– The Revised Strain Index –
A DUE Physical Exposure Model for Complex Tasks with Job Rotation

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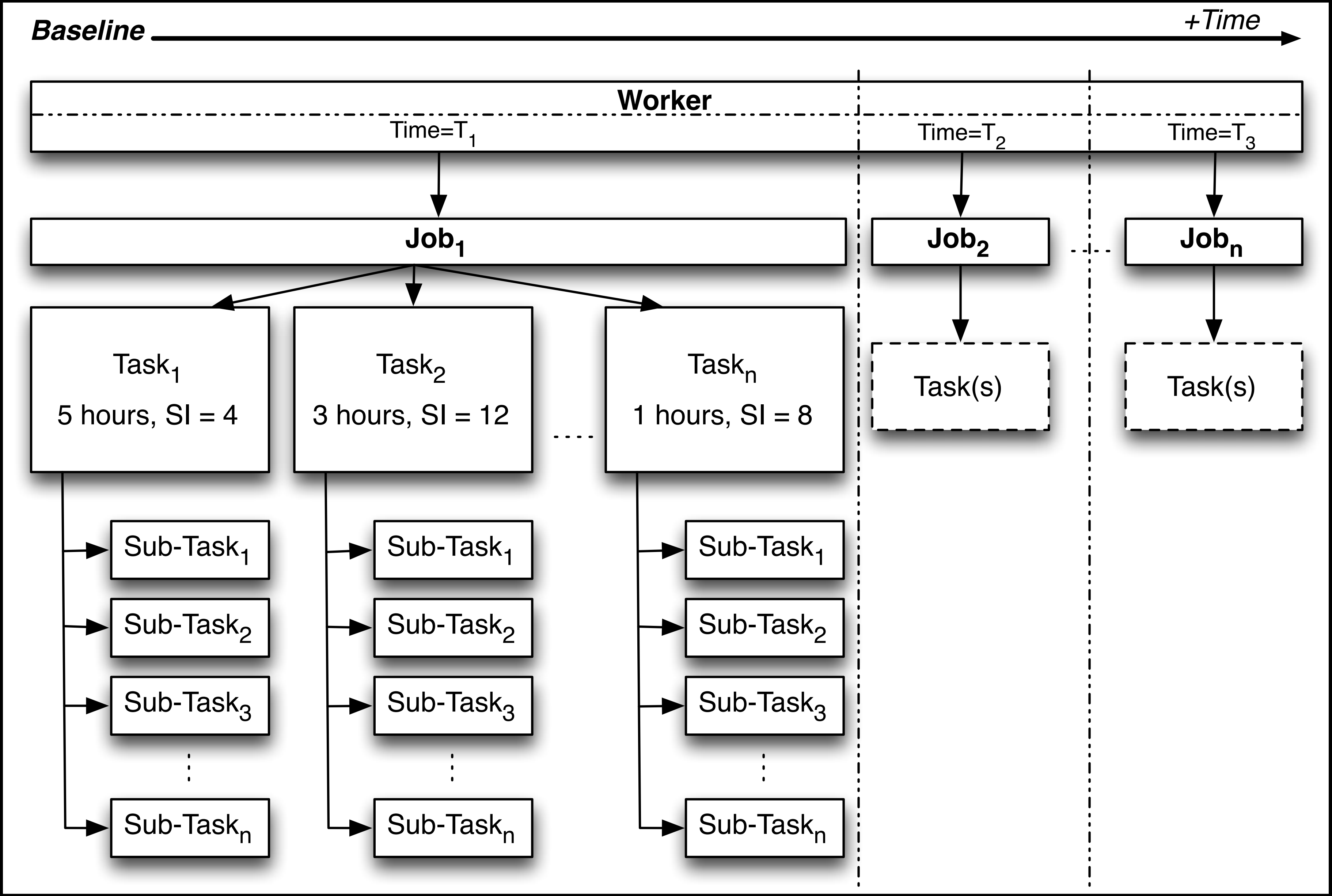
Background

- Occupational physical exposures typically consist of:
  - biomechanical stressors, and
  - physiological stressors
- Designing jobs by minimizing certain factors (eg repetition), or considering only one of these disciplines can mislead us about what is safe and what is not.
- Physical exposure analysis methods consider biomechanics and physiology in concert and thus are potentially useful design tools.

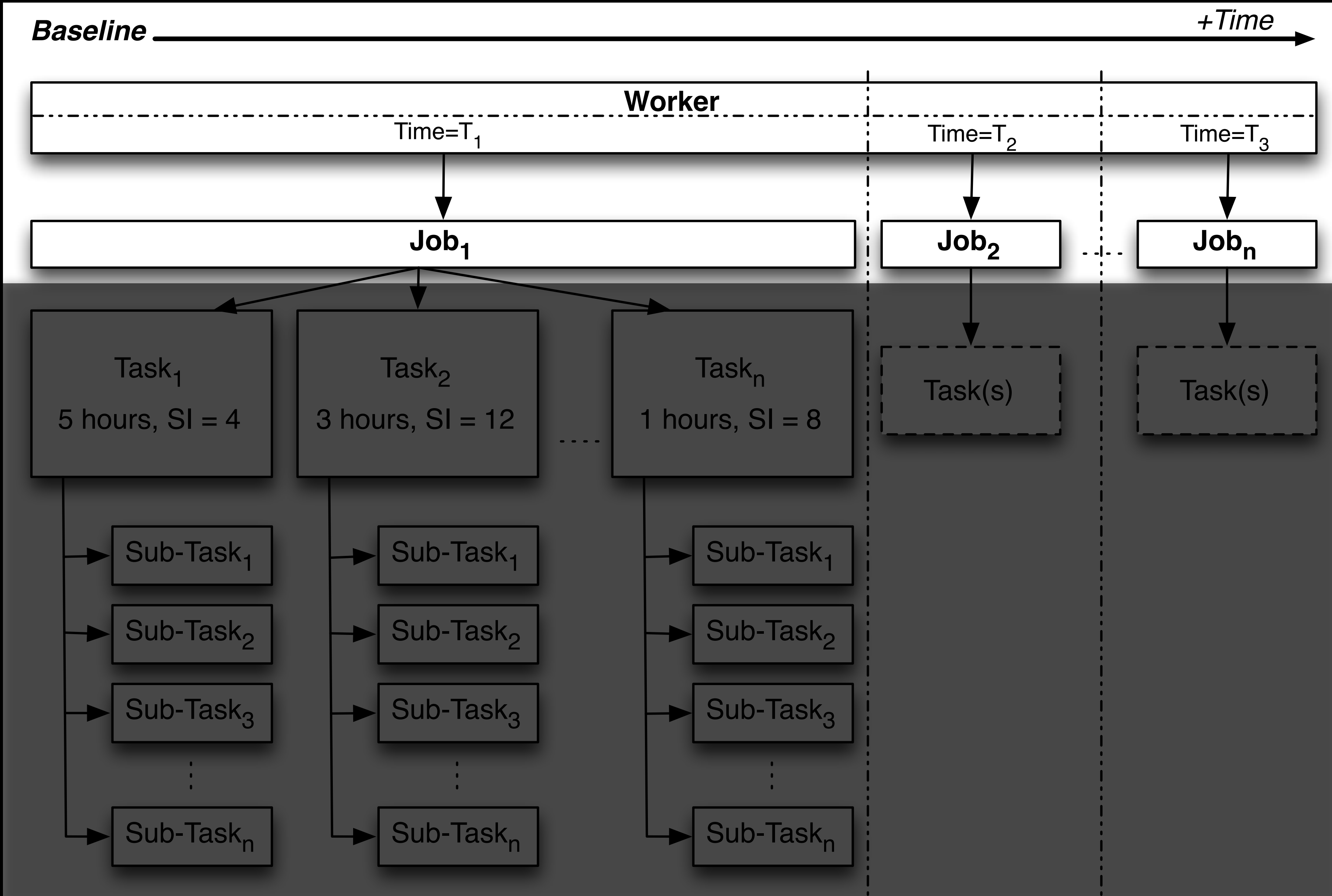
The 1995 Moore & Garg Strain Index

Background

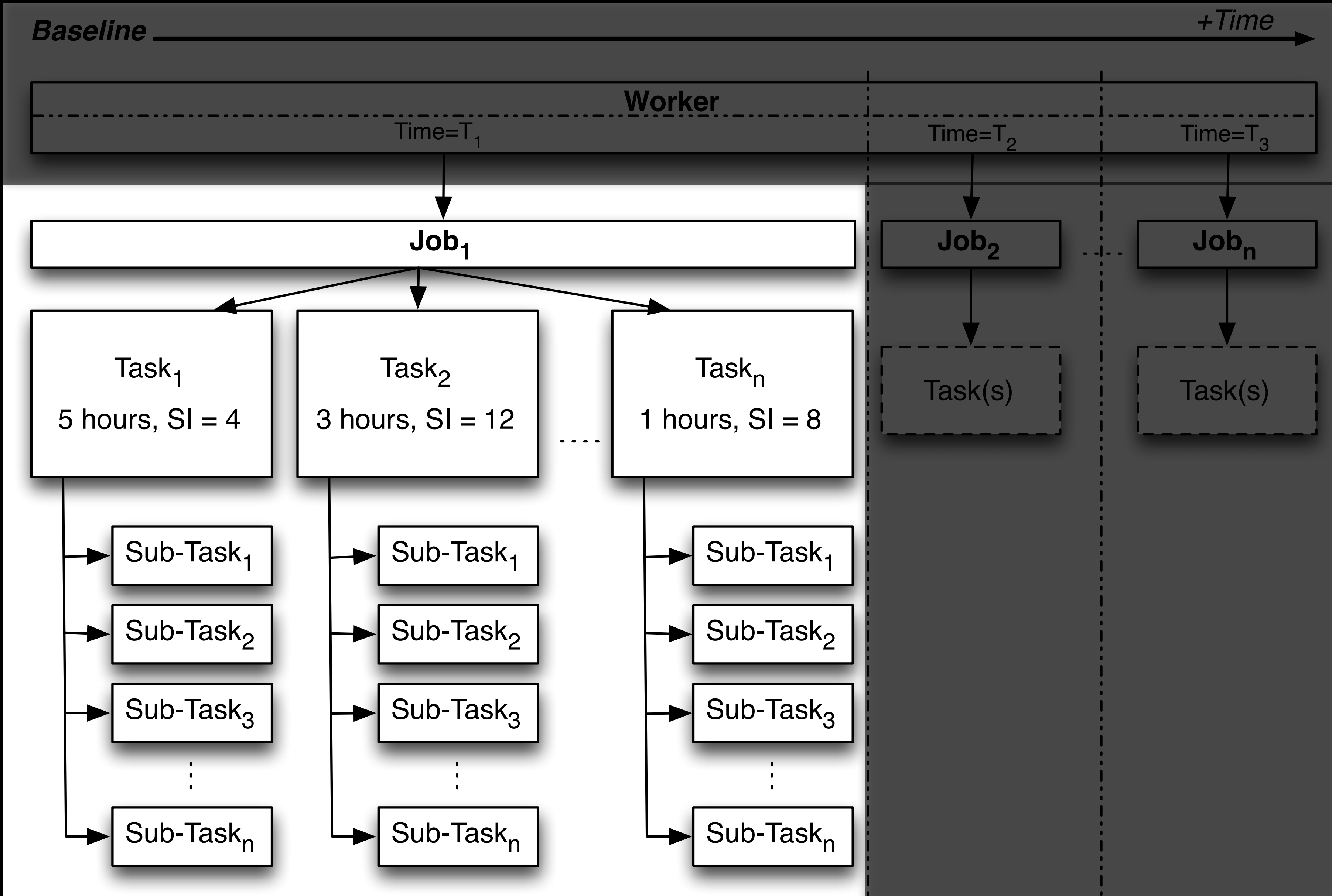
- Semi-quantitative tool for quantifying physical exposures from hand-intensive work
- Based upon principles of:
  - Biomechanics,
  - Physiology, and
  - Epidemiology
- Several epidemiological studies have shown association between the SI score, and prevalence and incidence of distal upper limb MSDs such as CTS.



