	-
109	57	-	17	24	25	49	53	-	-	-	-	-
	37	16	26	34	35	59	35	-	-	-	-	-
	25	-	15	21	22	46	22	-	-	-	-	-
106	57	12	20	27	28	53	53	-	-	-	-	-
	37	19	30	38	39	63	35	-	-	-	-	-
	25	-	18	24	26	50	22	-	-	-	-	-
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100	57	17	27	35	36	60	53	-	-	-	-	-
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	25	14	24	32	33	58	22	-	-	-	-	-
97	57	21	31	39	41	64	53	-	-	-	-	-
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82	57	43	54	62	63	79	53	-	-	-	14	22
	37	53	64	70	71	84	35	-	-	-	15	22
	25	39	51	59	60	78	22	-	-	-	-	-
79	57	48	59	66	67	82	53	-	-	14	19	27
	37	58	68	73	74	86	35	-	-	14	20	28
	25	44	56	63	64	80	22	-	-	-	-	-

+ = GREATER THAN 90% - = LESS THAN 10%

TABLE 8F - FEMALE POPULATION PERCENTAGES FOR PUSHING TASKS

SUSTAINED FORCE

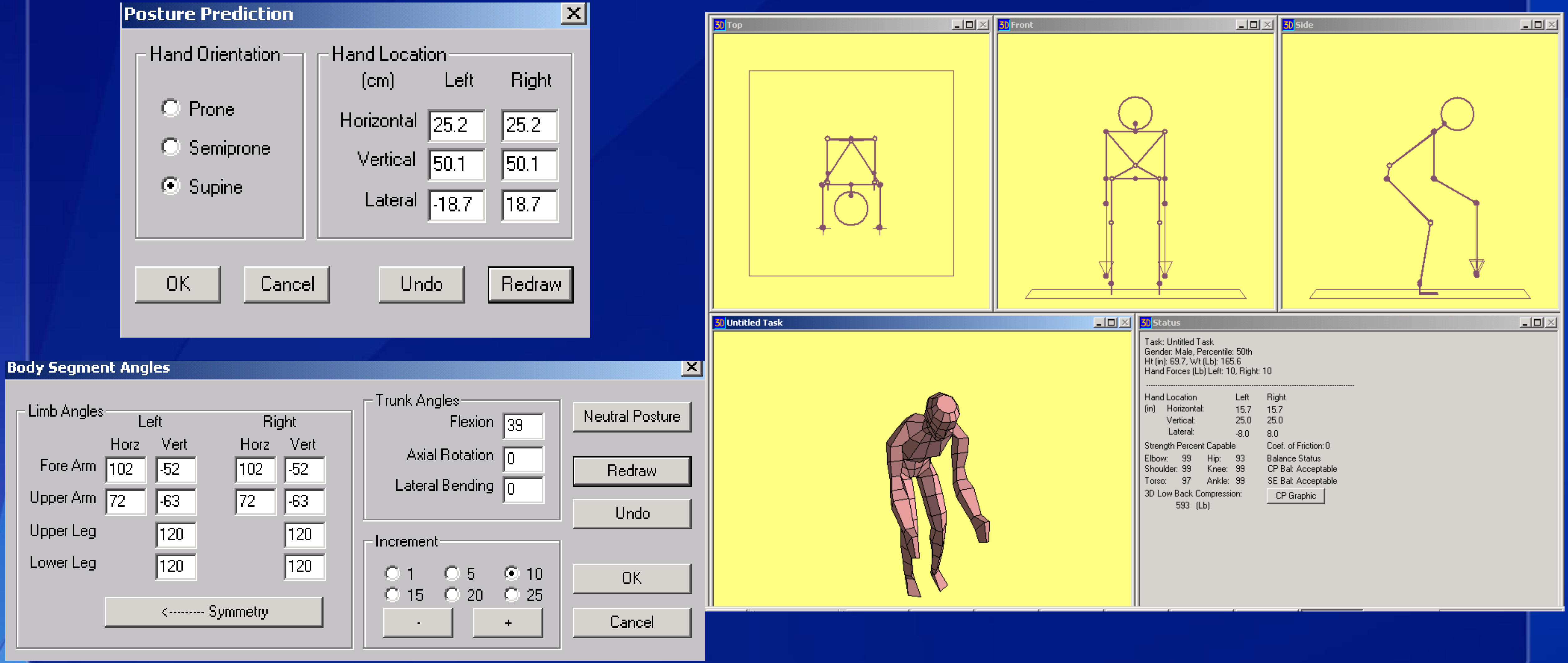
SUSTAINED PUSHING FORCE (POUNDS)	HAND HEIGHT (INCHES)	7 FEET 30s	7 FEET 1m	7 FEET 5m	7 FEET 30m	7 FEET 8h	25 FEET 30s	25 FEET 1m	25 FEET 5m	25 FEET 30m	25 FEET 8h	50 FEET 30s	50 FEET 1m	50 FEET 5m	50 FEET 30m	50 FEET 8h
80	53	-		-	-	23	-	-	-	-	-	-	-	-	-	-
	35	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76	53	-	-	-	-	28		-	-	-	-	-	-	-	-	-
	35	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	53	-	-	-	14	34	-	-	-	-	-	-	-	-	-	-
	35	-	-	-	-	26	-	-	-	-	12	-	-	-	-	-
	22	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-
68	53	-	-	13	19	40	-	-	-	-	12	-	-	-	-	-
	35	-	-	-	12	32	-	-	-	-	16	-	-	-	-	-
	22	-	-	-	-	18	-	-	-	-	11	-	-	-	-	-
64	53	-	-	18	25	47	-	-	-	-	17	-	-	-	-	-
	35	-	-	12	17	39	-	-	-	-	22	-	-	-	-	-
	25	-	-	-	-	24	-	-	-		15	-	-	-	-	-
60	53	-	13	24	31	54	-	-	-	-	23	-	-	-	-	-
	35	-	-	17	23	46	-	-	-	-	29	-	-	-	-	12
	22	-	-	-	11	30	-	-	-	-	21	-	-	-	-	-
56	53	-	19	31	39	60	-	-	-	11	30	-	-	-	-	14
	35	-	13	23	30	53	-	-	-	15	36	-	-	-	-	18
	22	-	-	11	17	38	-	-	-	-	28	-	-	-	-	12
52	53	16	26	40	47	66	-	-	12	17	39	-	-	-	-	20
	35	-	19	31	39	60	-	-	16	22	44	-	-	-	-	25
	22	-	-	17	24	46	-	-	-	15	36	-	-	-	-	18
48	53	23	35	48	55	72	-	-	18	25	47	-	-	-	-	28
	35	16	27	40	47	67	-	12	23	30	53	-	-	-	14	34
	22	-	14	25	32	54	-	-	16	23	45	-	-	-	-	26
44	53	32	44	57	63	77	13	15	27	34	56	-	-	11	17	38
	35	24	36	49	56	73	12	20	32	40	61	-	-	15	21	43
	22	12	21	34	42	62	-	13	25	32	54	-	-	-	15	35
40	53	43	54	65	70	82	21	24	37	44	65	-	-	19	26	48
	35	34	46	59	65	78	20	29	43	50	69	-	13	24	31	53
	22	20	31	45	52	70	18	22	35	42	63	-	-	17	23	46
36	53	54	64	73	77	86	32	35	48	55	72	-	17	30	37	58
	35	46	57	67	72	83	31	41	54	60	75	-	22	35	43	63
	22	30	43	55	62	77	28	33	46	53	71	-	16	27	35	57
32	53	64	73	80	83	89	45	48	60	66	79	16	29	42	50	68
	35	57	67	75	79	87	44	53	64	70	82	14	35	48	55	72
	22	43	55	66	71	82	41	46	58	64	78	13	27	40	47	67
28	53	74	80	85	87	+	58	61	71	75	85	29	44	56	62	77
	35	69	76	82	85	+	57	65	74	78	86	26	49	61	67	80
	22	57	67	75	79	87	55	59	69	74	84	25	41	54	60	76
24	53	82	86	89	+	+	71	73	80	83	89	46	59	69	74	84
	35	78	83	87	89	+	70	76	82	85	+	43	64	73	77	86
	22	70	77	83	85	+	68	71	79	82	89	42	57	68	72	83
20	53	88	+	+	+	+	81	82	87	89	+	64	73	80	83	89
	35	86	89	+	+	+	81	84	88	+	+	61	76	82	85	+
	22	80	85	89	+	+	79	81	86	88	+	60	72	79	82	89
16	53	+	+	+	+	+	89	89	+	+	+	79	84	88	+	+
	35	+	+	+	+	+	88	+	+	+	+	77	86	89	+	+
	22	88	+	+	+	+	88	89	+	+	+	76	83	88	89	+
12	53	+	+	+	+	+	+	+	+	+	+	89	+	+	+	+
	35	+	+	+	+	+	+	+	+	+	+	88	+	+	+	+
	22	+	+	+	+	+	+	+	+	+	+	88	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

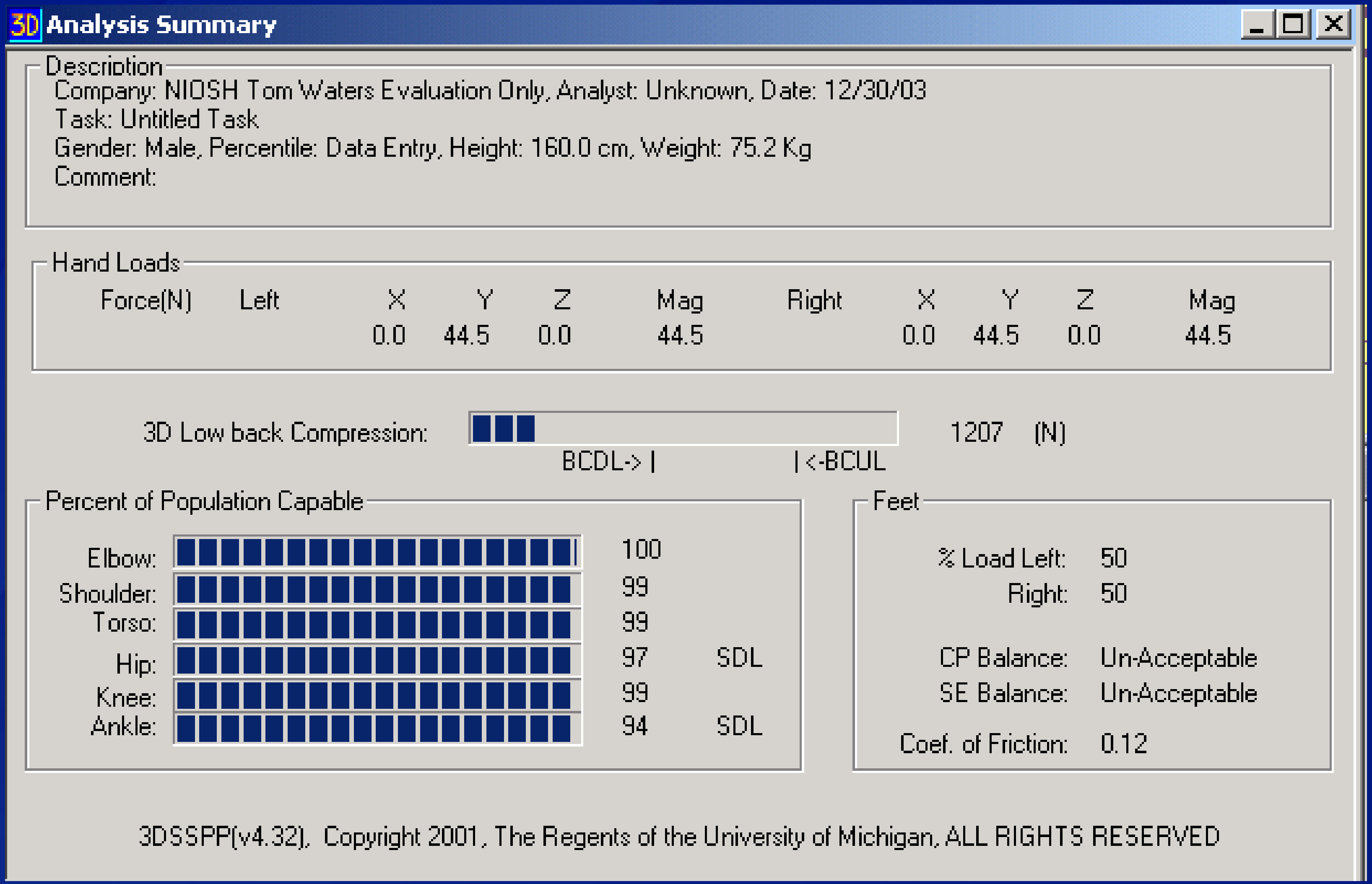
3D Static Strength Prediction Program (3D SSPP)

- Software program developed by the University of Michigan which predicts static strength requirements for tasks
- Provides an approximate job simulation that includes posture data, force parameters and male/ female anthropometry
- Analysis features an automatic posture generation and 3D human graphic illustrations