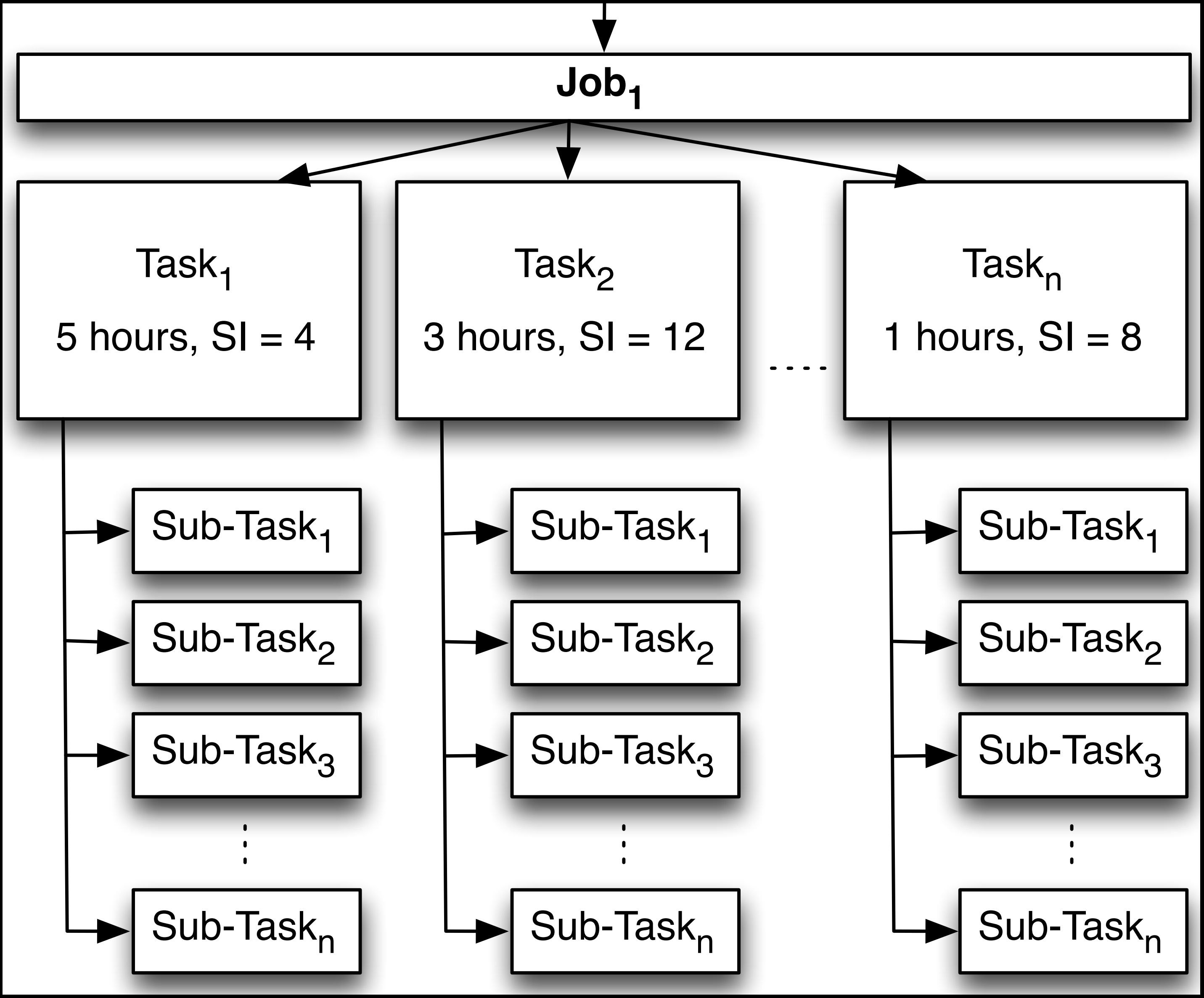
Physical Exposure Map



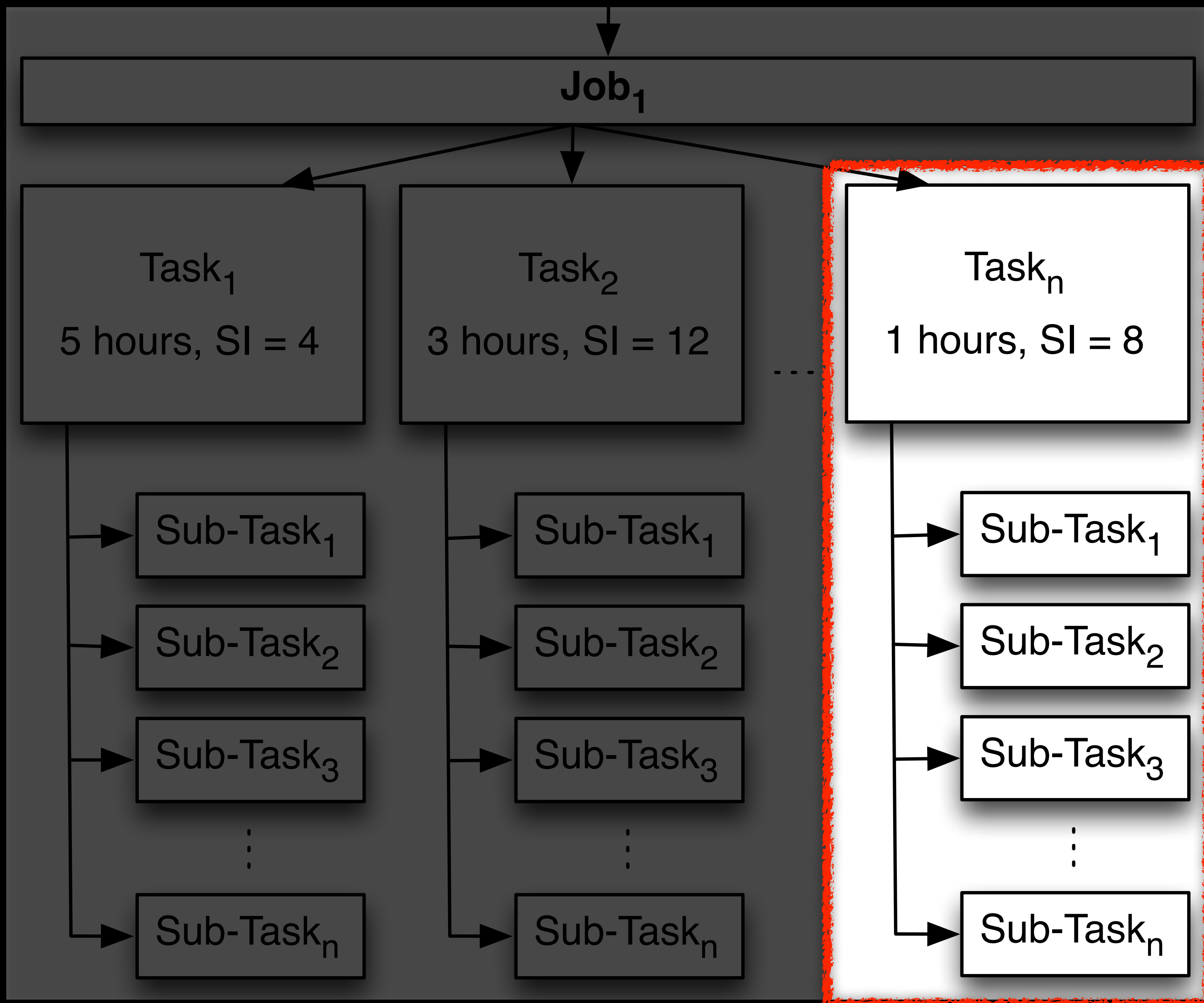
Physical Exposure Map



Physical Exposure Map



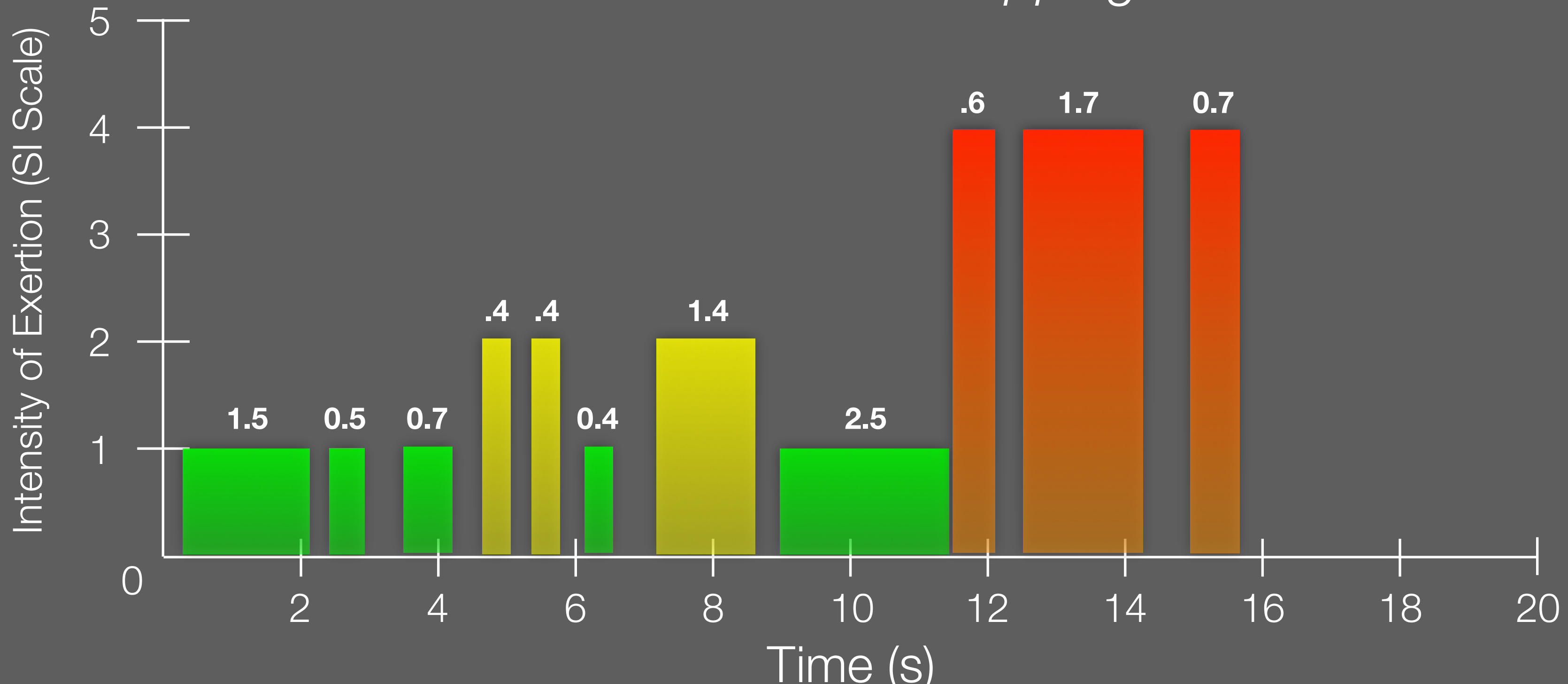
Physical Exposure Map



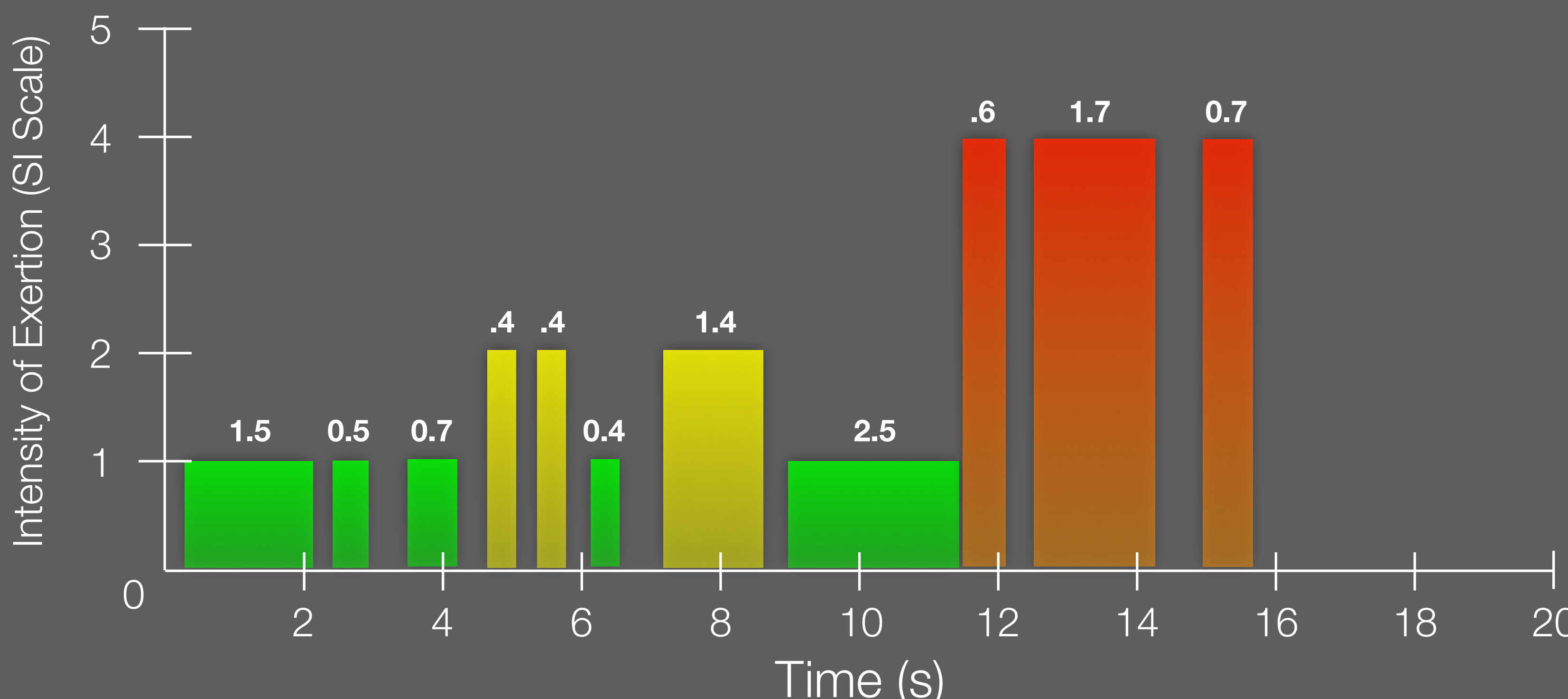
Physical Exposure Map

Example Complex Task

Stripping Shielded Cable

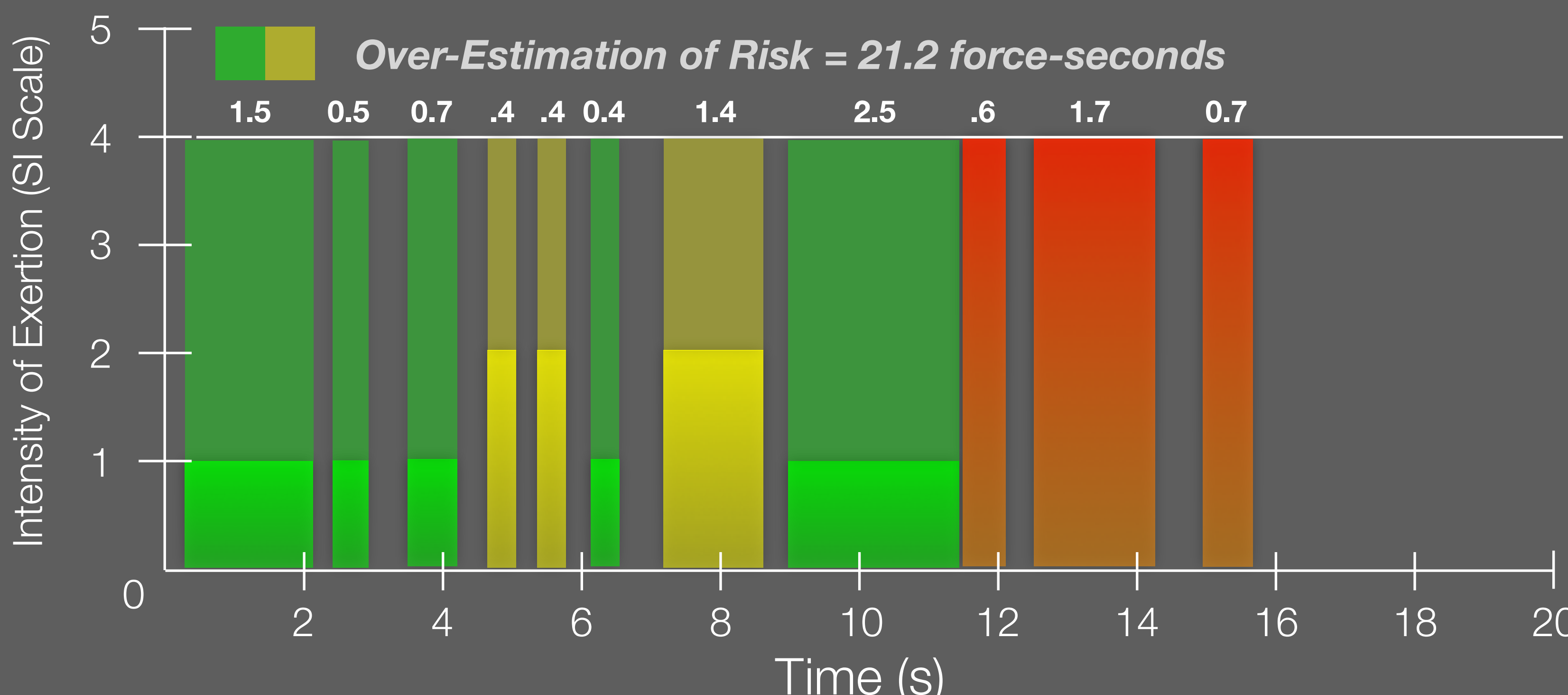


Sub-Task	Intensity of Effort	Efforts per Minute	% Duration of Cycle
(green)	1	15/min	28%
(yellow)	2	9/min	11%
(red)	4	9/min	15%
Combined	**??**	**33/min**	**54%**



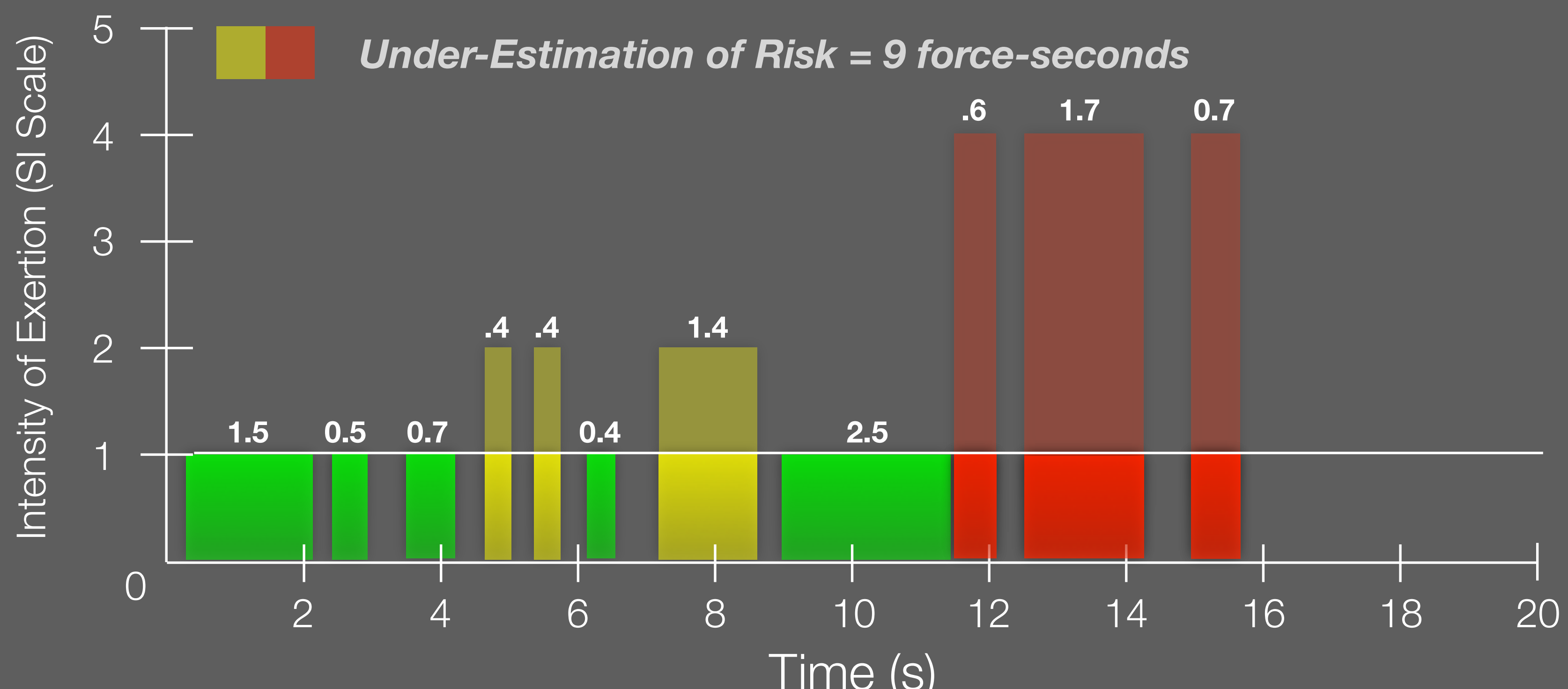
Sub-Tasks	Intensity of Effort	Efforts per Minute	% Duration of Cycle
Combined	Max = 4	33/min	54%

IM		EM		DM		PM		SM		HM		SI
9	x	3	x	2	x	1	x	1	x	1	=	54



Sub-Tasks	Intensity of Effort	Efforts per Minute	% Duration of Cycle
Combined	Typical = 1	33/min	54%

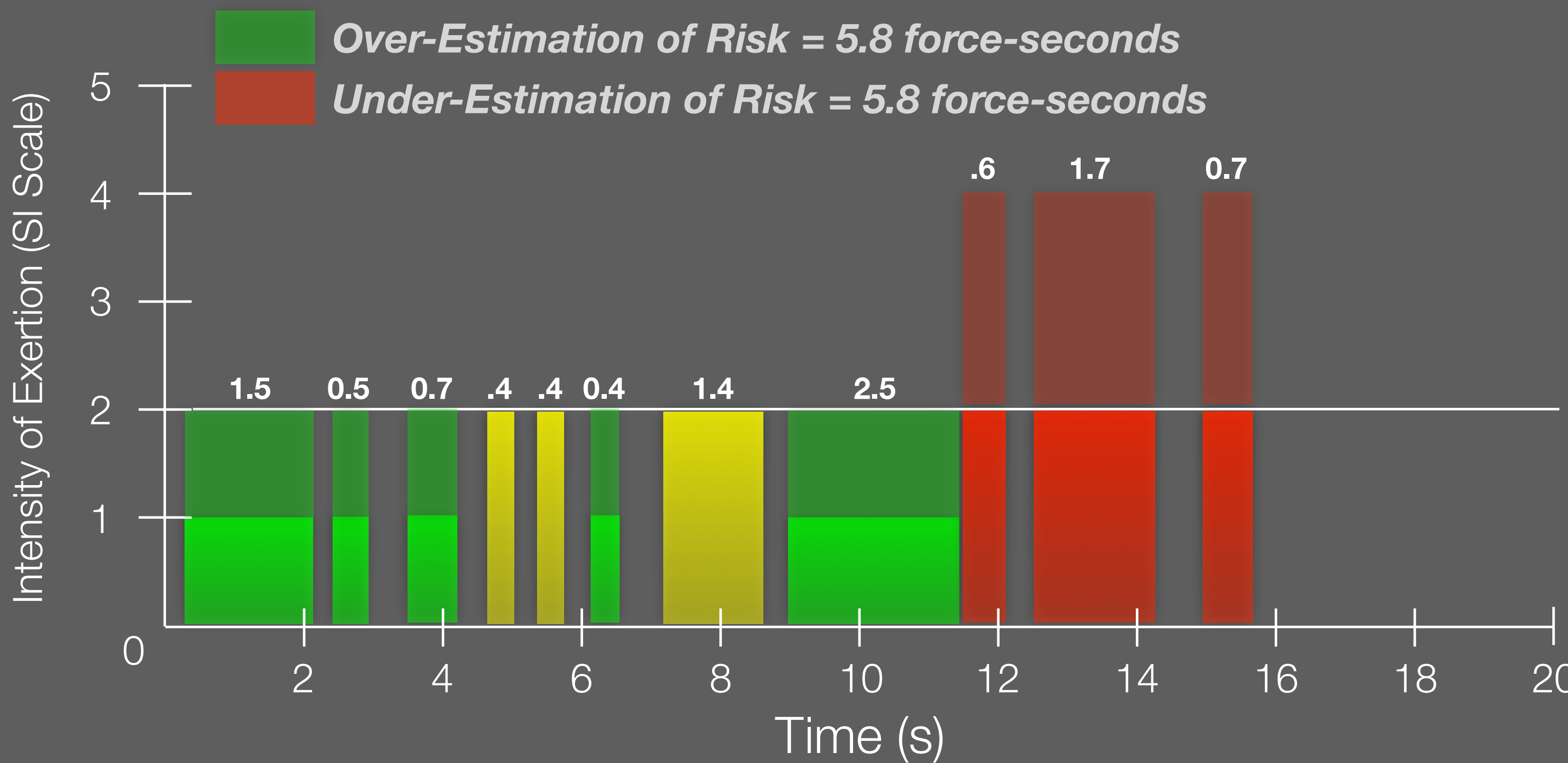
IM		EM		DM		PM		SM		HM		SI
1	x	3	x	2	x	1	x	1	x	1	=	6



Sub-Tasks	Intensity of Effort	Efforts per Minute	% Duration of Cycle
Combined	TWA** = 2	33/min	54%

**Time-Weighted Average

IM		EM		DM		PM		SM		HM		SI
3	x	3	x	2	x	1	x	1	x	1	=	18



Comparison of Intensity Summarization Techniques

Intensity Summarization Technique	SI Score	Over-estimation of Risk	Under-Estimation of Risk
Max Force	54	21.2 force-seconds	0 force-seconds
Typical Force	6	0 force-seconds	9 force-seconds
TWA Force	18	5.8 force-seconds	5.8 force seconds

Comparison of Intensity Summarization Techniques

Intensity Summarization Technique	SI Score	Over-estimation of Risk	Under-Estimation of Risk
Max Force	54	21.2 force-seconds	0 force-seconds
Typical Force	6	0 force-seconds	9 force-seconds
TWA Force	18	5.8 force-seconds	5.8 force seconds

Seems acceptable? But...

How Can Adding Efforts Make a Hazardous Task Safe?

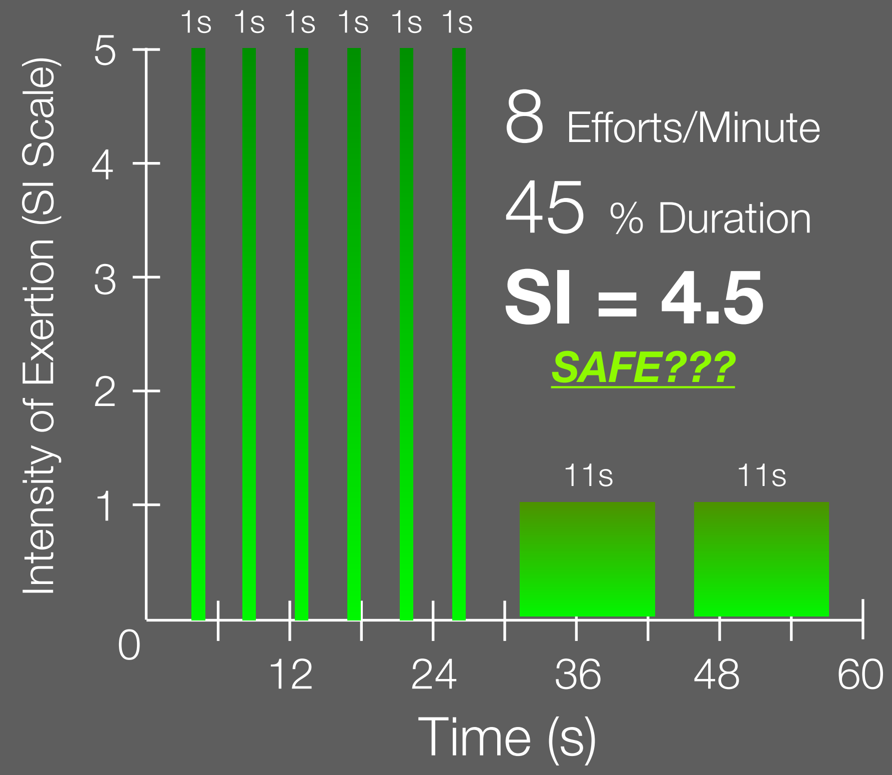
6 Efforts/Minute

10 % Duration

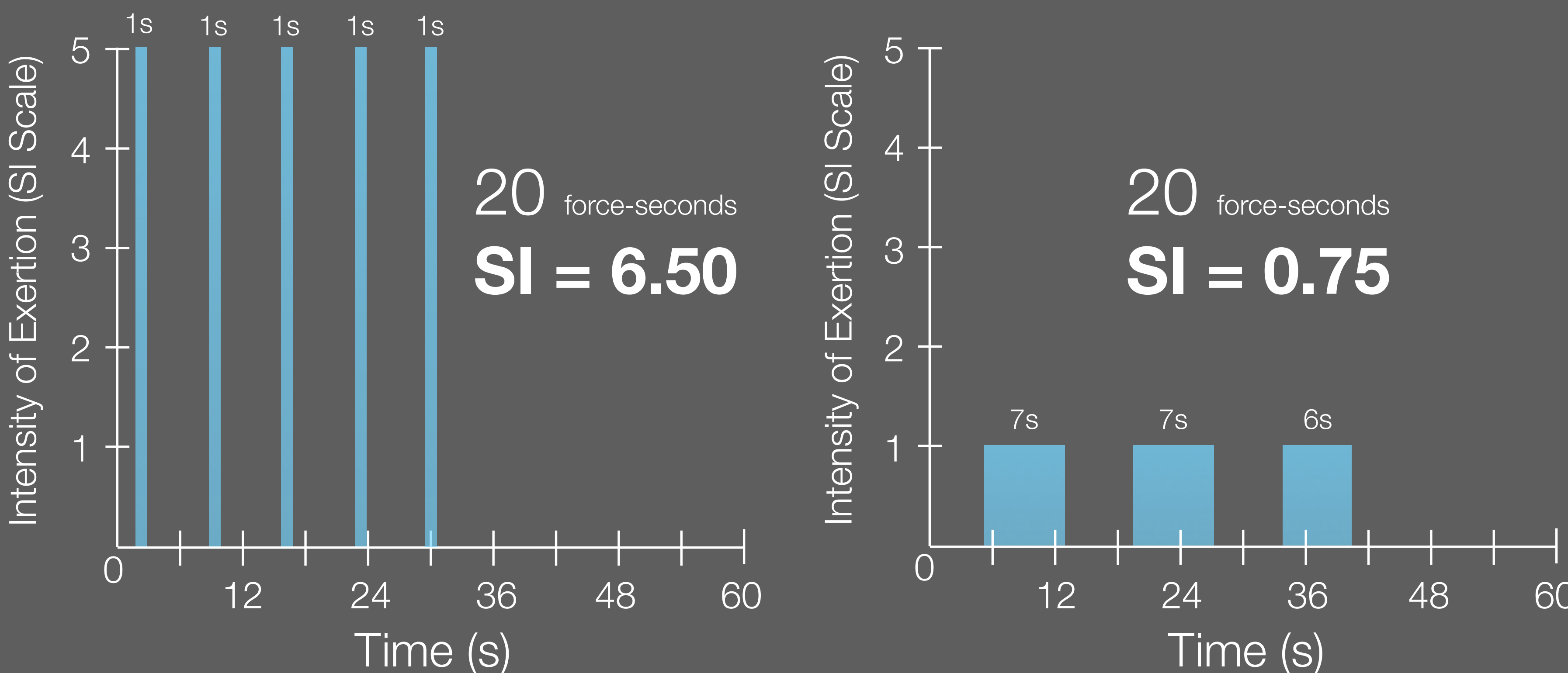
SI = 13.0

HAZARDOUS!