3DSSPP User Interface



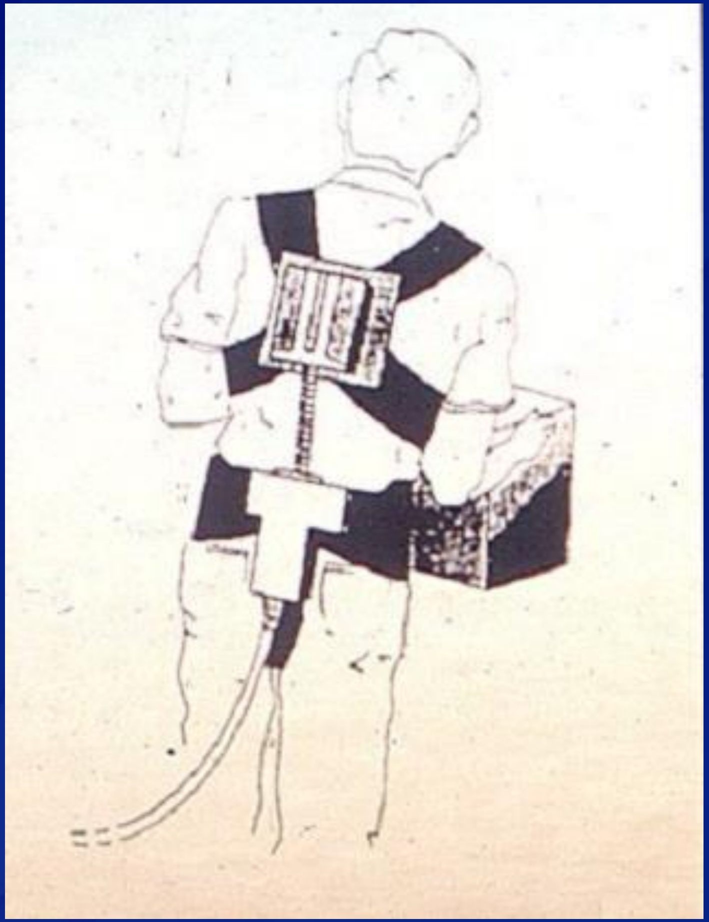
3DSSPP Outcome Variables

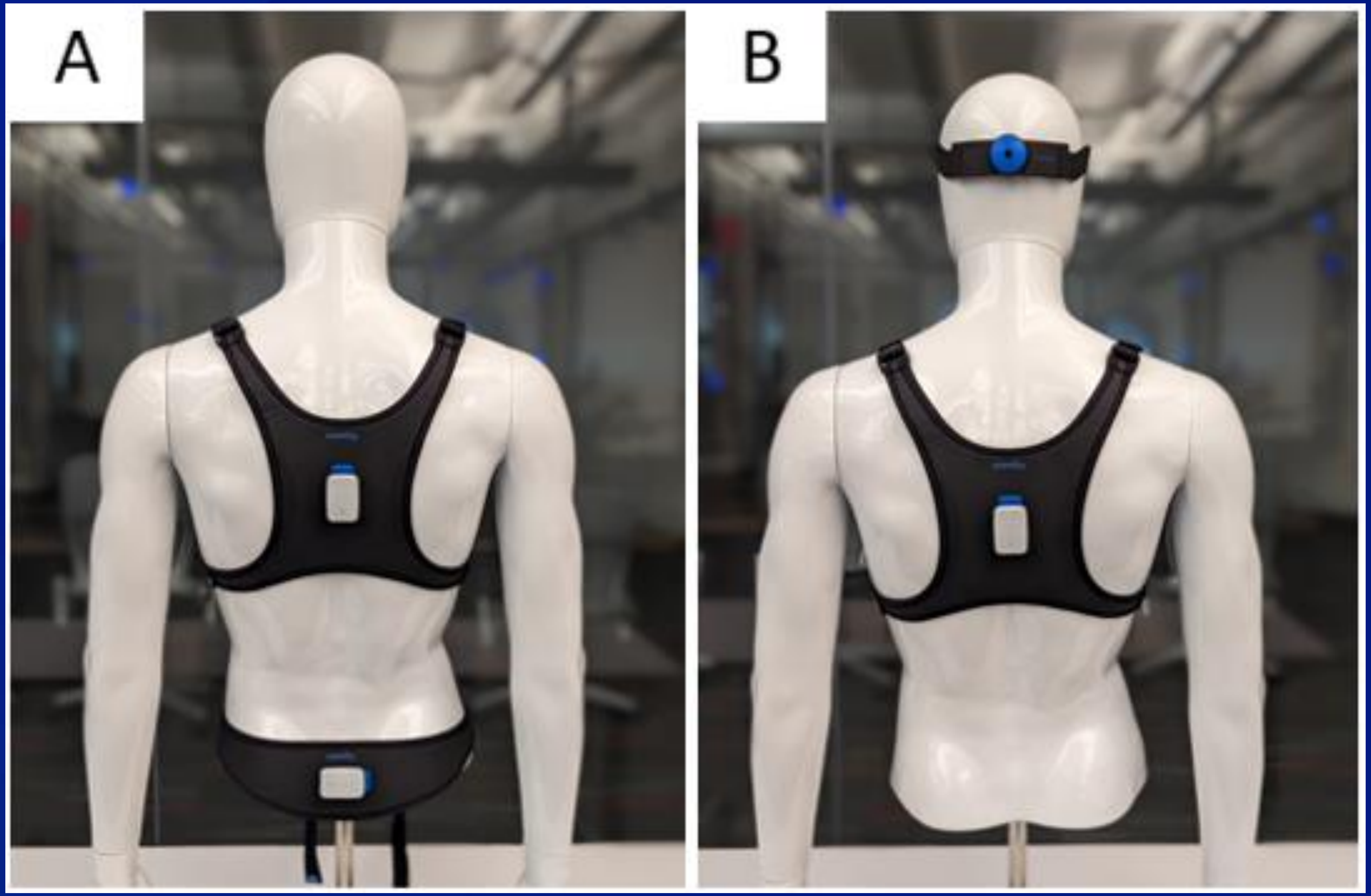


Equipment-based methods

- Electromyography (EMG)
  - Attempt to estimate muscle loads
  - Useful for measuring muscle fatigue
- Back posture measurement
  - Lumbar Motion Monitor (LMM)
  - Wearable sensors

Lumbar Motion Monitor (LMM)





Source: The Ohio State University

Whole Body Assessment Methods

- Ovako Working Posture Analysis System (OWAS)
- Method for the identification of musculoskeletal stress factors which may have injurious effects – PLIBEL
- Key Indicator Method (KIM)

Part3
Future Ergonomic Risk Assessments in the Age of AI

Computer Vision

Wearable Sensors

Machine Learning

IA → AI

Big Data Analysis

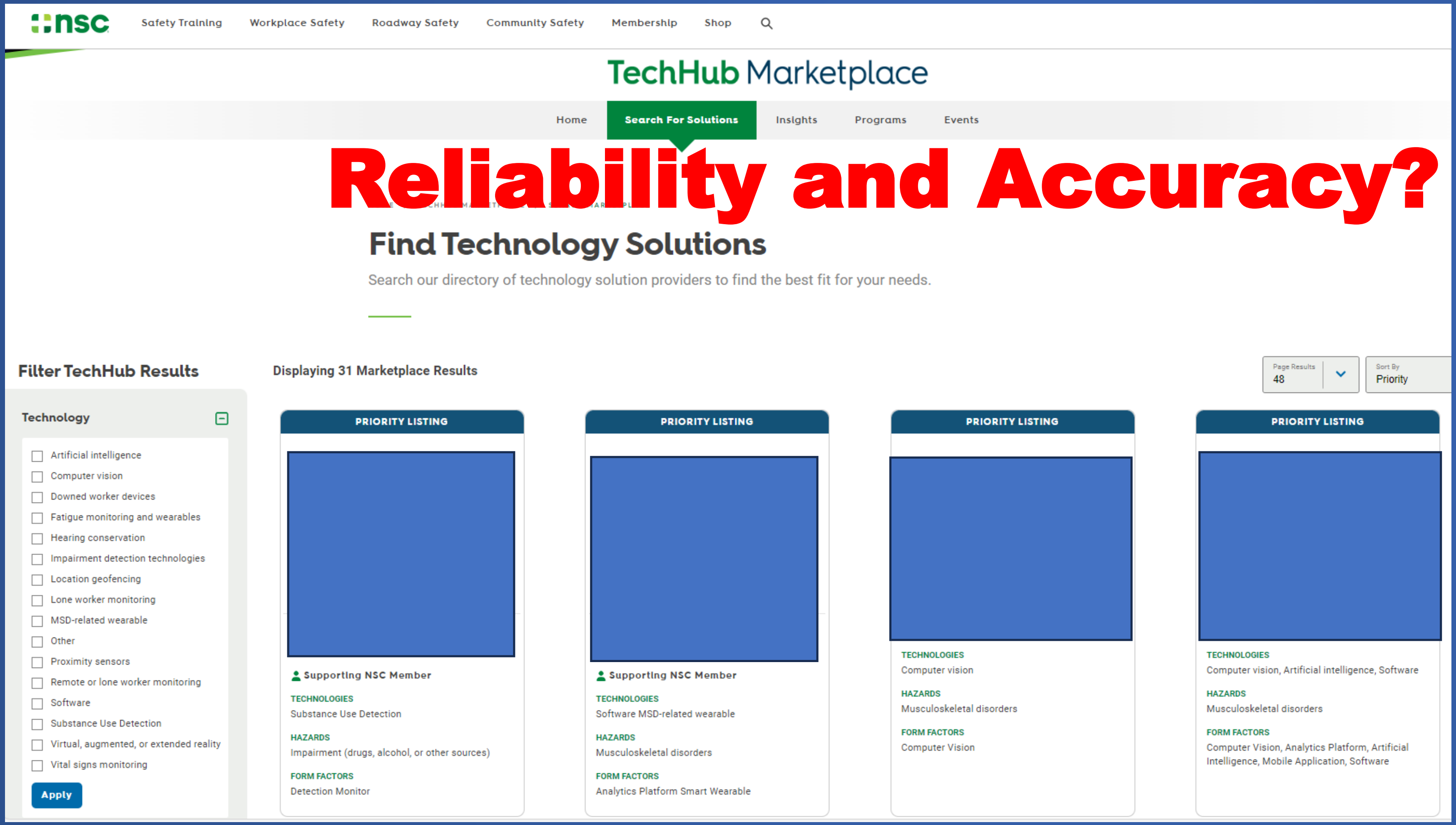
Artificial Intelligence

Selected interventions

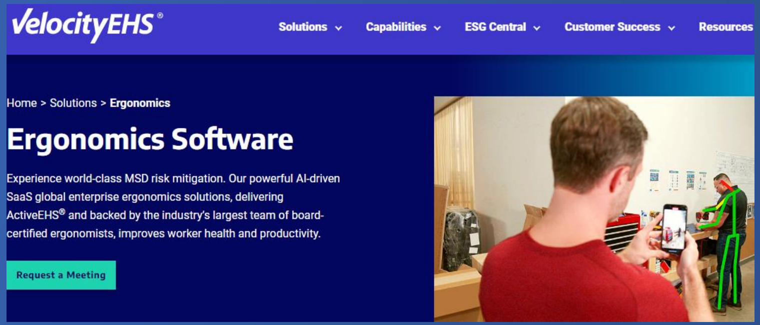
Graphic source: NIOSH

Photo credit: Purchased Getty Image

Applications of AI Based Ergonomic Risk Assessment Systems



Reliability and Accuracy?



NIOSH-University Partnerships

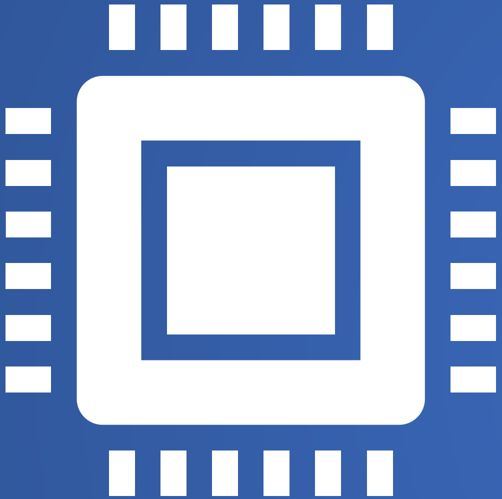
Sources: National Safety Council (left); www.compscience.com/ (top right); www.ehs.com/solutons/ergonomics (right middle); ergo.wisc.edu/research-2 (right bottom)

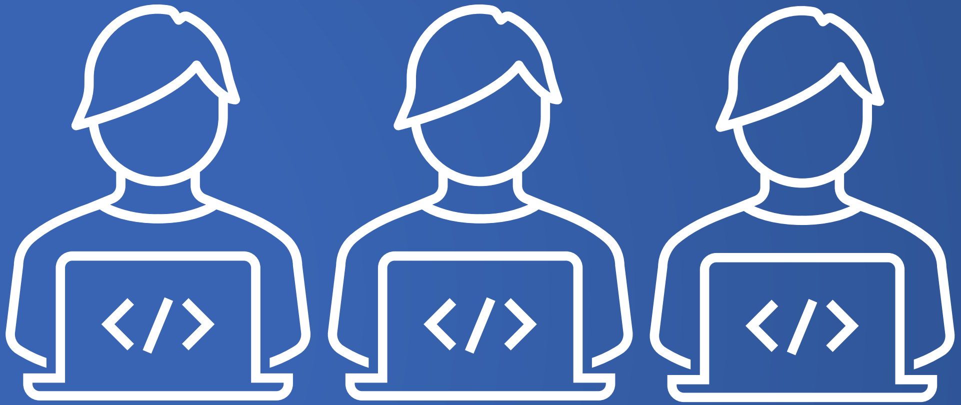
AI Projects at NIOSH

Natural Language Processing	Computer Vision	Wearable Sensors	Robotics
• Auto-coding workers comp records • Identify factors related to mining fatalities	• Performance of protective materials • Classify particle deposition • Ergo risk identification	• Heat detection • Proximity sensing • Ergo risk identification	• Smart path planning for co-bots • Exoskeletons