How Can Adding Efforts Make a Hazardous Task Safe?



Do Equal Force-Duration Efforts Produce Equal Strain?



SI Model: ***Force has much larger effect on Strain than Duration of the force***

The 1995 Moore & Garg Strain Index
Background

- The 1995 SI has several noteworthy limitations, including:
  - No reliable method to determine overall force for complex tasks
  - Frequency variable is limited to 20 efforts per minute
  - Intensity multiplier lacks fidelity for low-force exertions and under-penalizes for high-force
  - All multipliers are categorized leading to systemic inconsistencies in the ‘continuous' score
  - No method or guidance for quantifying exposure from multi-task jobs

The Revised Strain Index

Conceptually Similar to the 1995 SI

1995 SI

Intensity of Exertion

Frequency of Exertion

Duty Cycle

Hand/Wrist Posture

Speed of Work

Hours per Day

The Revised Strain Index

Conceptually Similar to the 1995 SI

1995 SI		RSI
Intensity of Exertion	→	Intensity of Exertion
Frequency of Exertion	→	Frequency of Exertion
~~Duty Cycle~~	→	Duration per Exertion
Hand/Wrist Posture	→	Hand/Wrist Posture
~~Speed of Work~~		
Hours per Day	→	Hours per Day

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The Revised Strain Index

Conceptually Similar to the 1995 SI

1995 SI		RSI
Intensity of Exertion	→	Intensity of Exertion
Frequency of Exertion	→	Frequency of Exertion
~~Duty Cycle~~	→	Duration per Exertion
Hand/Wrist Posture	→	Hand/Wrist Posture
~~Speed of Work~~		
Hours per Day	→	Hours per Day

The RSI Model

- 5 variable multiplicative model
  - Intensity of exertion, frequency of exertion, duration per exertion, posture, hours per day
- Key differences between RSI and 1995 SI
  - Continuous rather than categorical multipliers
  - Duration per exertion rather than duty cycle
  - Differentiation between flexion and extension postures
  - Accounts for up to 12 hours per day of exposure

Garg, Arun, J. Steven Moore, and Jay M. Kapellusch. "The Revised Strain Index: an improved upper extremity exposure assessment model." *Ergonomics* (2016): 1-11.

Garg, A., Moore, J. S., & Kapellusch, J. M. (2016). The Composite Strain Index (COSI) and Cumulative Strain Index (CUSI): methodologies for quantifying biomechanical stressors for complex tasks and job rotation using the Revised Strain Index. *Ergonomics*, 1-9.

Intensity of Exertion

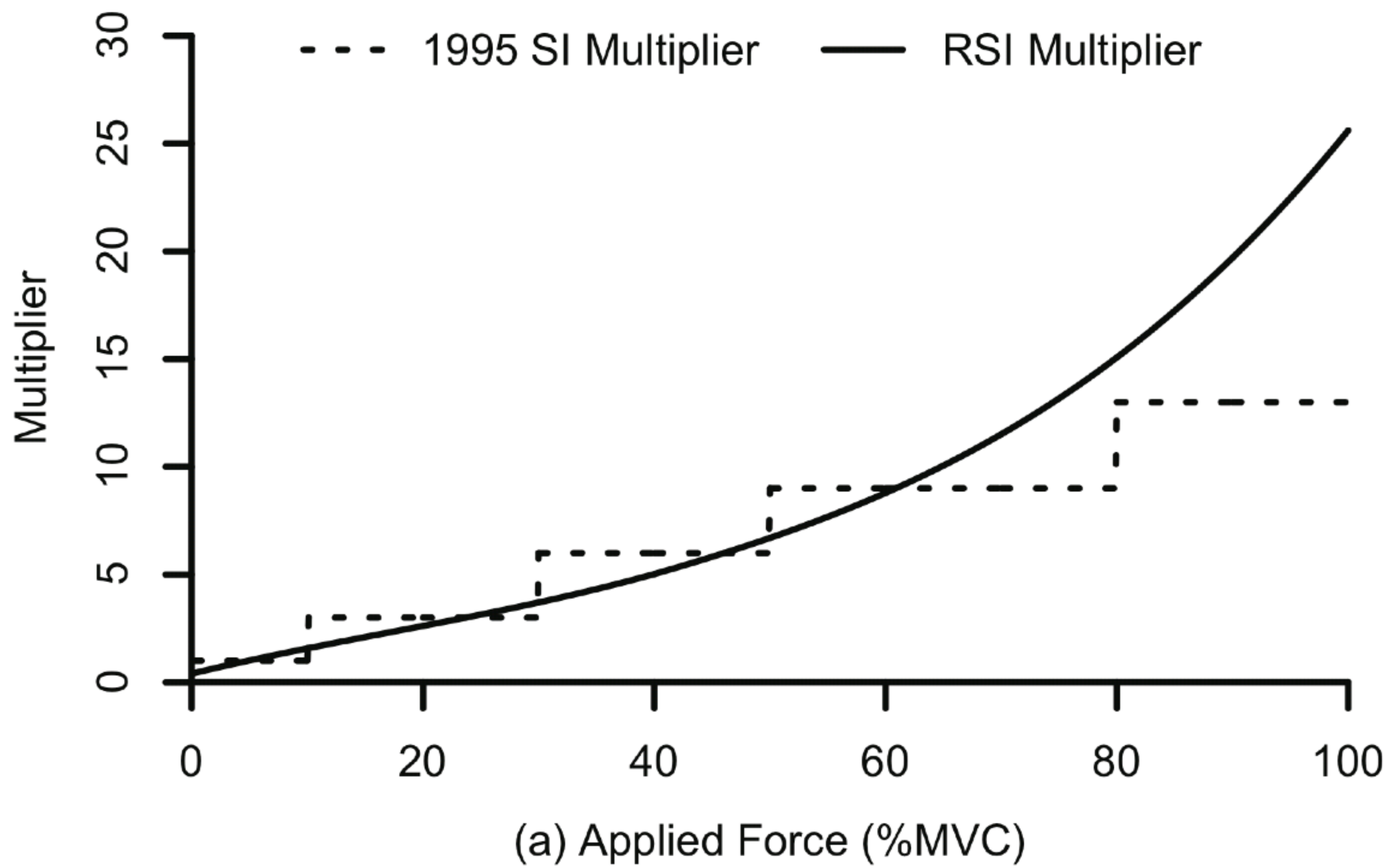
- A measure of the force required to perform the task once
  - Measured in %MVC, or estimated with Borg CR-10 Scale
  - %MVC = Borg CR-10 * 10

Intensity Multiplier (IM)

$$IM = \begin{cases} 30.00 \cdot I^3 - 15.60 \cdot I^2 + 13.00 \cdot I + 0.40, & 0.0 < I \leq 0.4 \\ 36.00 \cdot I^3 - 33.30 \cdot I^2 + 24.77 \cdot I - 1.86, & 0.4 < I \leq 1.0 \end{cases}$$

Where: '*I*' is %MVC between 0 and 1

Intensity of Exertion



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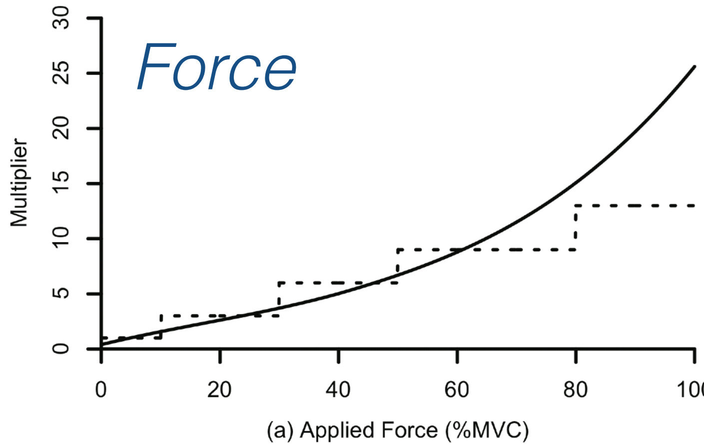
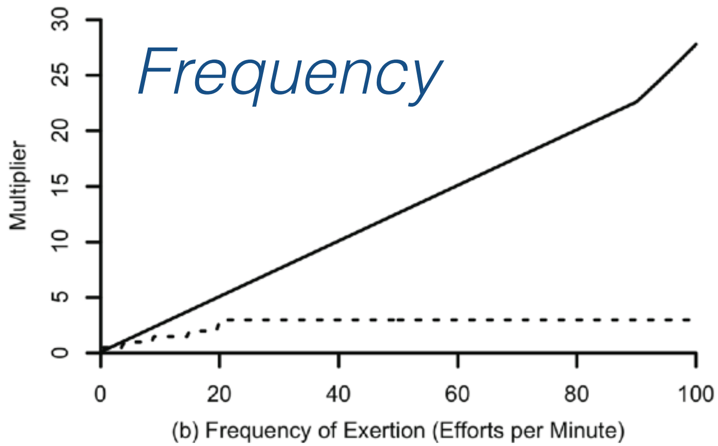
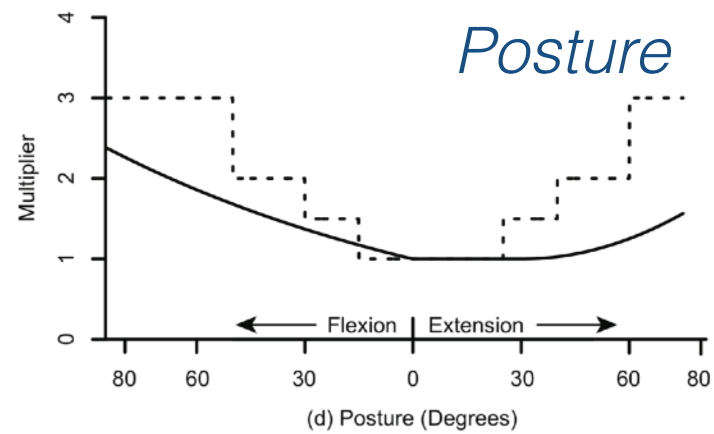
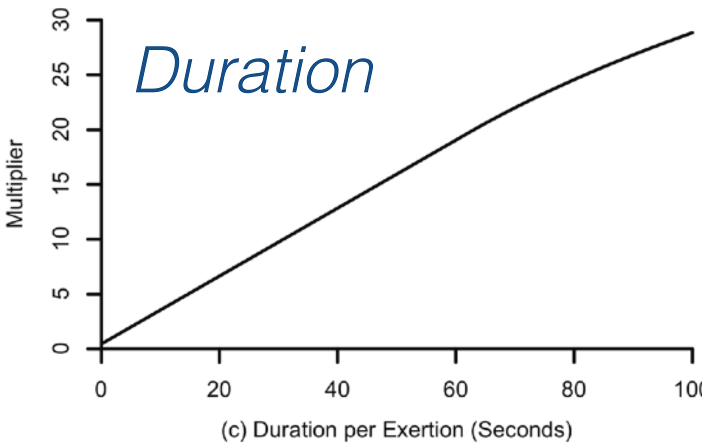
Revised Strain Index

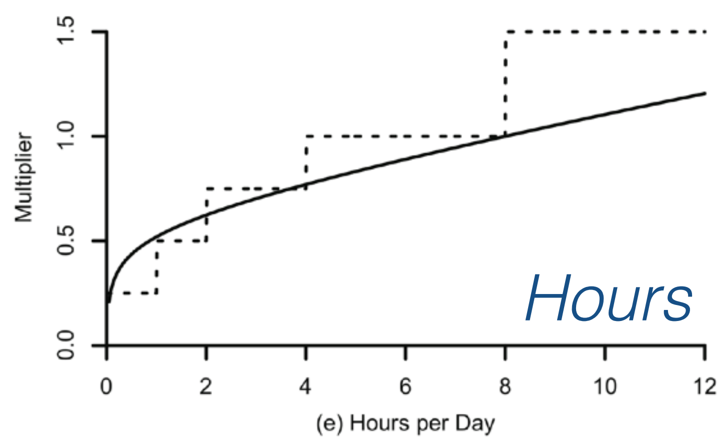
- 5 Continuous Variables & Multipliers
- Calculated from sub-tasks
- Uses duration *per* exertion
- Accounts for flexion vs. extension