Graphic source: NIOSH

NIOSH MSD Record Auto-coder Project





90% Accuracy

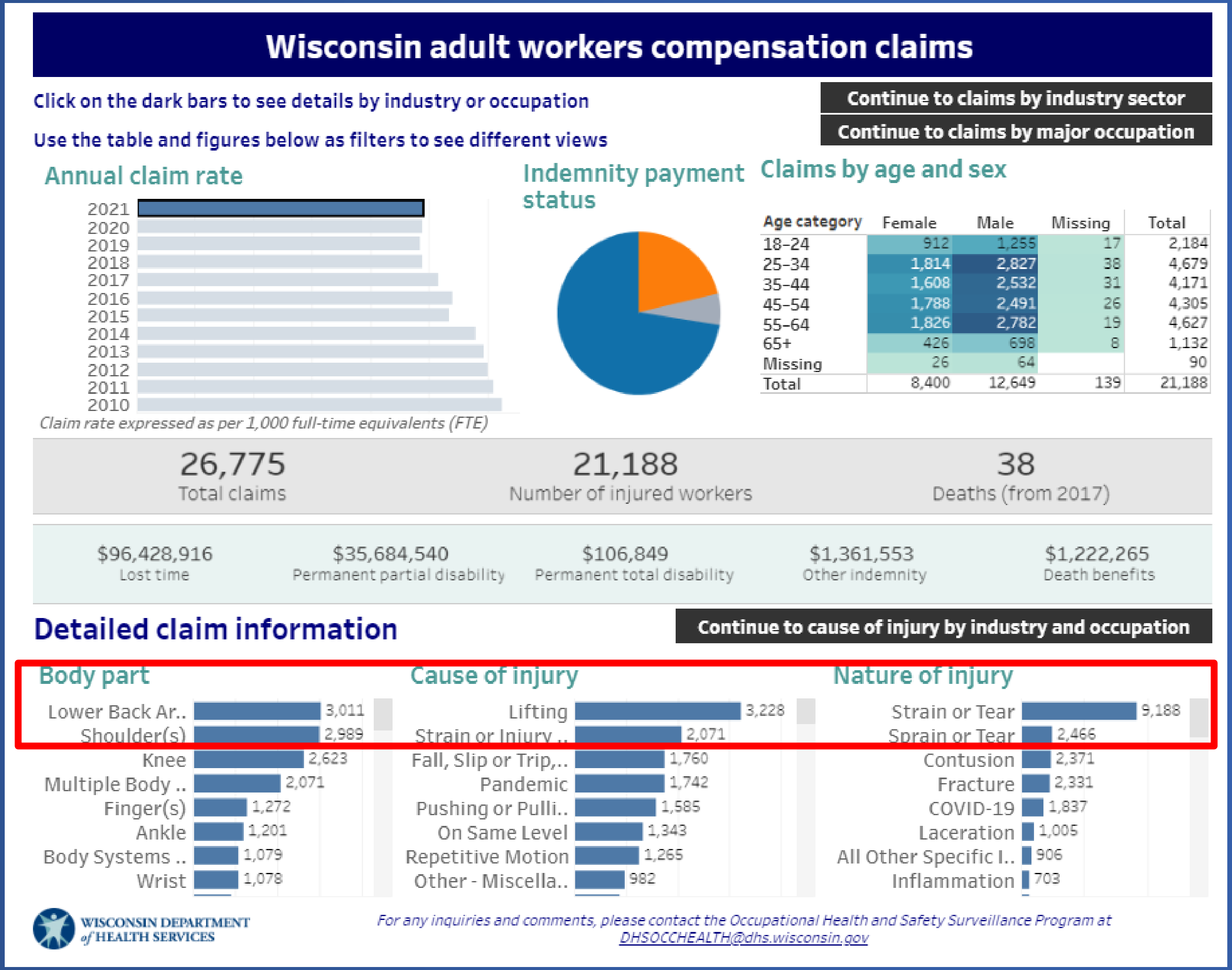
Efficiency: 360% by a standard PC

94% Accuracy

Efficiency: 1% by 1 coder

Graphic source: Microsoft Power Point icons; information source: Bertke et al. Development and evaluation of a Naïve Bayesian model for coding causation of workers compensation claims. J of Safety Research 43: 327-332 (2012)

Wisconsin Workers' Compensation Dashboard

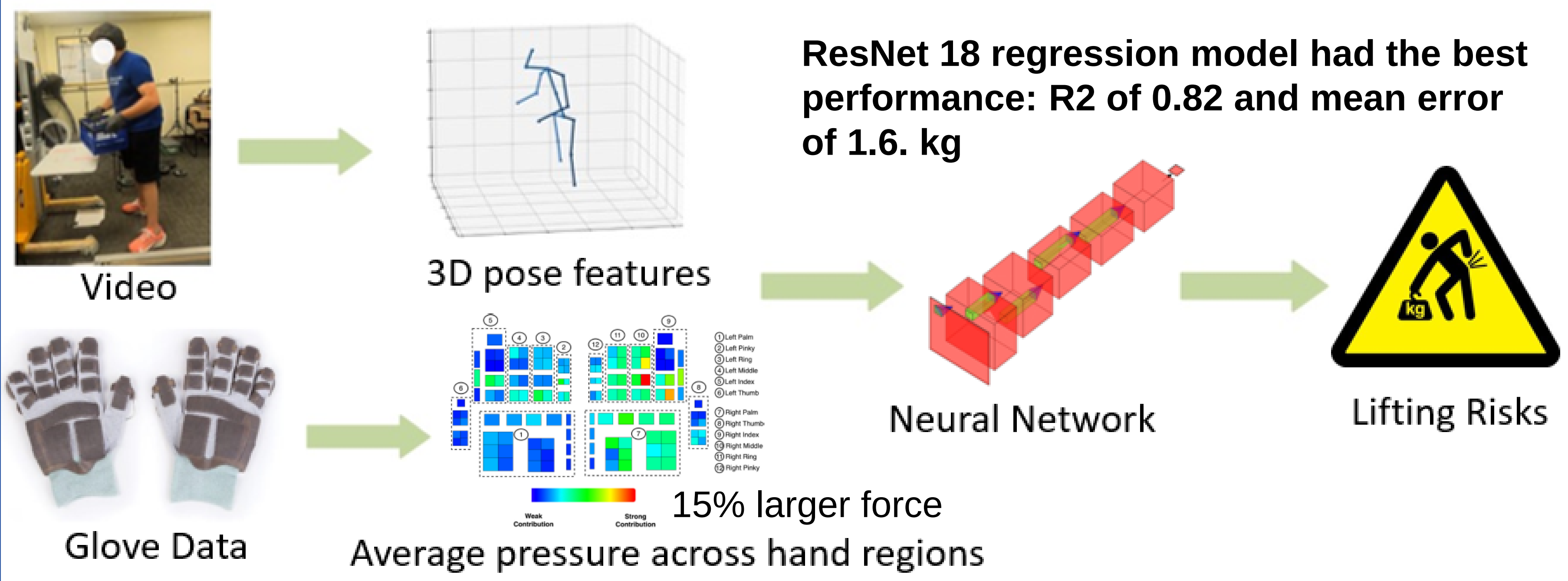


Source: https://www.dhs.wisconsin.gov/occupational-health/workers-compensation-dashboard.htm

Photo credit: Purchased Getty Image

NIOSH-Purdue Tactile Gloves Project

- ResNet 18 regression model had the best performance: R^2 of 0.82 and mean error of 1.6 kg*.
- Shapley additive explanations (SHAPs) indicated:
    - Right hand is more important than left hand
    - Fingers sensors are more important than palm sensors
    - Middle phase of lifting is more important that others
- Not suitable for assessing heavy loads (>13 kg)



An overall accuracy of 90% was achieved with our best model

	Precision	Recall	F1 score
Low Risk	0.97	0.97	0.97
Middle Risk	0.88	0.90	0.89
High Risk	0.80	0.75	0.77

Graphic source: Purdue University; and Chen H, et al. Lifting risk assessment using tactile gloves and computer vision. Presented at Applied Ergonomics Conference, Louisville, KY, March 25-28, 2024. *: Zhou G., Lu M. and Yu D.. Tactile gloves predict load weight during lifting with deep neutral networks. IEEE Sensors. Vol 23 (16): 18798-18809 (2023).

NIOSH Wearable Sensors Project (1/3)

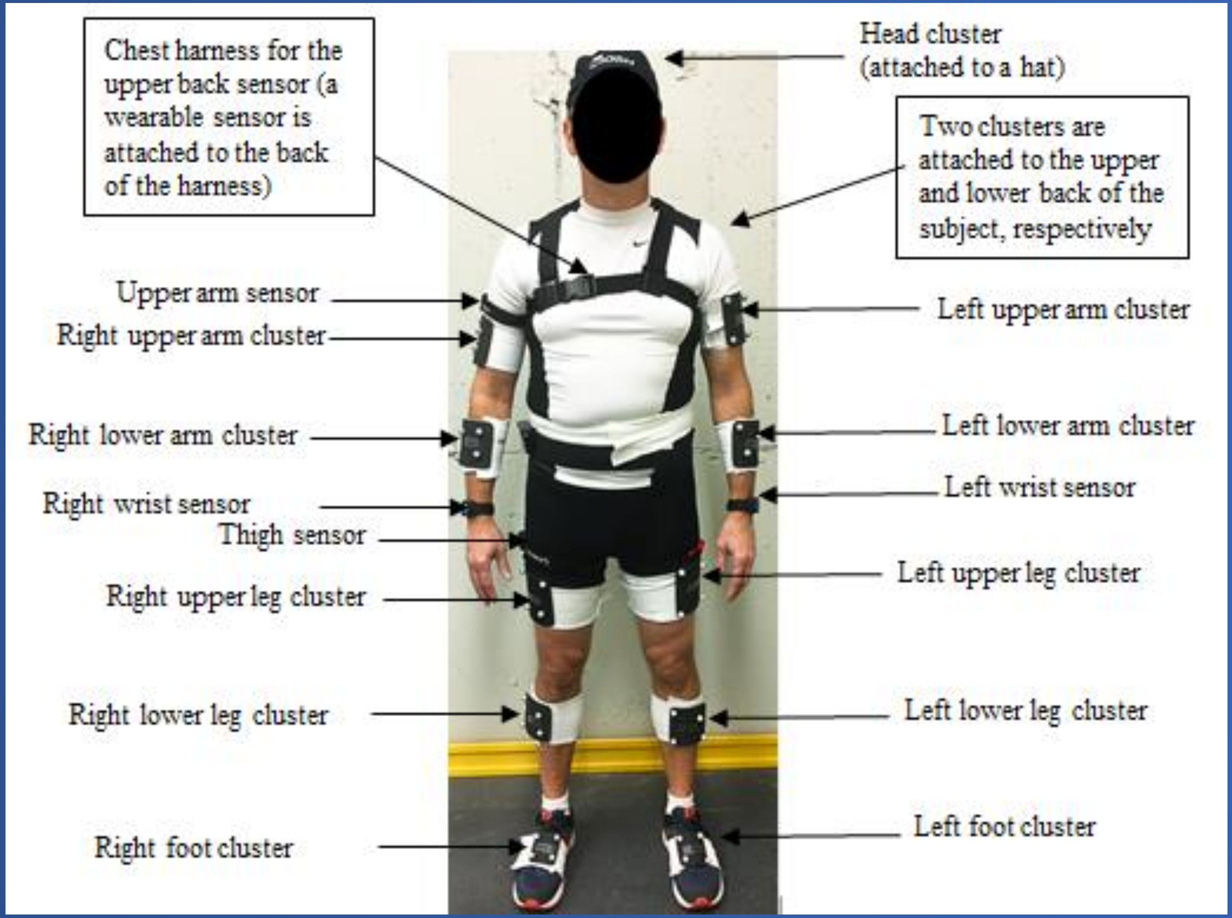
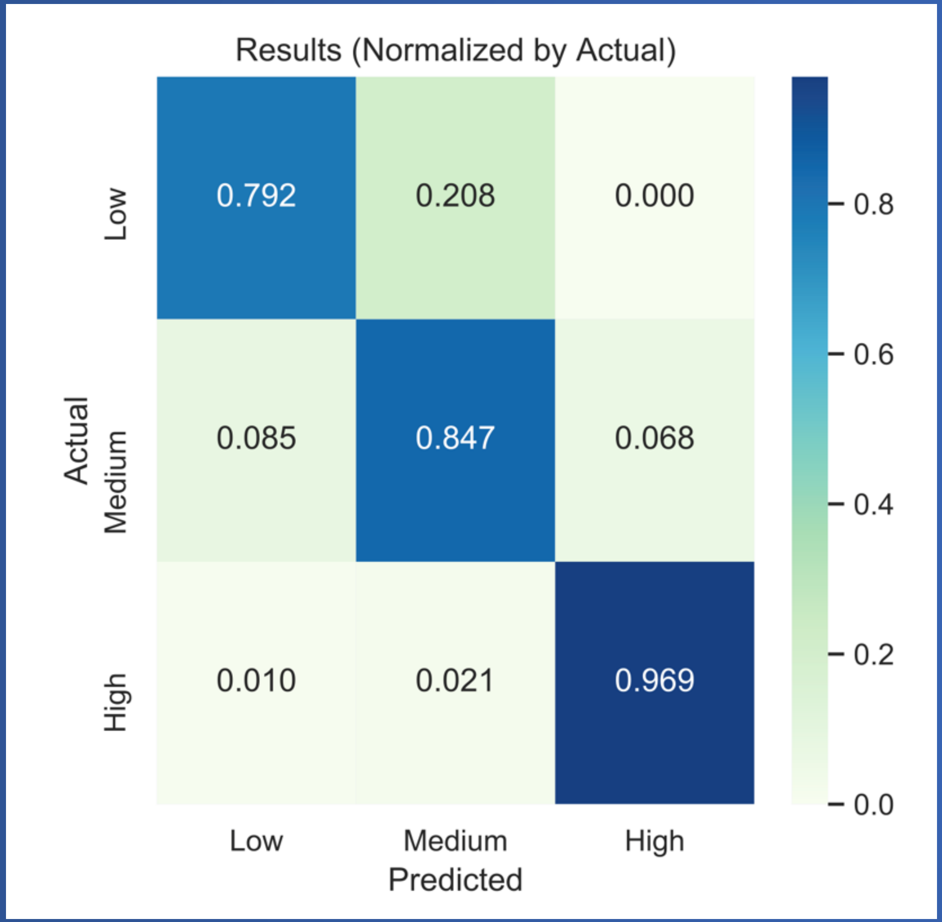
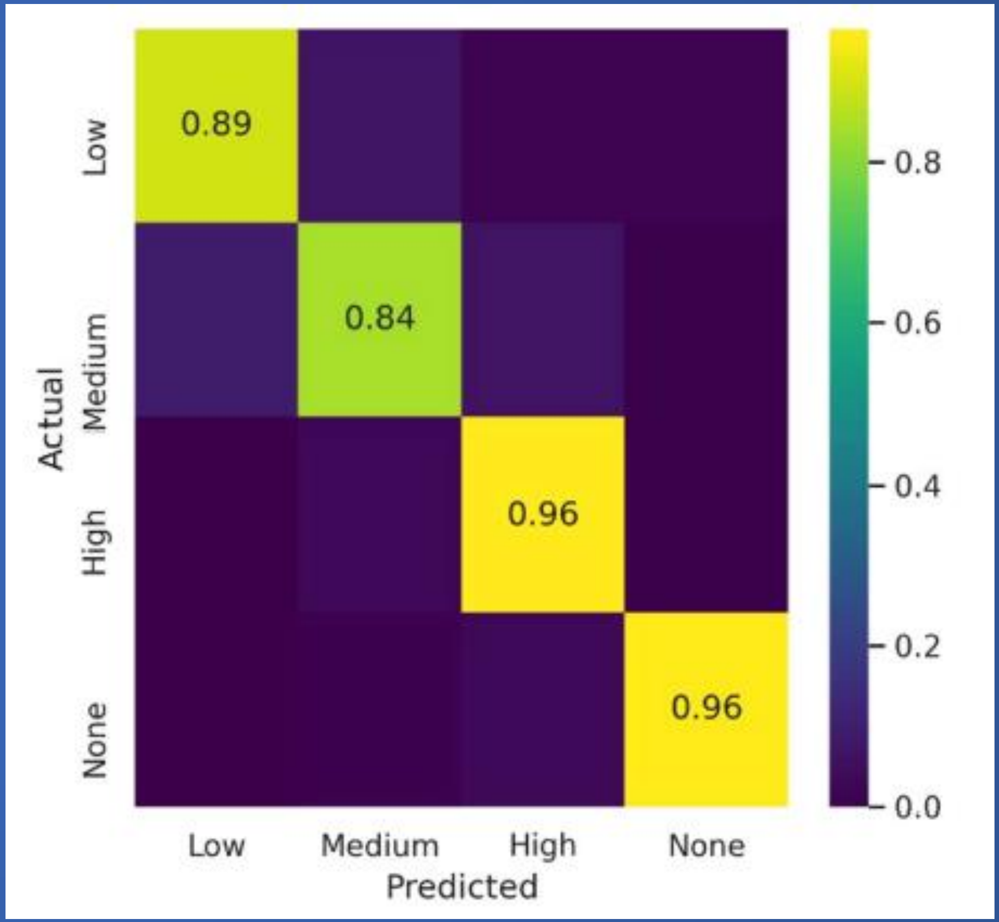


Photo source: NIOSH

Video source: NIOSH

NIOSH Wearable Sensors Project (2/3)



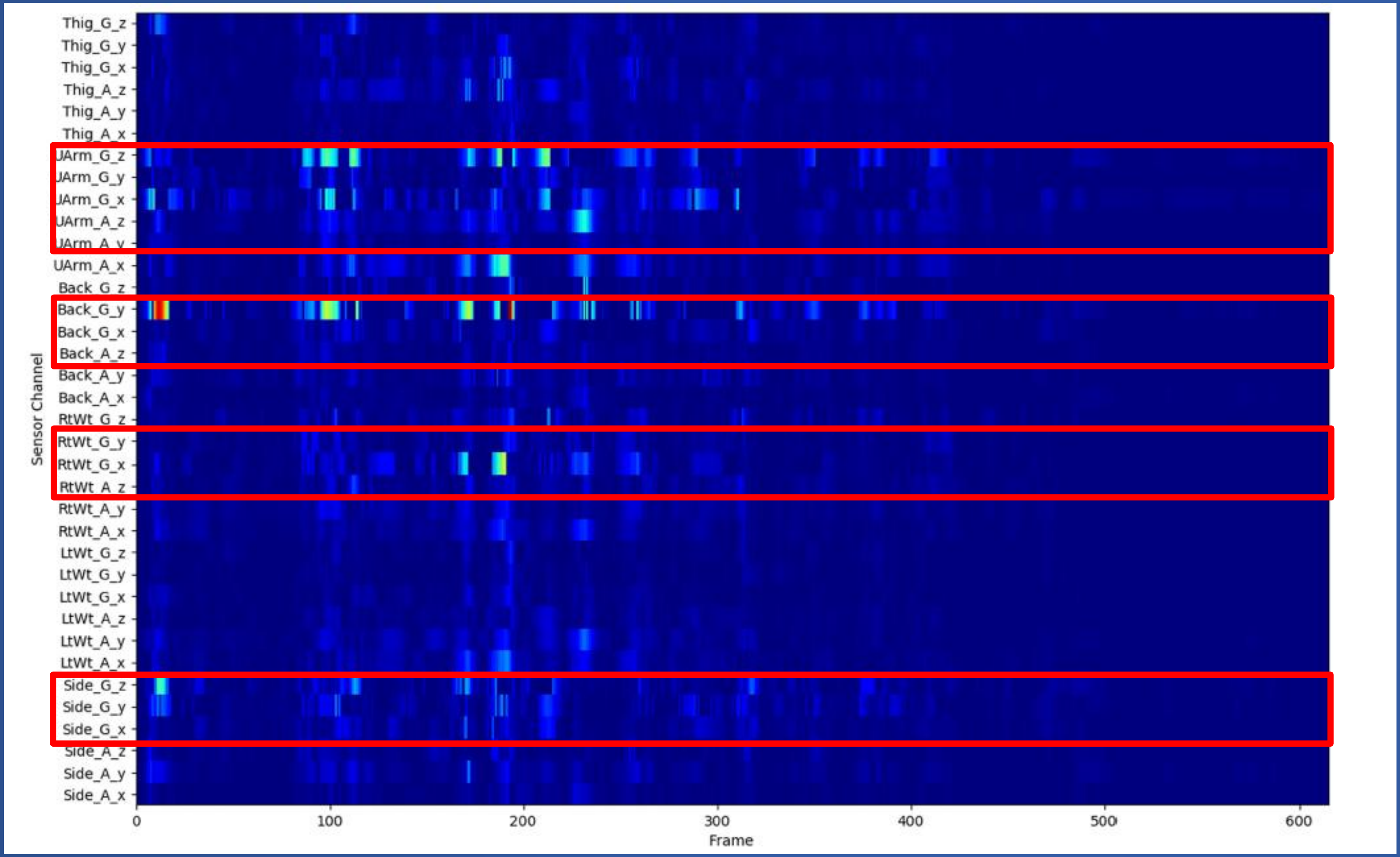


2D CNN Model: Accuracy: 90.6%

CNN +LSTM: Accuracy: 96%

Graphic source: Brennon Thomas, University of Cincinnati

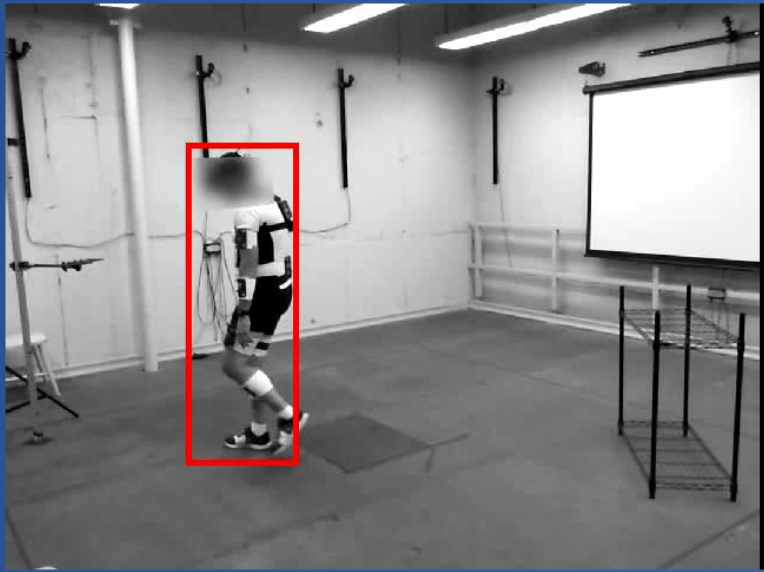
NIOSH Wearable Sensors Project (3/3)

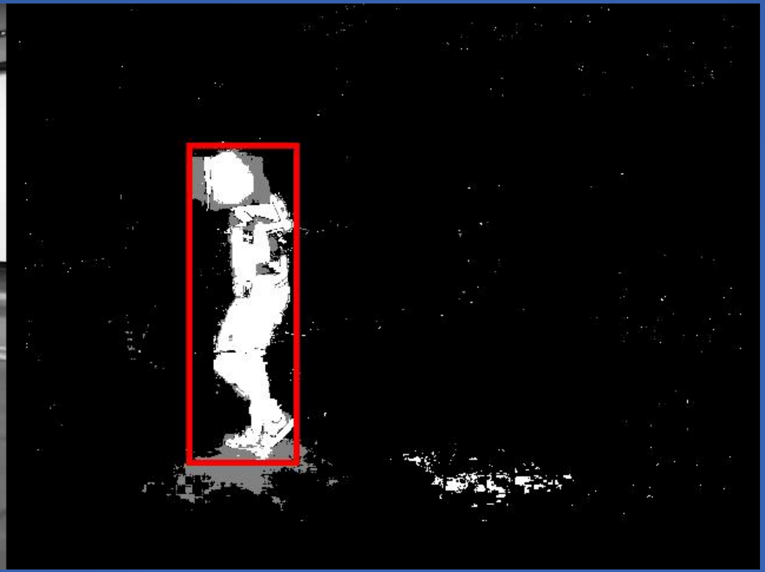


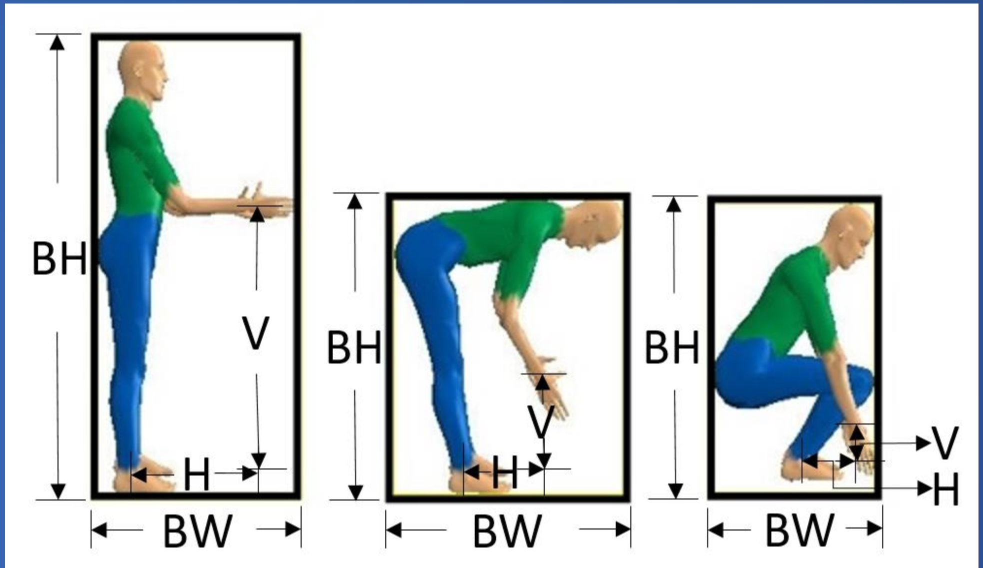
Graphic source: Brennon Thomas, University of Cincinnati for saliency mapping

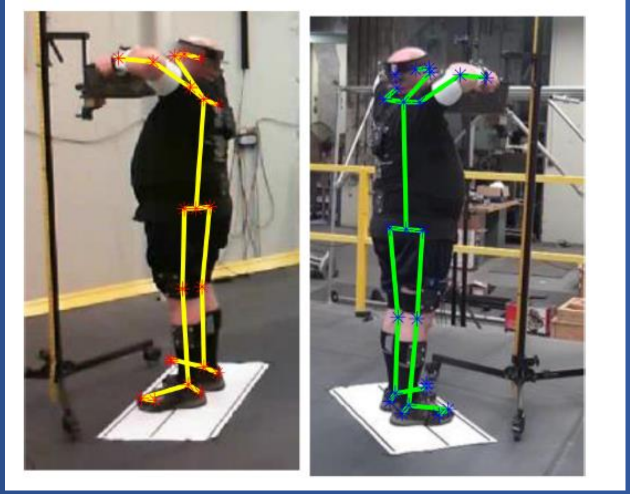
- The classic biomechanical method for estimating the lifting risk zones did not work well using a limited number of motion sensors.
- **The deep neural network models** predicted grouped lifting risk zones with a >90% accuracy.
- The main limitation of the models is the applicability of the information on two-handed lifting tasks without trunk asymmetry in a laboratory setting.
- More data from the field is needed for improving the applicability of the ML models