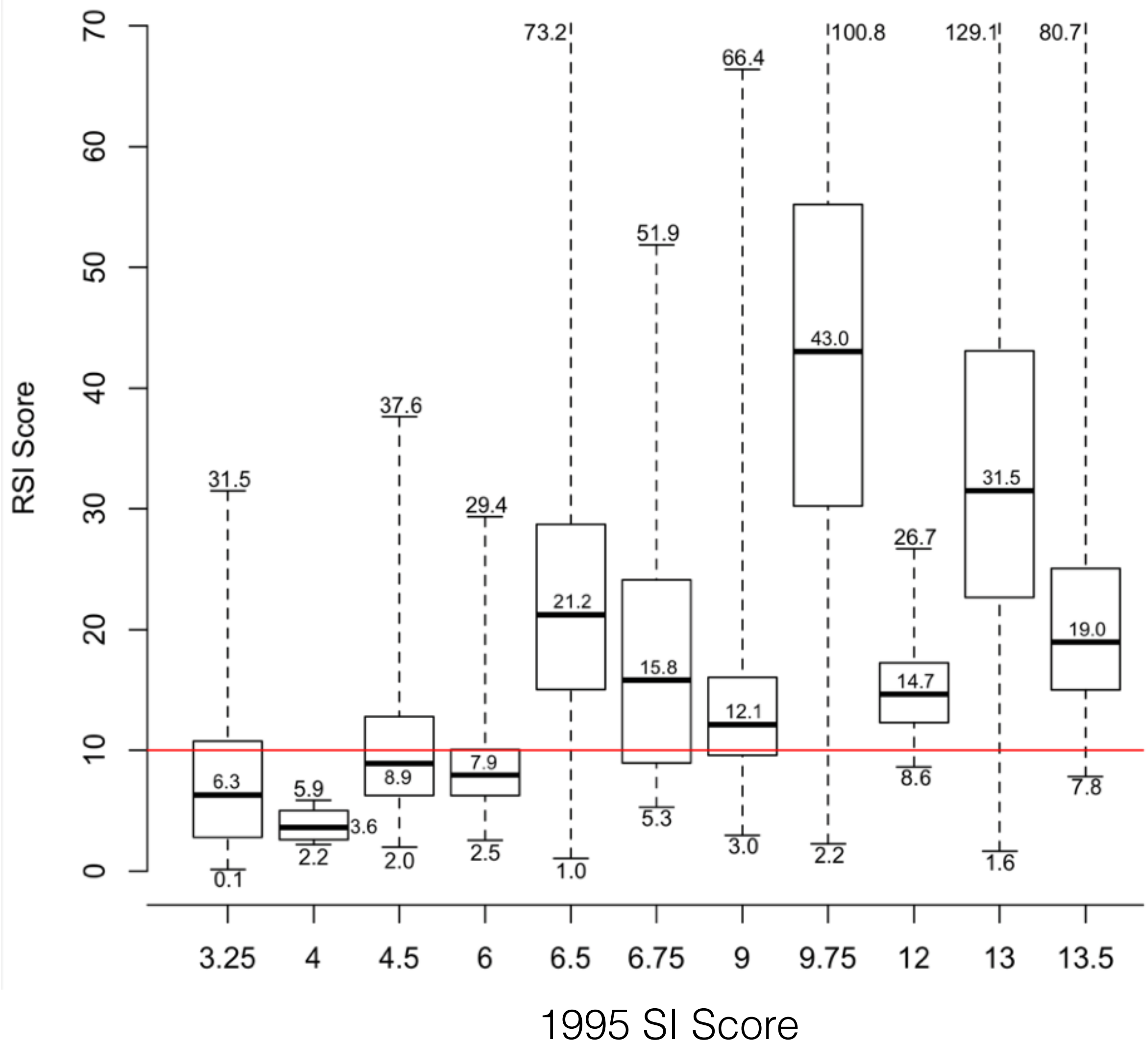
The RSI Score

$$RSI = IM \cdot EM \cdot DM \cdot PM \cdot HM$$

- Where:
- IM = Intensity Multiplier
- EM = Frequency Multiplier
- DM = Duration Multiplier
- PM = Posture Multiplier
- HM = Hours Multiplier

- A-priori high-risk cut-point: RSI = 10.0

Task Discrimination



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The RSI Score

- The Composite SI (COSI) for complex tasks:

Order from highest to lowest RSI

$$RSI_1 \geq RSI_2 \geq RSI_3 \geq \cdots \geq RSI_n$$

COSI is highest subtask stress plus incremental stress of remaining subtasks.

$$COSI = RSI_1 + \sum_2^n \Delta RSI_i$$

Each delta RSI is the product of the frequency independent RSI, and the differential frequency multiplier

$$\Delta RSI_i = (FIRSI_i \times \Delta EM_i)$$

FIRSI is the subtask RSI divided by the subtask frequency multiplier

$$FIRSI_i = RSI_i \div EM_i$$

Differential frequency multiplier is the penalty as the multiplier moves from the n-1 to the nth cumulative frequency of exertion

$$\Delta EM_i = EM_{\left(\sum_1^i E_j\right)} - EM_{\left(\sum_1^{i-1} E_j\right)}$$

The RSI Score

- The cumulative SI (CUSI) for multiple tasks:

Order from highest to lowest COSI

$$COSI_1 \geq COSI_2 \geq COSI_3 \geq \cdots \geq COSI_m$$

CUSI is highest task stress plus incremental stress of remaining tasks.

$$CUSI = COSI_1 + \sum_2^m \Delta COSI_k$$

Each delta CUSI is the product of the hours independent COSI, and the differential hours multiplier

$$\Delta COSI_k = (HICOSI_k \times \Delta HM_k)$$

HICOSI is the task COSI divided by the task hours multiplier

$$HICOSI_k = COSI_k \div HM_k$$

Differential hours multiplier is the penalty as the multiplier moves from the n-1 to the nth cumulative hour of daily exposure

$$\Delta HM_k = HM_{(\sum_1^k H_j)} - HM_{(\sum_1^{i-k} H_j)}$$

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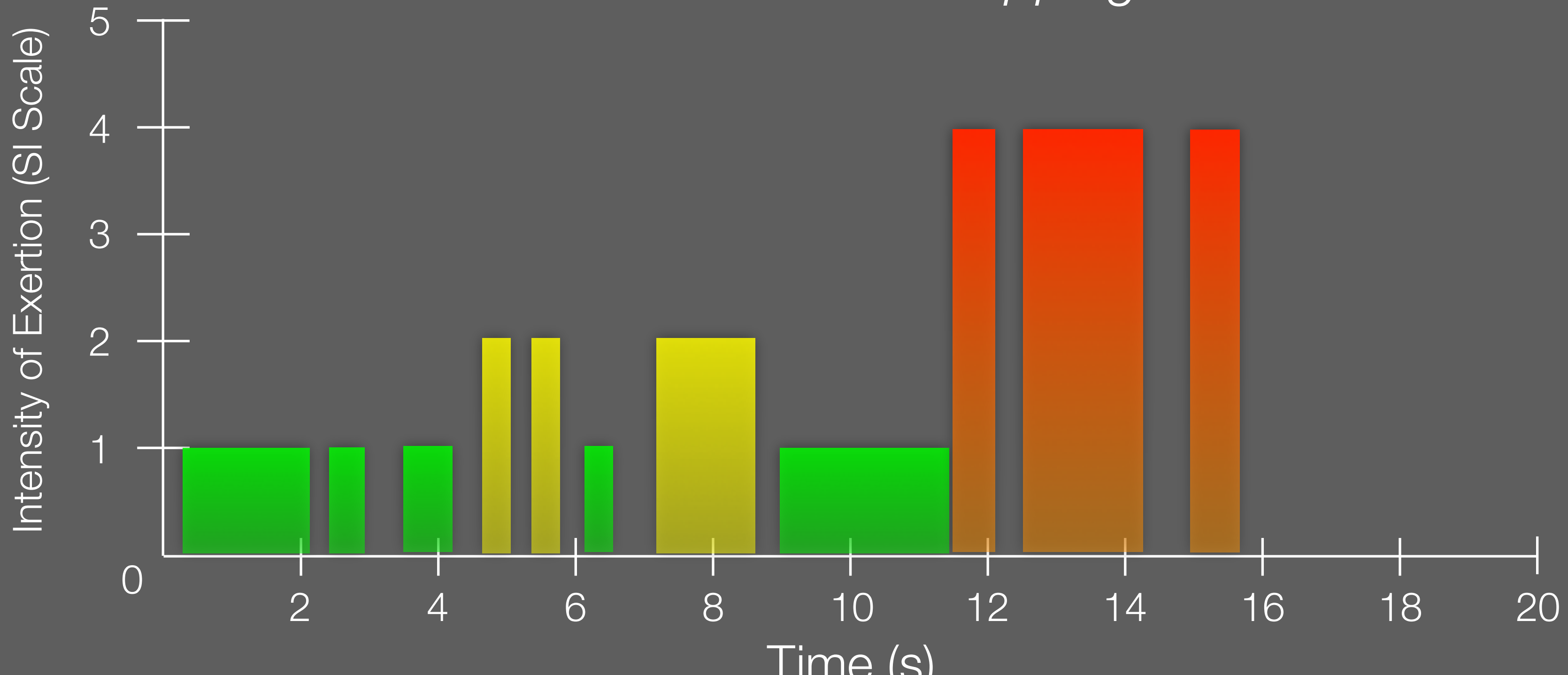
Composite Strain Index
&
Cumulative Strain Index