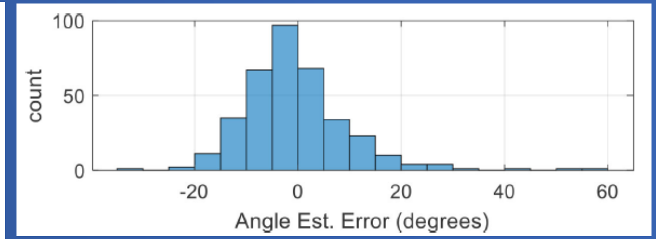
NIOSH-UWM Computer Vision Project (1/2)

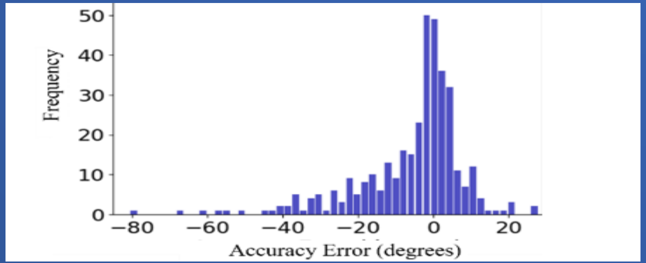








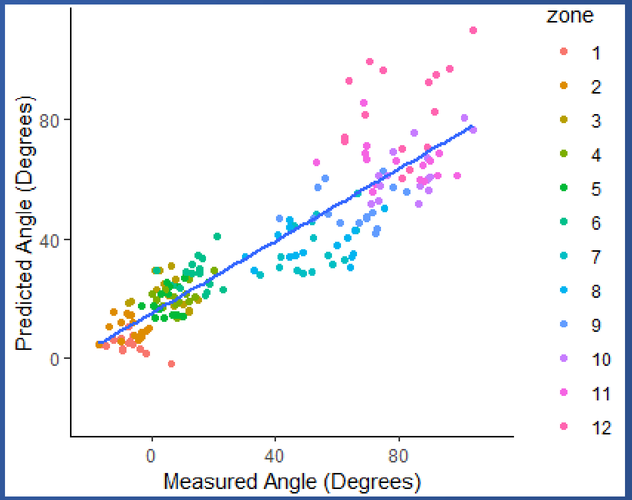




Multi-camera view:
Mean=0.5 °± 10
(2021)

Single-camera view
(2024)

Precision Error	Error Percentiles
15 °	8.6%
30 °	3.1%
45 °	1.1%
60 °	0.3%



All graphic sources: Dr. Robert Radwin, University of Wisconsin-Madison (UWM) and NIOSH

NIOSH-UWM Computer Vision Project (2/2)

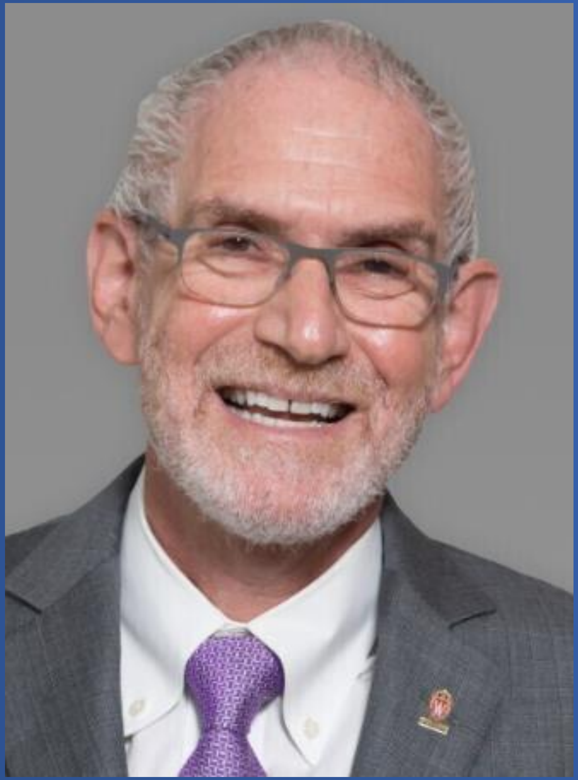
Occupational Ergonomics and Biomechanics Laboratory

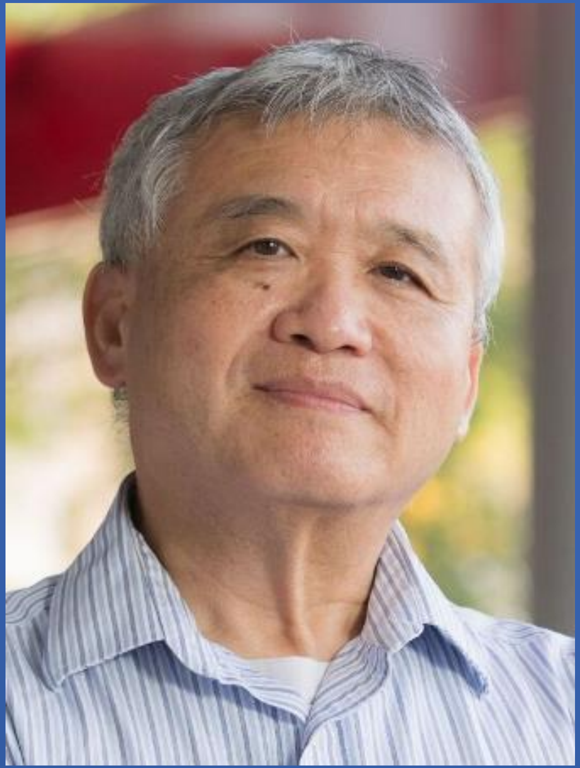
University of Wisconsin-Madison

DEPARTMENT OF HEALTH AND HUMAN SERVICES · USA

CDC Workplace Safety and Health

NIOSH





Graphic and photo sources: University of Wisconsin-Madison and NIOSH

NIOSH-ASTM Exoskeleton Projects

1. To evaluate the longitudinal effects of passive shoulder exoskeletons (PSE) on **company injury records** and associated workers' **compensation costs** for overhead assembly work in the manufacturing setting.
2. To assess **shoulder functions** of PSE users and non-users (control group) at baseline, one-year and two-year follow-ups.
3. To assess a change in the risk of impaired **back function** associated at baseline and one-year follow-up.

Photo and logo credits: PSE Company, ASTM and AExG websites

ASTM CENTER of EXCELLENCE Research to Standards EXO TECHNOLOGY

AExG AUTOMOTIVE EXOSKELETON GROUP

Part 4
National Occupational Research Agenda (NORA)

https://www.cdc.gov/nora/councils/mus

- The NORA Musculoskeletal Health Cross-Sector (MUS) Council
- Objective: Protecting workers' musculoskeletal health.
- Council members (N=33): academia, industry, insurance, safety organizations and labor safety and health advocates.
- Co-chairs: Scott P. Schneider (retired, Laborers' Health and Safety Fund) and Jack Lu (NIOSH)
- Council members (presented by last name in alphabetical order): Benjamin C. Amick III, Kari Babski-Reeves, Brent Baker, Menekse Barim, Deborah Berkowitz, David Brodie, Ann Marie Dale, Woody Dywer, Eva Henry, Robert R. Fox, Sean Gallagher, Richard Gardner, Ninica Howard, Jay, Kapellusch, Jennifer Marcum, William S. Marras, Kelsey L. McCoskey, Blake McGowan, Alysha Meyers, Robert Radwin, Gary Orr, Jessica Ramsey, David M. Rempel, John Rosecrance, Acran Salmen Navarro, Shannon Jones, Penney Stanch, Mike Lampel, Jeffrey E. Vogel, Steve Wurzelbacher, Ben Zavitz

NORA

NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

NATIONAL OCCUPATIONAL RESEARCH AGENDA FOR MUSCULOSKELETAL HEALTH

October 2018

Developed by the NORA Musculoskeletal Health Cross-Sector Council

NORA MUS Research Agenda

Objective 1: Defining the incidence and impact of WMSDs
- Improve surveillance of MSDs
- Quantify understanding of musculoskeletal injuries
- Quantify the human and economic burden of MSDs

Objective 2: Understanding the risk factors for WMSDs
- Improve methods of exposure assessment
- Develop new risk assessment models and methods
- Assess the changing nature of job tasks

Objective 3: Describing the underlying mechanism of MSDs
- Describe the underlying mechanisms of MSDs
- Investigate the role of work-related psychosocial factors on musculoskeletal health

Objective 4: Developing and evaluating interventions to prevent WMSDs and limit disability
- **Develop new interventions**
- Evaluate intervention effectiveness
- Evaluate medical management of MSDs
- Design and evaluate interventions for changing workforce demographics

Objective 5: Disseminating and implementing interventions to prevent WMSDs and limit disability
- Investigate control efforts for the prevention of MSDs
- Disseminate information on knowledge concerning barriers and facilitators for the implementation of preventive measures for MSDs.
- Identify effective means for treating affected workers

Source: Stock photos from iStockphoto.com

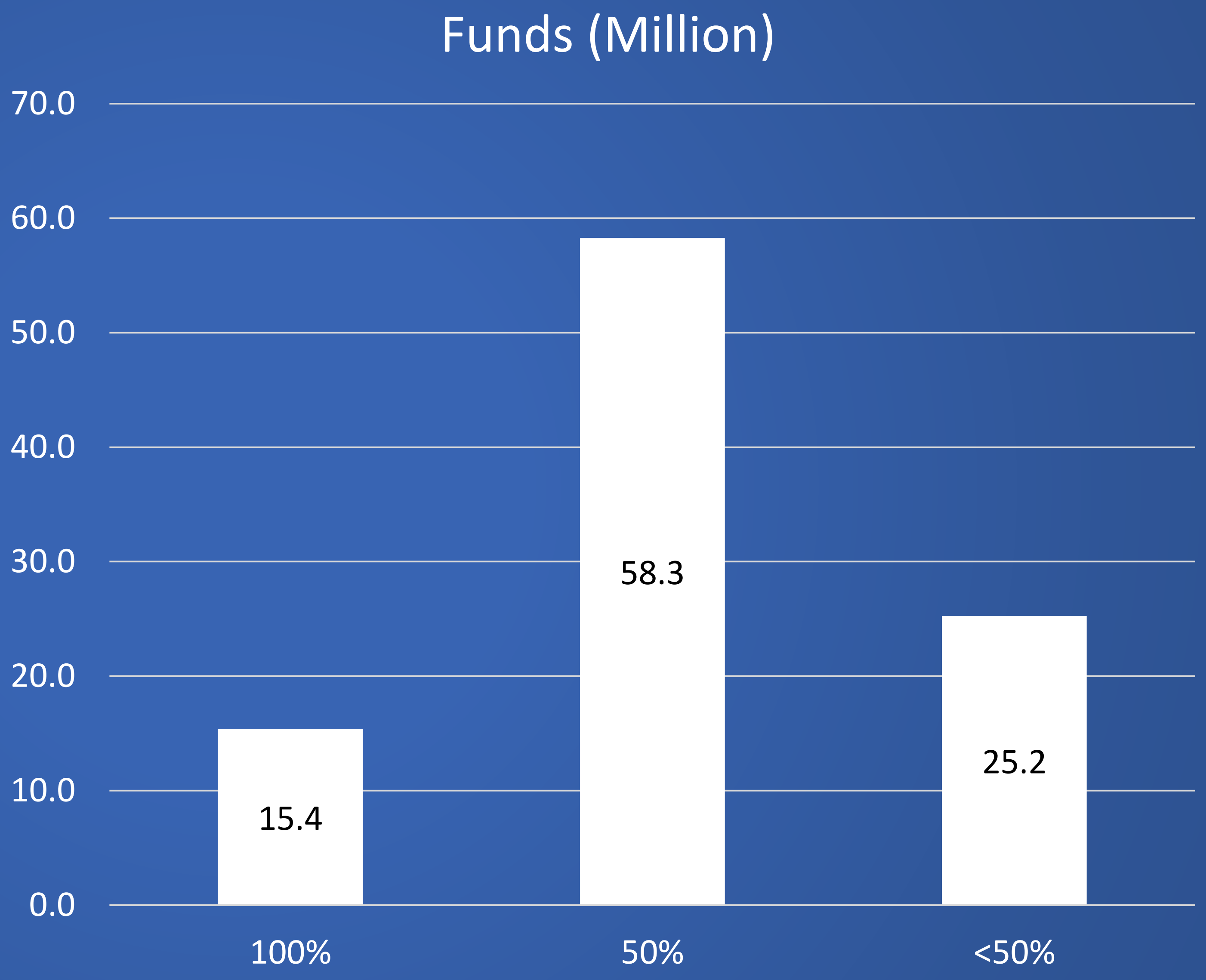
Intersecting Goals of MUS and Sector Programs