Examples of Utility

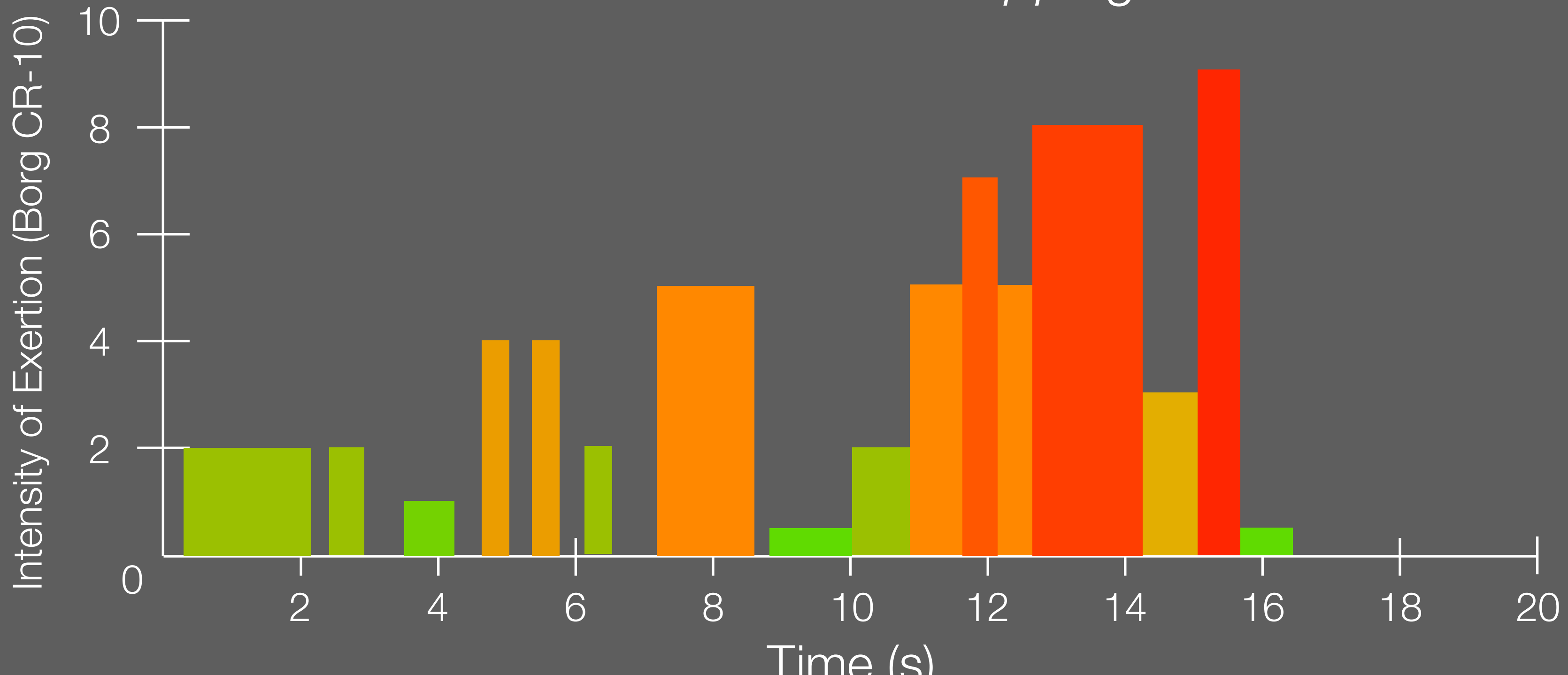
Example Complex Task

Stripping Shielded Cable



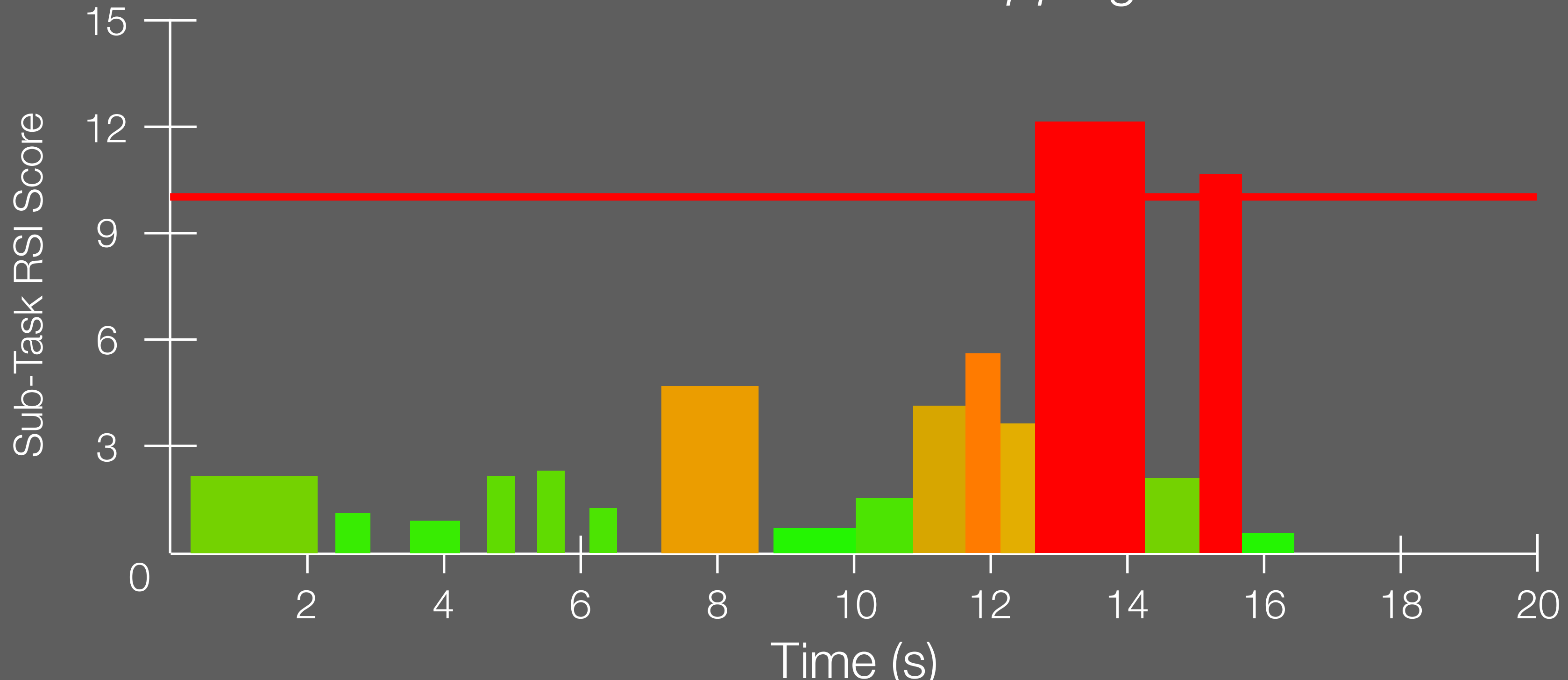
Example Complex Task

Stripping Shielded Cable



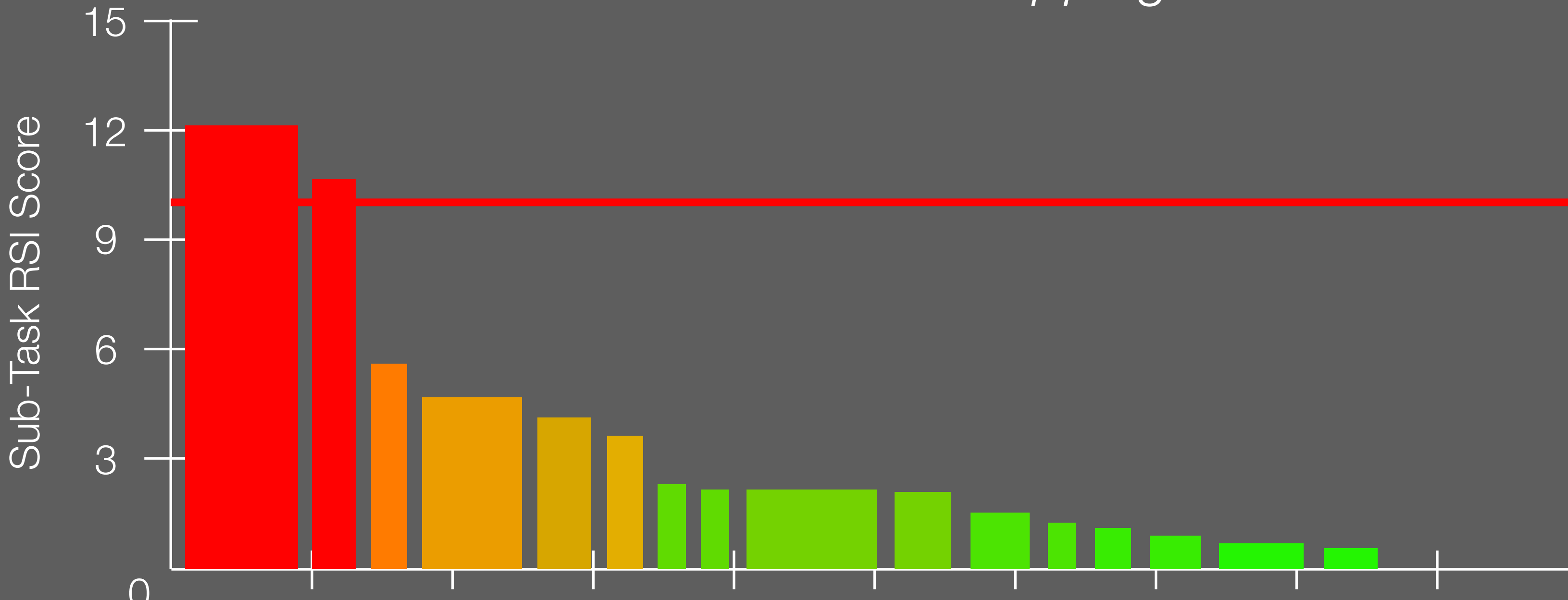
Example Complex Task

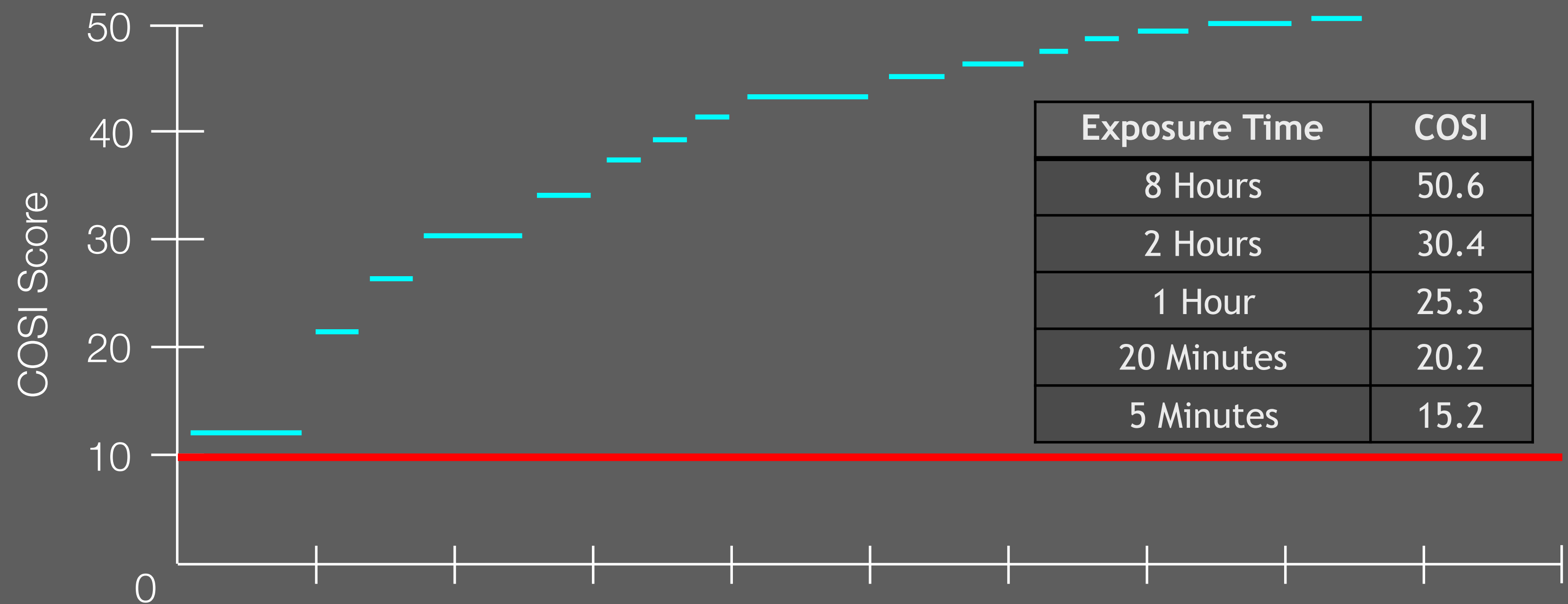
Stripping Shielded Cable



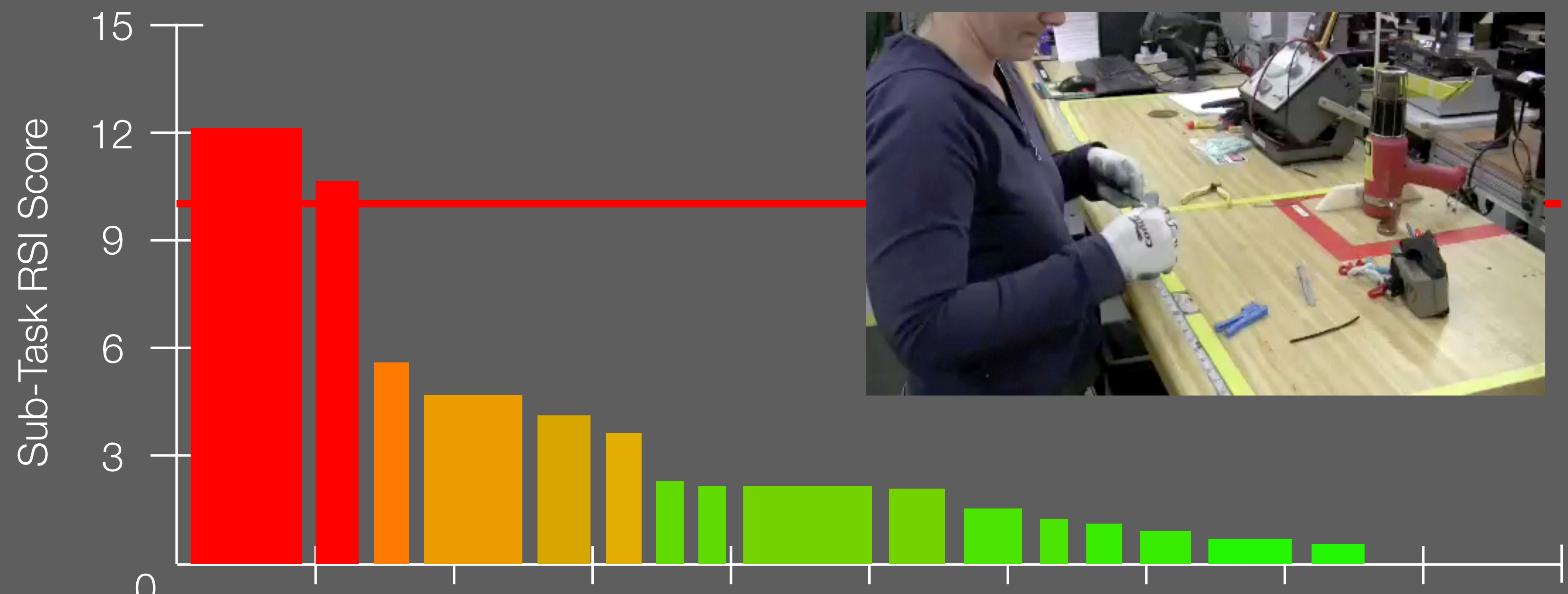
Example Complex Task

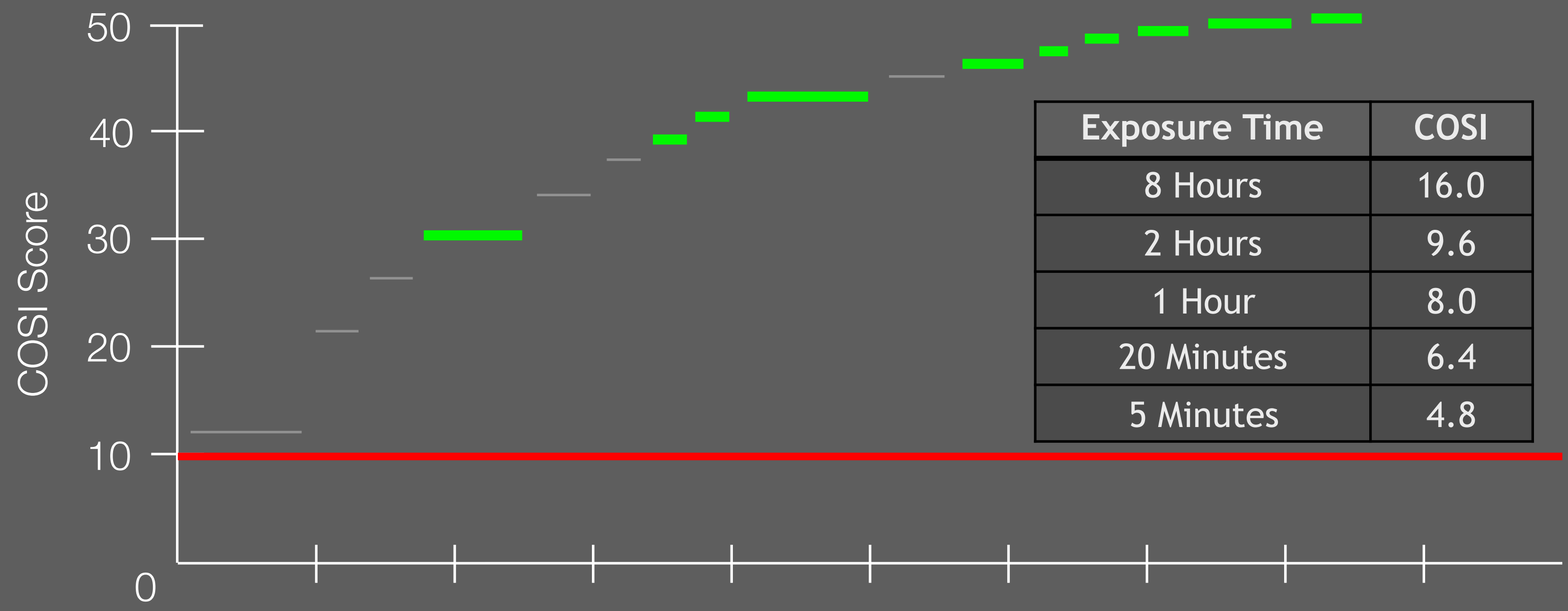
Stripping Shielded Cable



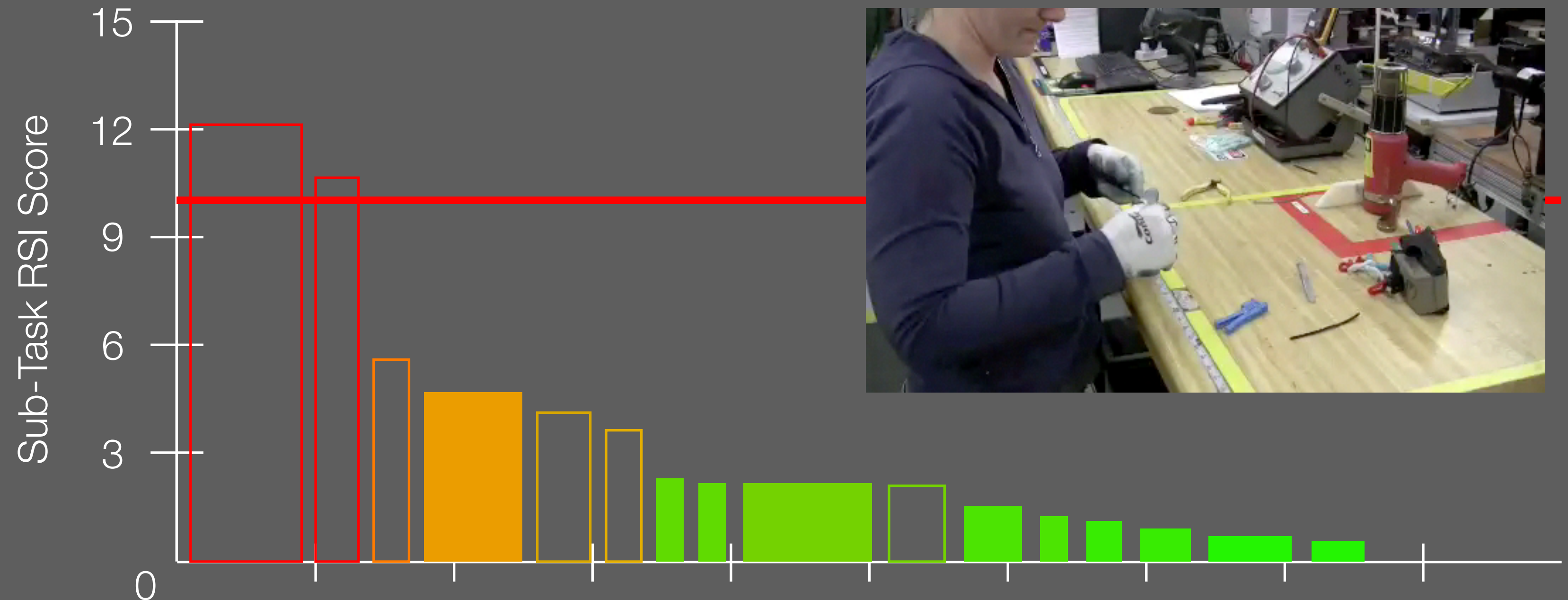


Exposure Time	COSI
8 Hours	50.6
2 Hours	30.4
1 Hour	25.3
20 Minutes	20.2
5 Minutes	15.2





Exposure Time	COSI
8 Hours	16.0
2 Hours	9.6
1 Hour	8.0
20 Minutes	6.4
5 Minutes	4.8



CUSI Example - Luminaire Wiring & Prep

Pre-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
Exposure Time	20 Minutes	100 Minutes	180 Minutes	180 Minutes
COSI	20.2	8.2	3.2	4.6

	Job Score	Implication
TWA COSI	5.5	SAFE
Typical COSI	4.6	SAFE
Peak COSI	20.2	HAZARDOUS

CUSI Example - Luminaire Wiring & Prep

Pre-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
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COSI	20.2	8.2	3.2	4.6

	Job Score	Implication
TWA COSI	5.5	SAFE
Typical COSI	4.6	SAFE
Peak COSI	20.2	HAZARDOUS

COSI	HICOSI	Σ H (i)	Σ H (i-1)	HM (i)	HM (i-1)	Δ HM	Δ COSI
20.2	50.6	0.33	–	0.39	0	0.39	20.2
8.2	13.9	2.00	0.33	0.62	0.39	0.23	3.2
4.6	6.6	5.00	2.00	0.83	0.62	0.21	1.4
3.2	4.6	8.00	5.00	1.00	0.83	0.17	0.8

CUSI Example - Luminaire Wiring & Prep

Pre-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
Exposure Time	20 Minutes	100 Minutes	180 Minutes	180 Minutes
COSI	20.2	8.2	3.2	4.6

	Job Score	Implication
TWA COSI	5.5	SAFE
Typical COSI	4.6	SAFE
Peak COSI	20.2	HAZARDOUS
CUSI	25.6	HAZARDOUS

COSI	HICOSI	Σ H (i)	Σ H (i-1)	HM (i)	HM (i-1)	Δ HM	Δ COSI
20.2	50.6	0.33	—	0.39	0	0.39	20.2
8.2	13.9	2.00	0.33	0.62	0.39	0.23	+ 3.2
4.6	6.6	5.00	2.00	0.83	0.62	0.21	+ 1.4
3.2	4.6	8.00	5.00	1.00	0.83	0.17	+ 0.8

CUSI: 25.6

CUSI Example - Luminaire Wiring & Prep

Post-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
Exposure Time	20 Minutes	100 Minutes	180 Minutes	180 Minutes
COSI	6.4	8.2	3.2	4.6

	Job Score	Implication
TWA COSI	4.9	SAFE
Typical COSI	4.6	SAFE
Peak COSI	8.2	SAFE

COSI	HICOSI	Σ H (i)	Σ H (i-1)	HM (i)	HM (i-1)	Δ HM	Δ COSI
8.2	13.9	1.67	—	0.59	0	0.59	8.2
6.4	16.0	2.00	1.67	0.62	0.59	0.03	0.5
4.6	6.6	5.00	2.00	0.83	0.62	0.21	1.4
3.2	4.6	8.00	5.00	1.00	0.83	0.17	0.8

CUSI Example - Luminaire Wiring & Prep

Post-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
Exposure Time	20 Minutes	100 Minutes	180 Minutes	180 Minutes
COSI	6.4	8.2	3.2	4.6

	Job Score	Implication
TWA COSI	4.9	SAFE
Typical COSI	4.6	SAFE
Peak COSI	8.2	SAFE
CUSI	10.9	HAZARDOUS

COSI	HICOSI	Σ H (i)	Σ H (i-1)	HM (i)	HM (i-1)	Δ HM	Δ COSI
8.2	13.9	1.67	—	0.59	0	0.59	8.2
6.4	16.0	2.00	1.67	0.62	0.59	0.03	+ 0.5
4.6	6.6	5.00	2.00	0.83	0.62	0.21	+ 1.4
3.2	4.6	8.00	5.00	1.00	0.83	0.17	+ 0.8
						CUSI:	10.9

CUSI Example - Luminaire Wiring & Prep

Post-Intervention

	Wire Stripping - A	Wire Stripping - B	Termination	Wiring
Exposure Time	20 Minutes	100 Minutes	180 Minutes	180 Minutes
COSI	6.4	8.2	3.2	4.6

Needs Intervention

	Job Score	Implication
TWA COSI	4.9	SAFE
Typical COSI	4.6	SAFE
Peak COSI	8.2	SAFE
CUSI	10.9	HAZARDOUS

COSI	HICOSI	Σ H (i)	Σ H (i-1)	HM (i)	HM (i-1)	Δ HM	Δ COSI
8.2	13.9	1.67	—	0.59	0	0.59	8.2
6.4	16.0	2.00	1.67	0.62	0.59	0.03	+ 0.5
4.6	6.6	5.00	2.00	0.83	0.62	0.21	+ 1.4
3.2	4.6	8.00	5.00	1.00	0.83	0.17	+ 0.8
						CUSI:	10.9

Conclusions

- COSI and CUSI are powerful design tools:
  - Discrete estimates of physical exposure for sub-tasks and tasks
  - Require fewer assumptions to use
  - Should prove more repeatable and reliable for continuous improvement of manual and semi-automated operations

References:

Garg, A., & Kapellusch, J. M. (2016). The cumulative lifting index (CULI) for the revised NIOSH lifting equation: quantifying risk for workers with job rotation. *Human factors*, *58*(5), 683-694.

Garg, Arun, J. Steven Moore, and Jay M. Kapellusch. "The Revised Strain Index: an improved upper extremity exposure assessment model." *Ergonomics* (2016): 1-11.

Garg, A., Moore, J. S., & Kapellusch, J. M. (2016). The Composite Strain Index (COSI) and Cumulative Strain Index (CUSI): methodologies for quantifying biomechanical stressors for complex tasks and job rotation using the Revised Strain Index. *Ergonomics*, 1-9.

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NIOSH Upper Limb Consortium Studies: What did we learn about Carpal Tunnel Syndrome, and what should we do next?

Bradley Evanoff, MD, MPH

Washington University in St. Louis
School of Medicine

Overview

- NIOSH Upper Extremity Consortium Study
  - Design
  - Main findings
  - Comparison to OCTOPUS studies
- Thoughts on future MSD research

Why study CTS?

- Most common entrapment neuropathy – compression of median nerve at the wrist
- Common upper extremity surgery: almost twice as common as rotator cuff repair among people aged 45-64
- Associated with large financial burden in compensation systems, disability
- Model for other UE MSD

Problems with studying CTS

- Common enough to be a societal problem, rare enough to make it difficult to study
- Estimates of prevalence and incidence vary widely depending on how CTS is defined (case definition) and counted (active vs. passive surveillance)
- Multiple exposures thought to be relevant (force, repetition, posture, vibration)
- Important personal risk factors
- Highly politicized controversies

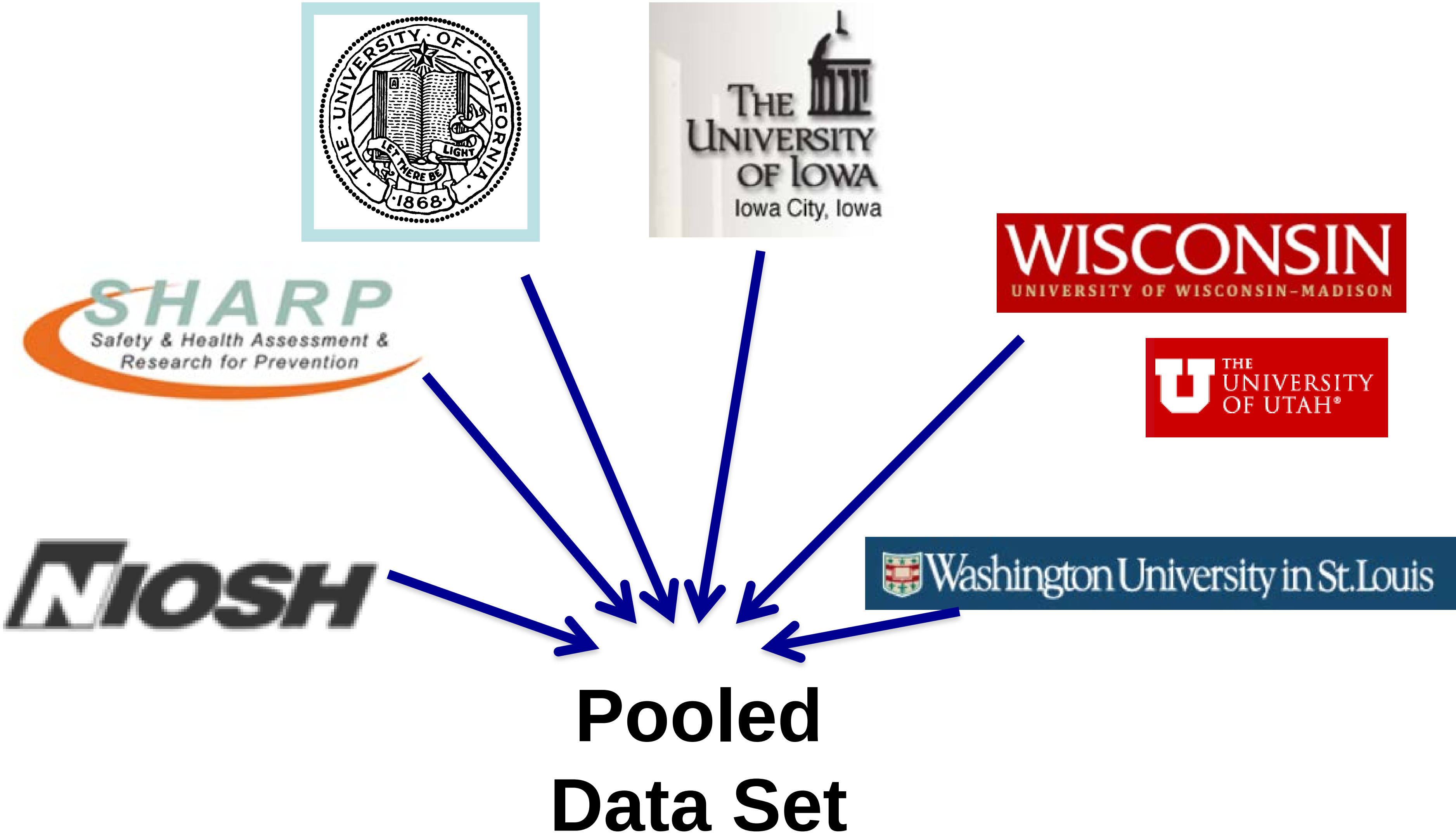
Rationale for NIOSH Upper Extremity Consortium (2001)

- Few previous studies with
  - Prospective design
  - Individual level exposures
  - Assessment of both work-related and personal risk factors
  - Rigorous case definitions
- Exposure response relationships, attributable risk not well defined

Six NIOSH studies collected similar data

- Multiple health outcomes via interview and questionnaire
- Individual level exposure assessment
- Structured physical examination
- Nerve Conduction Studies
- Prospective, longitudinal follow up 3-7 years

NIOSH Upper Extremity Consortium



Total = 4321 Workers

Subjects/site = 346-1219

55 Companies in 10 US States

Production, food processing, health care, construction, service, technical

Common case definition for CTS required symptoms <u>and</u> abnormal nerve conduction