	CRC	HLP	IID	MUS	RHP	TIP	HWD
AFF				Intermediate Goal 4.1 Vibration and Repetitive Motion			
CON				Intermediate Goal 4.3 MSDs and Emerging Technologies			
HSA				Intermediate Goal 4.1 Reducing Occupational MSDs			
MNF				Intermediate Goal 4.3 MSDs and Emerging Technologies			
MIN							
OGE							
PSS							
SRV				Intermediate Goal 4.5 Risk Factors for Back Injuries			
TWU				Intermediate Goal 4.3 MSDs and Emerging Technologies			
WRT				Intermediate Goal 4.6 MSDs among Older Workers			

Extramural Projects Funded by NIOSH (2019-2024)

Project End Date	Institution	Title (NIH RePORTER Hyperlink)	Principal Investigator Last Name	Total Funding
5/31/2019	Northeastern University	RANDOMIZED CONTROLLED TRIAL OF WHOLE BODY VIBRATION INTERVENTION IN TRUCK DRIVER	Dennerlein	$2,199,302.00
8/31/2021	Texas A&M Engineering Experiment Station	**NEW BIOMECHANICAL KNOWLEDGE BASE AND DIGITAL DESIGN TOOL FOR PREVENTION OF OCCUPATIONAL NECK DISORDERS**	Zhang	$1,577,536.00
9/29/2020	University of Southern California	SONOGRAPHIC TISSUE MORPHOLOGY IN EARLY STAGE WORK-RELATED MEDIAN NERVE PATHOLOGY	Roll	$2,324,186.00
8/31/2019	University of Pittsburgh	IN VIVO CHANGES IN THE LOWER EXTREMITY JOINTS AND MUSCLES DURING PROLONGED STANDING	Chambers	$323,880.00
8/31/2020	University of Wisconsin-Milwaukee	EXPOSURE-RESPONSE RELATIONSHIPS FOR LOW BACK PAIN FROM POOLED DATA	Kapellusch	$890,068.00
8/31/2020	University of Wisconsin-Madison	**A DIRECT READING VIDEO ASSESSMENT INSTRUMENT FOR REPETITIVE MOTION STRESS**	Radwin	$1,392,819.00
8/31/2020	Washington University	DEVELOPING A GENERAL POPULATION JOB EXPOSURE MATRIX FOR STUDIES OF WORK-RELATED MSD	Evanoff	$987,514.00
8/31/2022	Auburn University	**ADVANCING WORKPLACE SAFETY SURVEILLANCE WITH AMBULATORY INERTIAL SENSORS**	Schall	$324,000.00
8/31/2022	Auburn University	THE LOW BACK CUMULATIVE TRAUMA INDEX:A FATIGUE-FAILURE BASED RISK ASSESSMENT TOOL	Gallagher	$380,968.00
2/28/2021	Herowear, LLC	**SPRING-POWERED EXOSUIT TO PREVENT LOW BACK PAIN DUE TO OVERUSE INJURY**	Yandell	$150,000.00
9/29/2023	University of Iowa	**USING COMPUTER VISION AND DEEP LEARNING TO MEASURE WORKER KINEMATICS**	Fethke	$397,415.00
8/31/2024	Fishing Partnership Health Plan	COMMUNITY-BASED SAFETY TRAINING FOR THE MID-ATLANTIC FISHING INDUSTRY	Bartlett	$731,250.00
8/31/2024	Oregon State University	IMPROVING DUNGENESS CRAB VESSEL EQUIPMENT: AN ERGONOMIC INTERVENTION TO REDUCE RISK FOR MUSCULOSKELETAL INJURIES AND FALLS OVERBOARD	Kim	$671,465.00
8/31/2025	University of Wisconsin-Madison	**A COMPUTER VISION LIFTING MONITOR**	Radwin	$1,552,514.00
8/31/2026	Oregon State University	**EXOSKELETONS FOR COMMERCIAL DUNGENESS CRAB FISHING TO REDUCE MUSCULOSKELETAL INJURIES**	Kim	$710,881.00
8/31/2024	University of Illinois-Chicago	**COLLABORATIVE RESEARCH: NRI: INT: CUSTOMIZABLE LOWER-LIMB WEARABLE ROBOT USING SOFT-WEARABLE SENSOR TO ASSIST OCCUPATIONAL WORKER**	Kim	$749,608.00

Funds for extramural projects (2019-2024) by MUS relevance

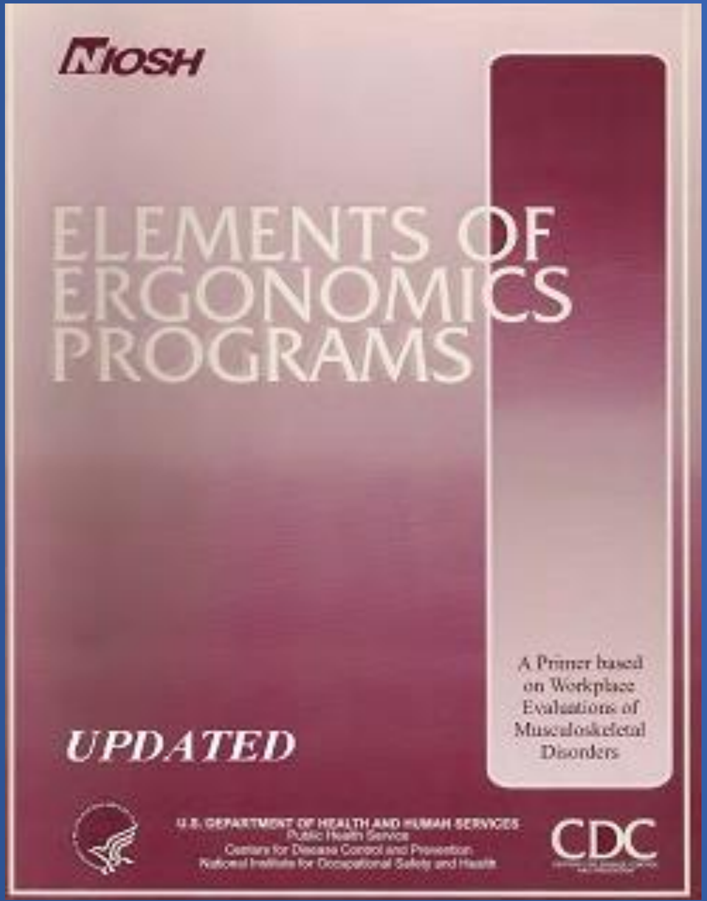


Source: NIOSH Office of Extramural Program (https://www.cdc.gov/niosh/oep/researchgrants.html)

NIOSH Intramural MUS Projects (FY19-23)

	PI (s)	Title of Study
1	Daniel Welcome and Ren Dong	Development of Exoskeleton-Assisted Vibration Mitigation Techniques for Riveters
2	Steve Wurzelbacher and Libby Moore	Intervention and exposure assessment studies
3	Alysha Meyers	Claims analyses for MSD
4	Brian Chin	Chiropractic effectiveness and opioids study on low back problems in construction
5	Christopher Pan	Evaluation of Exoskeletons for Construction Workers on Elevated Work Platforms
6	John Wu and Scott Breloff	Effects of Footwear on Roofers' Slip Potential and Musculoskeletal Disorder Risk
7	Liying Zheng	Application of Exoskeletons for Safe Patient Handling—a Feasibility Study
8	Brent Baker	Molecular Potentiation of the Aging Phenotype through Repeated Physical Exposures
9	Mahiyar Nasarewanji and Patrick Dempsey	Prevention of manual materials handling injuries in mining
10	Samantha Case and Laura Syron	Preventing Nonfatal Injuries among Seafood Harvesters and Processors
11	Menekse Barim and Scott Breloff	Effects of Back Assist Exoskeletons in Manual Handling in the WRT Sector
12	Jack Lu and Menekse Barim	Evaluation of long-term health effects of passive shoulder exoskeletons in the manufacturing sector
13	Menekse Barim and Jack Lu	Workplace psychosocial stressors and MSD among healthcare professionals
14	Kristine Krajnak and Ren Dong	Finger Biological Responses to Vibration & Pressure Using Rat Tail Model
15	Erik Rader	Reexamination of the NIOSH Lifting Equation Calculator in a Research Mouse Model
16	Sherry Xu and Ren Dong	Technology Development and Evaluation for Controlling Hand-Arm Vibration Exposure
17	John Wu	Biomechanical Evaluation of Knee Savers for Reducing Joint Load During Squatting

Part 5
Elements of Ergonomics Programs

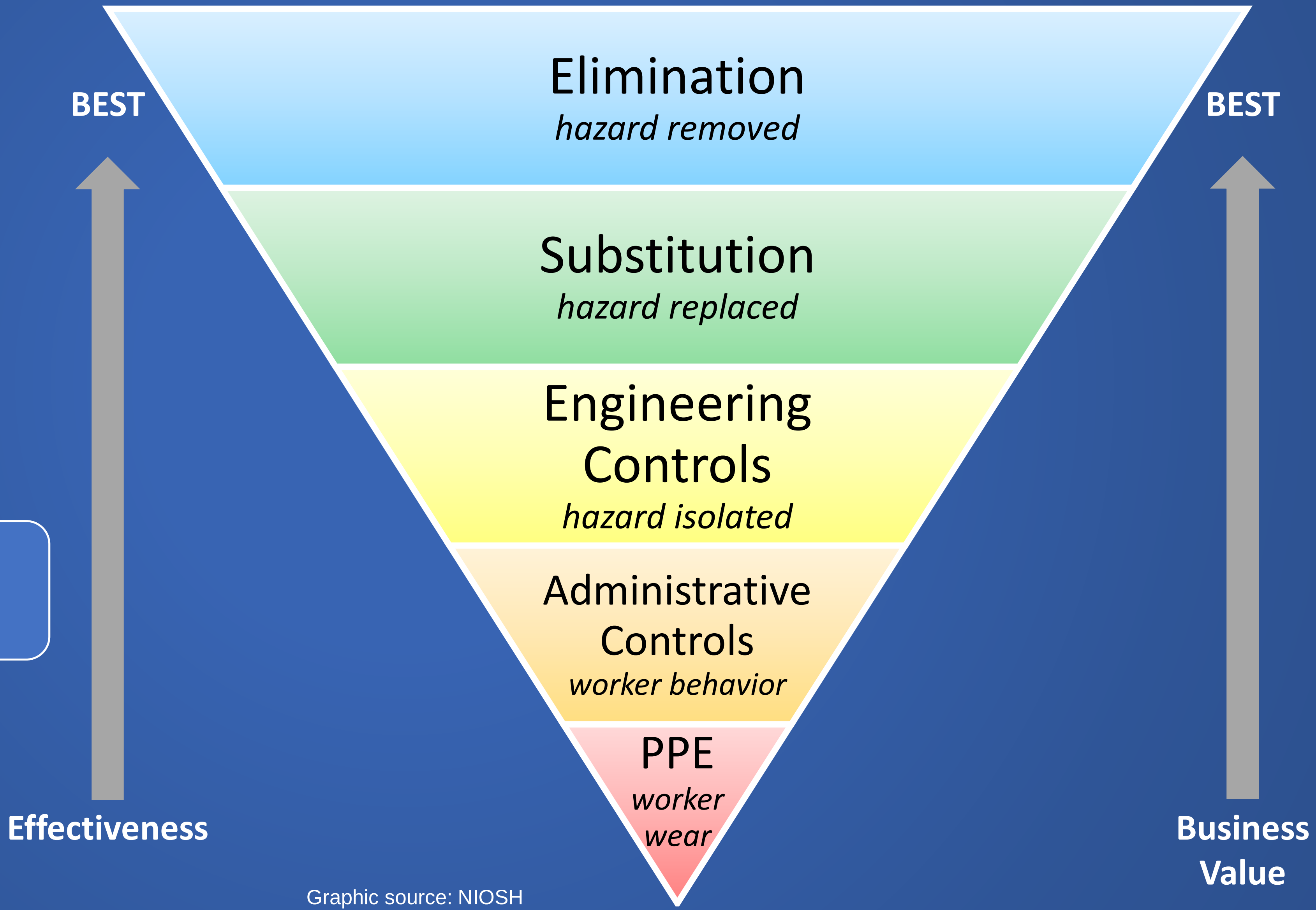


1. Identify risk factors
2. Train management and workers
3. Collect health and med records
4. Implement program
5. Evaluate program
6. Promote recovery and health
7. Maintain management commitment and worker engagement

PtD and Hierarchy of Control

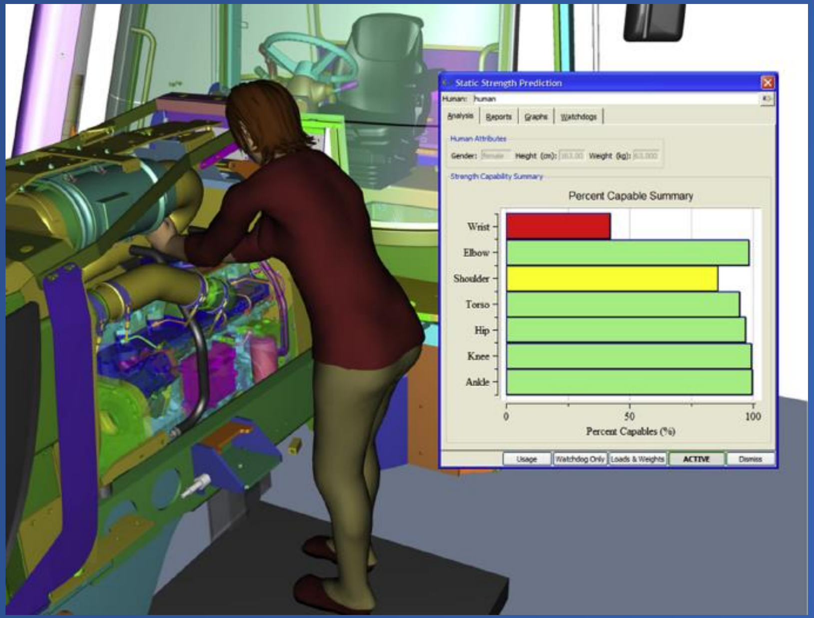
PtD
Prevention through Design

Graphics credit: NIOSH

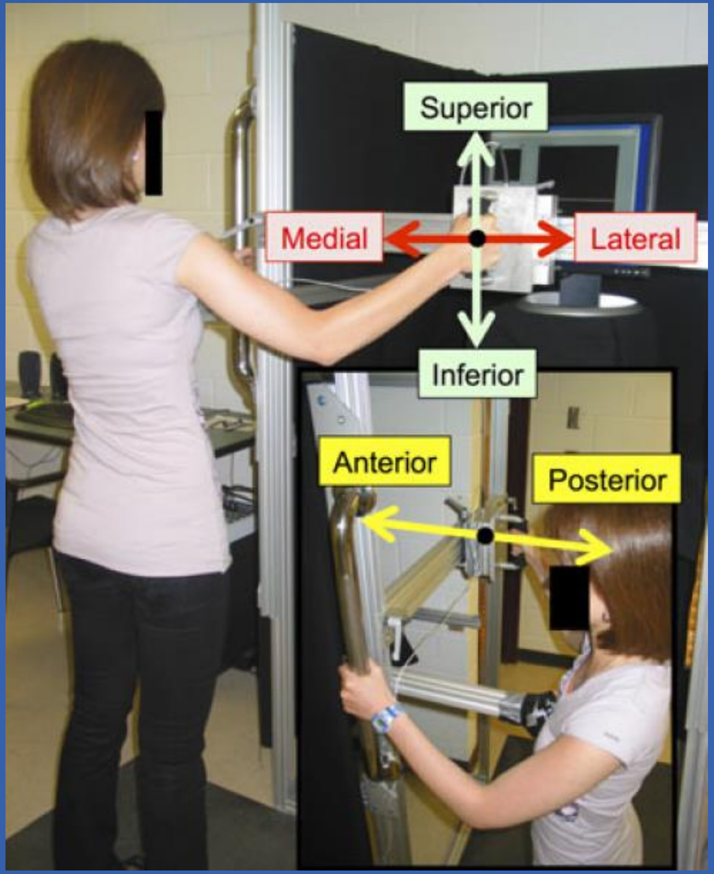


Graphic source: NIOSH

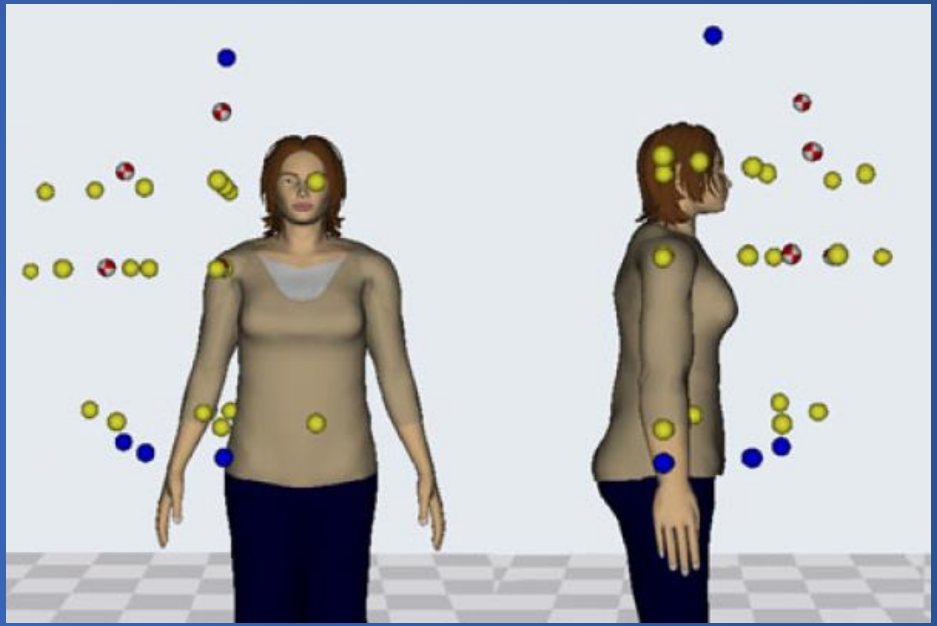
Innovative Technologies (1/6)



Digital Human modeling (DHM).[1]

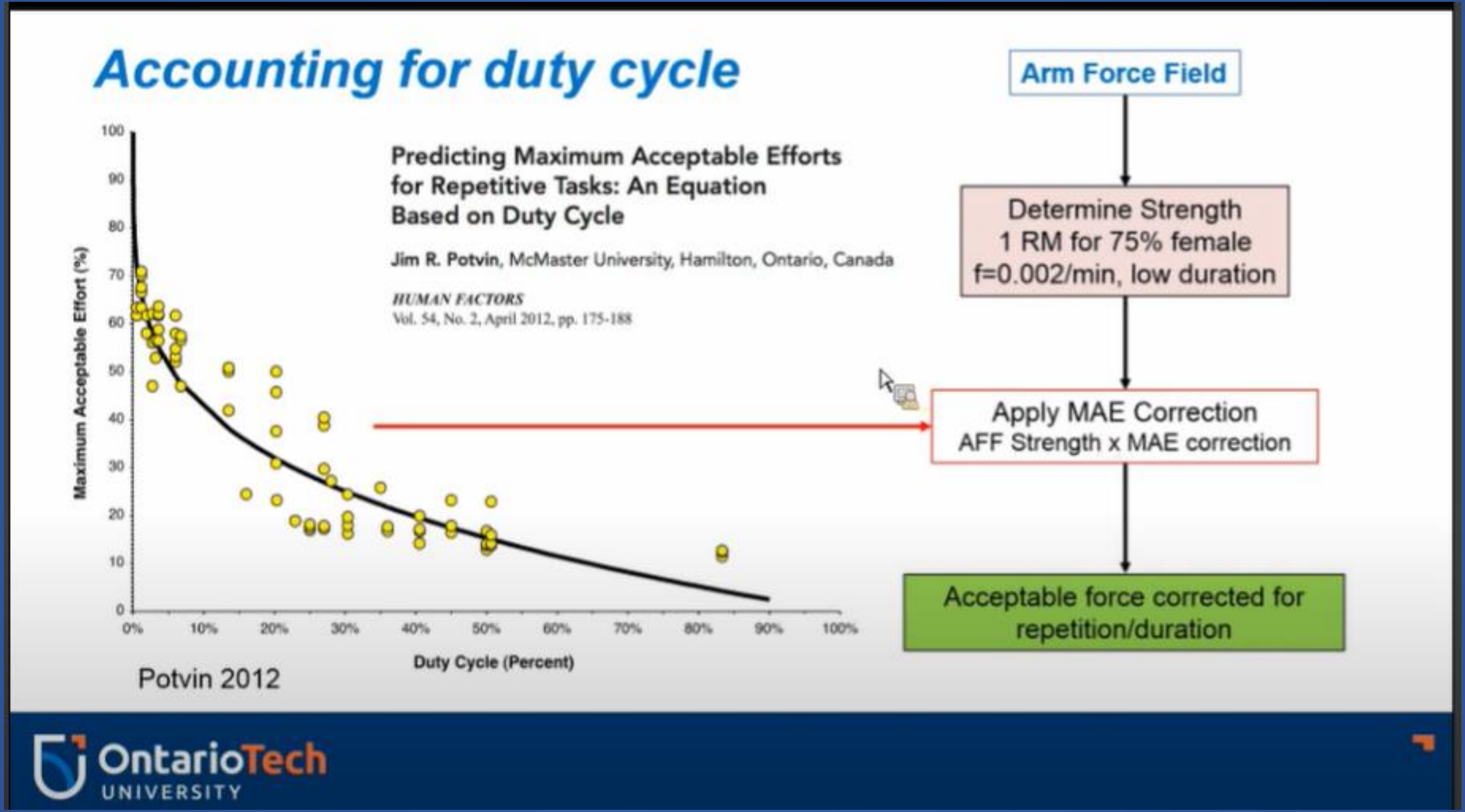


Arm Force Field (AFF).[2]



Sources: 1. Raschgke and Cprt. Siemens Jack. Ch3 in Book “DHM and Posturography” pp. 35-48 (2019). 2. La Delfa et al. Equations to predict female manual arm strength based on hand location relative to the shoulder. Ergonomics. 57 (2): 254-261 (2014)

Innovative Technologies (2/6)



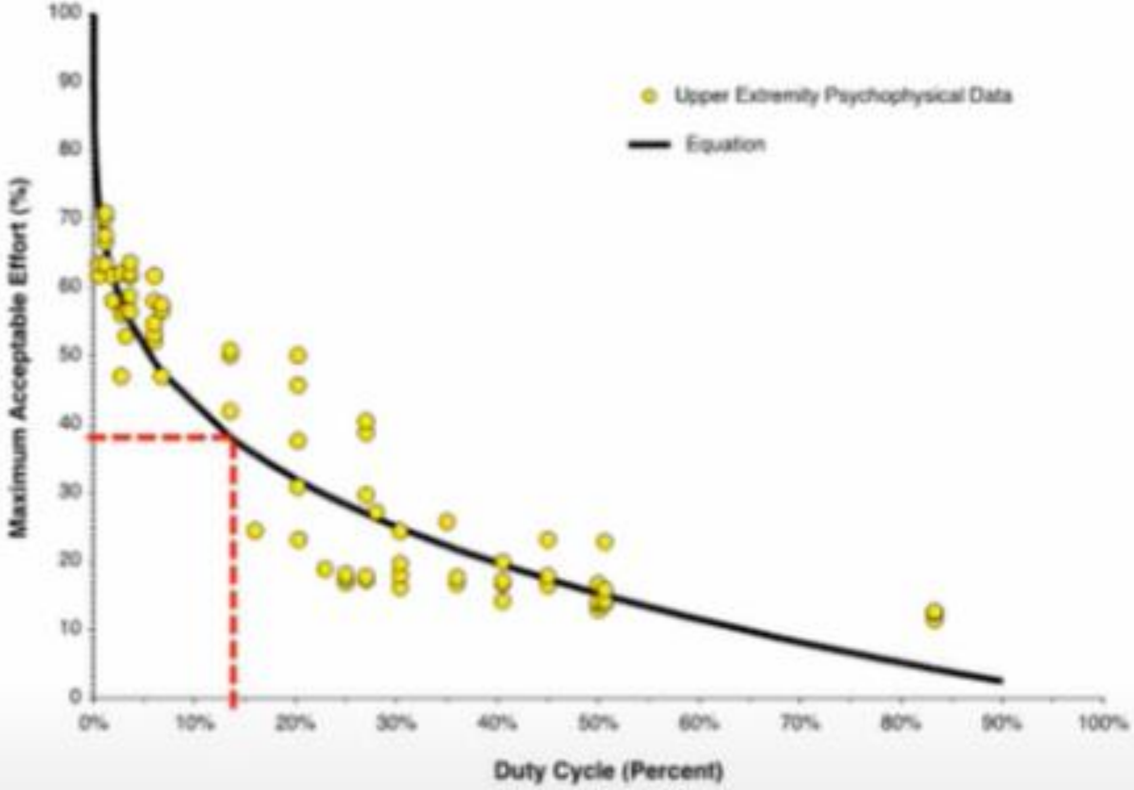
Source: Slides provide by Nick La Delfa

Innovative Technologies (3/6)

Accounting for duty cycle

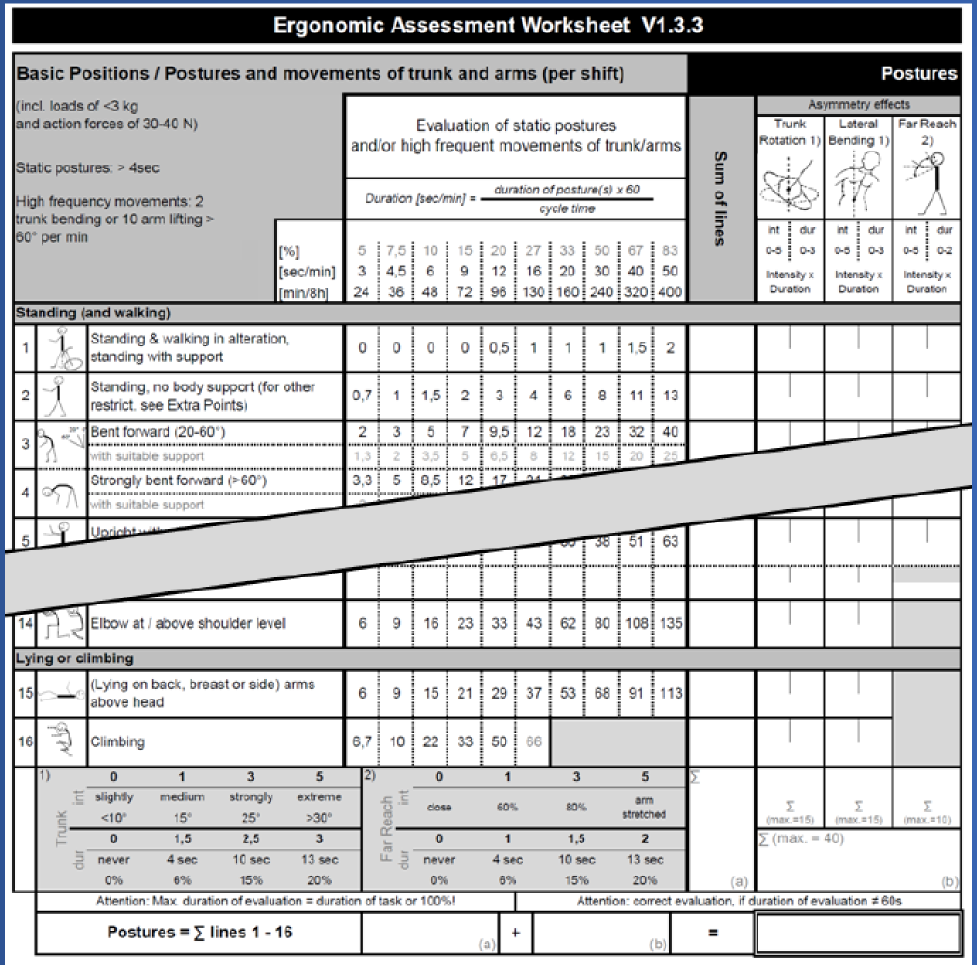
- What if task has following parameters:
  - Frequency = 12 efforts/min
  - Duration effort = 0.7 s

- DC = (12 x 0.7)/60 = 0.14 (14%)
- MAE = 1 - $(0.14 - 0.000035)^{0.24}$ = 0.38 (38%)



Source: Slides provide by Nick La Delfa

Innovative Technologies (4/6)



Methods-Time Measurement
Ergonomic Assessment Worksheet
MTM-EAWS.1

Patient lifting equipment.2

1. Sachaub et al. EAWS. Int J Human Factors Modeling and Simulation Vol 3. pp. 414. (2012). 2. Getty Image on NIOSH document.

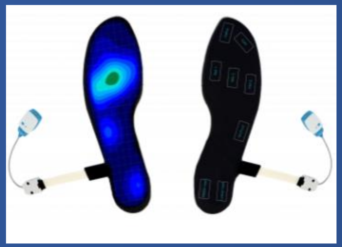
Innovative Technologies (5/6)

Computer vision.1

Wearable motion sensors.2

Industrial exoskeletons.3

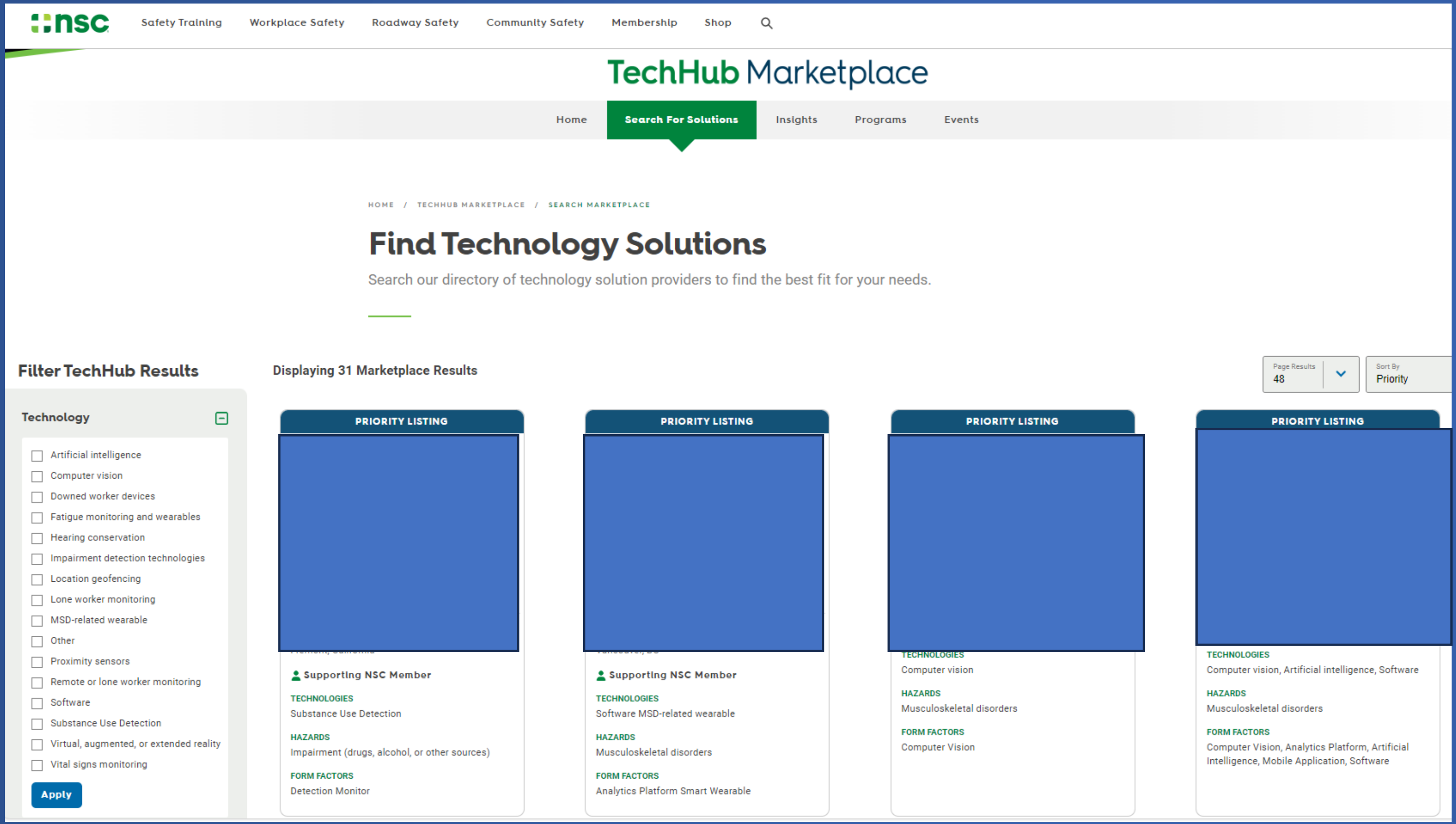
Tactile gloves.4

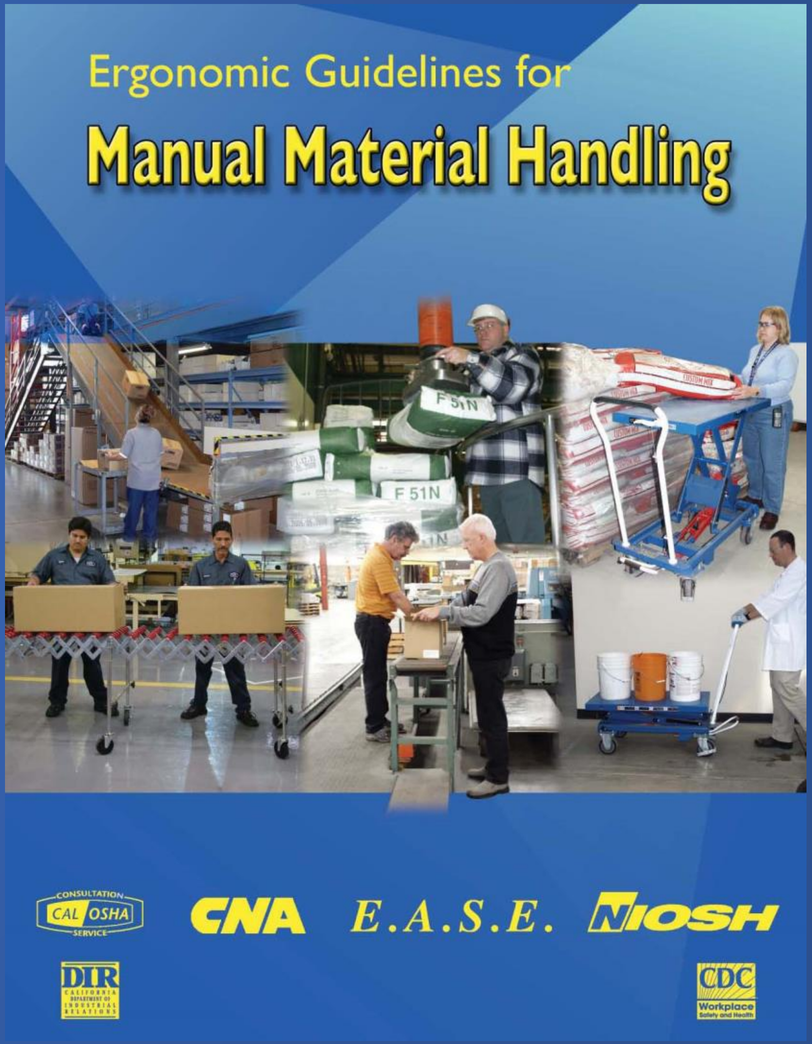


Pressure insert.5

Sources: 1.2. NIOSH. 3. Permission to use by Chris Reid, Boeing company, 4.Permission by the Pressure Profile System. 5. https://www.noraxon.com/our-products/insole-smartlead/

Innovative Technologies (6/6)





https://www.nsc.org/techhub/search-for-solutions

https://og.mhi.org/ease

Psychosocial Well-being

- Multilevel approach:
  - Organization (Primary)
  - Workstation (Secondary)
  - Individual (Tertiary)

- Understand work design
- Commit to change
- Integrate risk information
- Engage workers in design
- Support workers' effort
- Participatory ergo program

Photo Credit: Purchased Getty Image.

7. Maintain management commitment and worker engagement

Future of Ergonomics

- Future of jobs: mentally demanding and manually variable in response to robotics and automation of manual jobs.
- Future of ergonomic risk assessments: shift from manual to automatic identification of risk factors based on AI technologies
- Future MSD prevention strategies may focus on the integration of physical, psychosocial and personal risk information (a holistic approach)

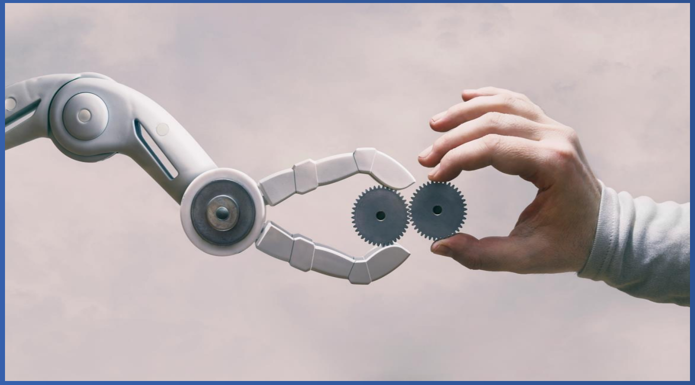


Photo Credit: Purchased Getty Image.

Key Takeaway Messages

- Establish OSH as the core business
- Implement ergonomics and psychosocial well-being programs
- Prevent MSDs through design
- Engage workers for solutions
- Consider innovative technologies, such as AI

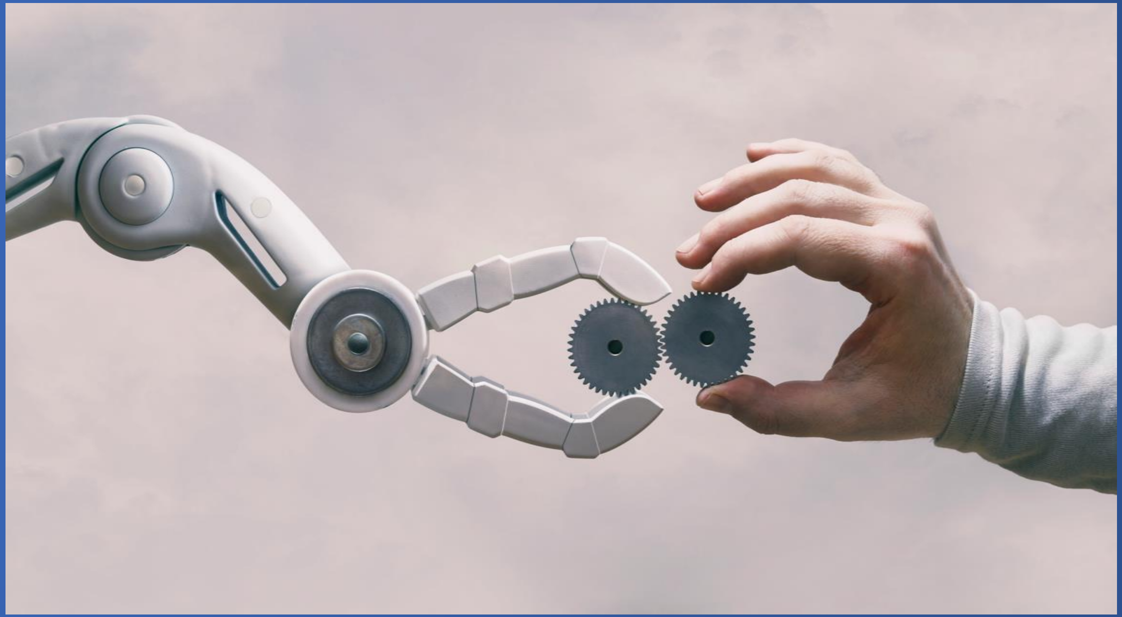


Photo Credit: Purchased Getty Image.

Questions?

Modern Occupational Diseases Diagnosis, 2022, 287-353 287

CHAPTER 14

Work-related Musculoskeletal Disorders

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[3] *General Motors Company, Global Ergonomics Lab, Warren, Michigan, USA (Retired)*

(7) (PDF) Work-related Musculoskeletal Disorders (researchgate.net)

Or

https://www.researchgate.net/publication/364133749_Workrelated_Musculoskeletal_Disorders

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