- Symptoms of numbness, burning, tingling, or pain in digits 1,2, or 3 **- and -**
- Median neuropathy (NCS adjusted for skin temperature and electrode placement)
  - median sensory latency (peak >3.7 ms) **–or-**
  - median motor latency (onset >4.5 ms) **–or-**
  - median ulnar sensory difference (>0.85 ms)

Biomechanical Exposure

	Exposure Measurement	Method
FORCE	Peak Force (Borg CR-10 scale)	Worker Analyst
REPETITION	HAL Rating (Rating scale) Total Repetition Rate	Analyst Video Analysis
POSTURE	% time spent in >30° Ext % time spent in >30° Flx	Video Analysis
% TIME	% time all Hand Exertions	Video Analysis
% TIME & FORCE	% time Forceful* Hand Exertions	Video Analysis
REPETITION & FORCE	Forceful* Repetition Rate	Video Analysis

*Forceful = ≥9N (1 kg) pinch force or ≥45N (4.5 kg) of power grip

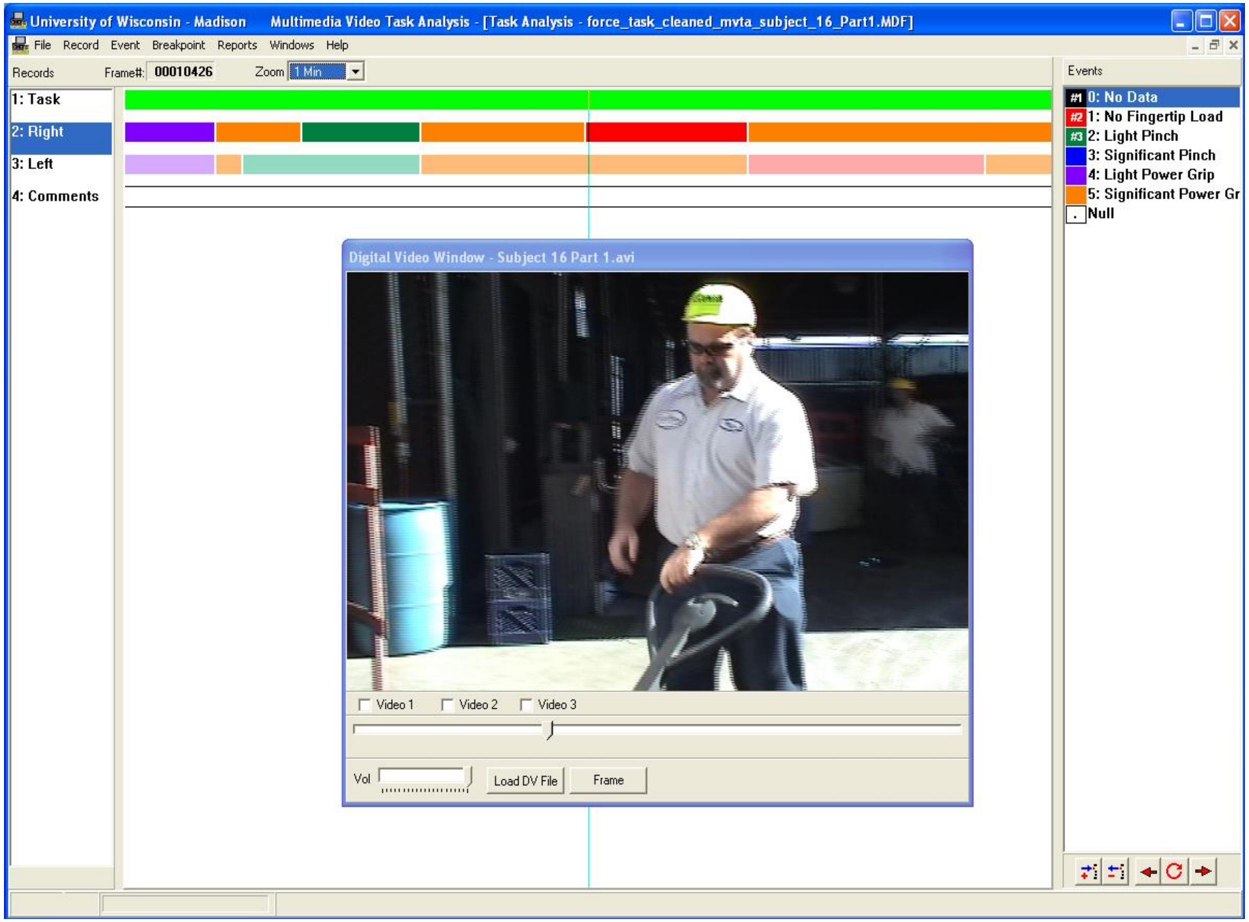
Borg CR-10, HAL Scales

Estimated Intensity of Task Peak Hand Force

Score	☐ Worker Verbal Estimate	☐ Observer Estimate (ONLY if unable to talk to worker)
0	Nothing at all	
0.5	Extremely weak (just noticeable)	Barely noticeable or relaxed effort
1	Very weak	
2	Weak (light)	Noticeable or definite effort
3	Moderate	
4		Obvious effort, but unchanged facial expression
5	Strong (heavy)	
6		Substantial effort with changed facial expression
7	Very strong	
8		
9		Uses shoulder or trunk for force
10	Extremely strong (near maximal)	

Hand Activity Level Rating

0	2	4	6	8	10
Hands idle most of the time; no regular exertions	Consistent conspicuous long pauses; or very slow motions	Slow steady motion/exer-tions; frequent brief pauses	Steady motion/ exertion; infrequent pauses	Rapid steady motion/exer-tions; no regular pauses	Rapid steady motion/ difficulty keeping up or continuous exertion



Multimedia Video Task Analysis used to estimate:

- Time spent in flexion/extension
- Total repetition rate / forceful repetition rate
- Time spent in all hand exertions / forceful hand exertions

NIOSH Upper Extremity Consortium: Research Outputs to Date

>80 Publications; 13 Publications using pooled consortium data

- Exposure methods
- Case definitions
- Risk factors for Prevalent CTS
- Risk Factors for Incident CTS

5 Incidence Studies

Kapellusch, SJWEH 2014 →
N = 2751 (186 cases, 6243 PY)

Harris-Adamson, SJWEH 2013
N=3515 (206 cases, 8833 PY)

Harris-Adamson, OEM 2015
N=2474 (179 cases, 5103 PY)

Rempel, OEM 2015
N=2396

Dale, Am J Epidemiol 2015
N=3452

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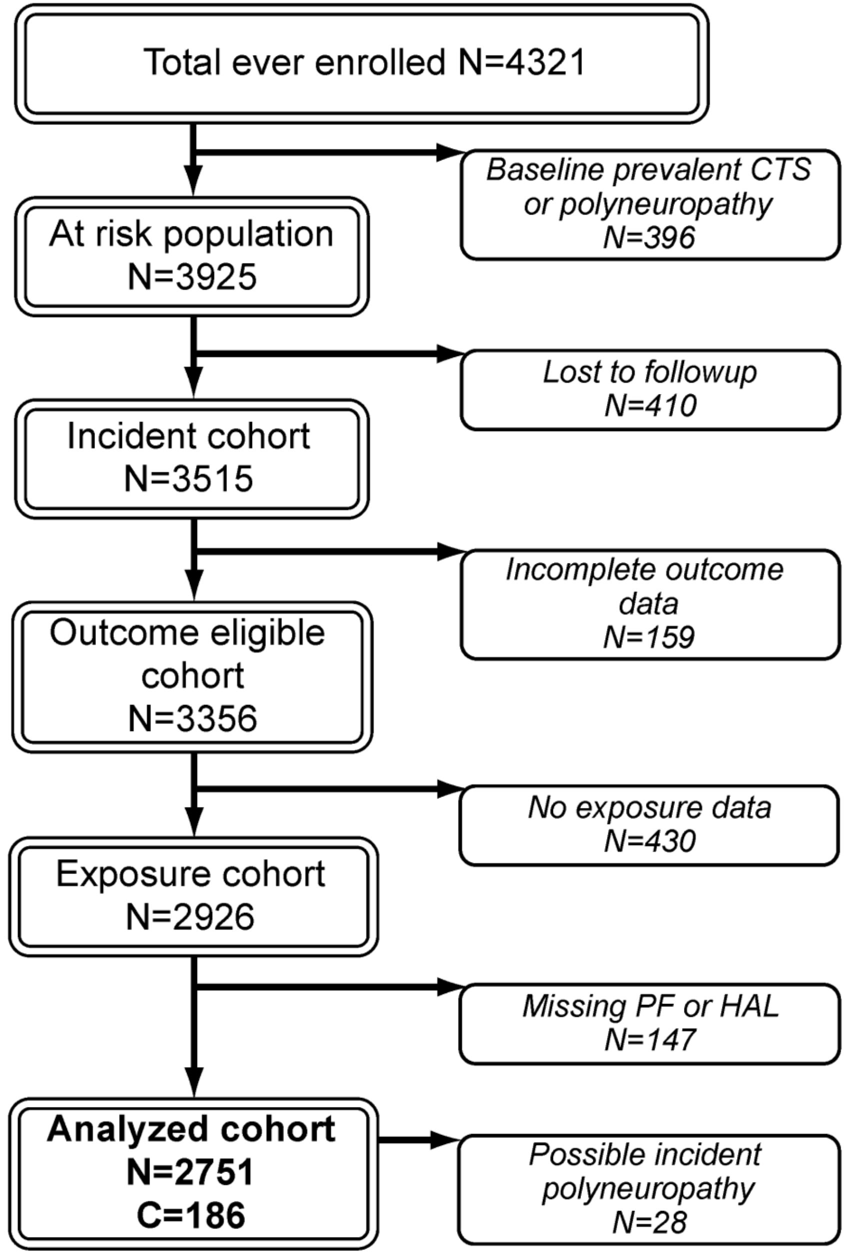


Figure 1. Flowchart of subjects in the pooled analyses. [CTS=carpal tunnel syndrome; HAL=hand-activity level; PF=peak force]

Statistical Analysis

- Categorical splits based on baseline exposure distribution
- Cox Proportional Hazards model using robust confidence intervals
- Adjusted for age, gender, BMI, study site, & <u>non-overlapping</u> biomechanical exposures

Demographic Characteristics

[Dale SJWEH 2013]

	Pooled cohort n=4321
Male	52 %
Caucasian race	54 %
Mean Age	38.5 years
Mean Body Mass Index	28.6 %
Smoking	26%
< High School Diploma	16%
Mean time in current job	6.5 years
Incidence of CTS	2.3 per 100 person years

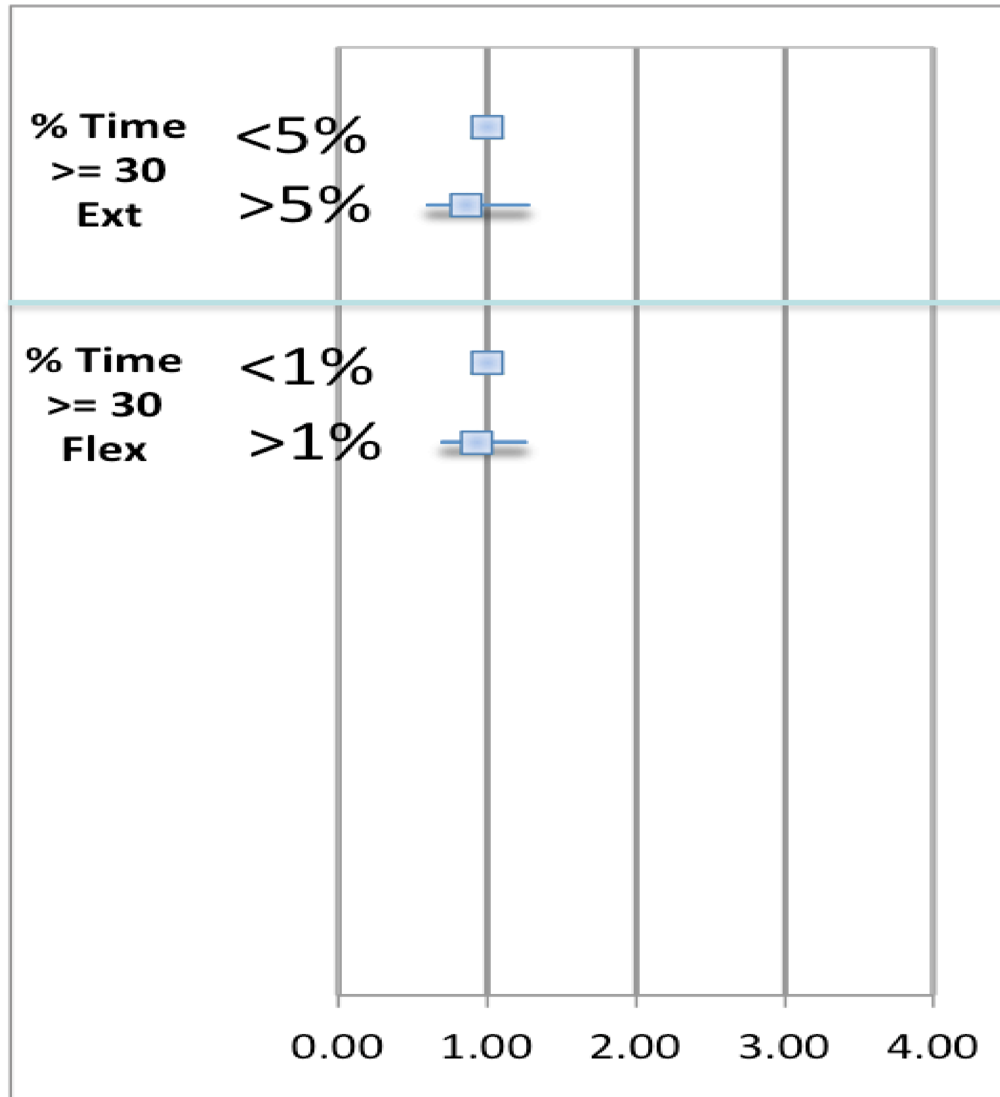
Hazard Ratios for Personal Factors

[Harris C et al. OEM 2013]

Factor	HR (95% c.i.)
Female	1.30 [0.98-1.72]
Age (≥40 years)	2.84 [1.85-4.37]
BMI (≥30 kg/m^2)	1.67 [1.26-2.21]
Co-morbidities (DM, RA, thyroid)	0.95 [0.62-1.44]

Hazard Ratios: Wrist Posture*

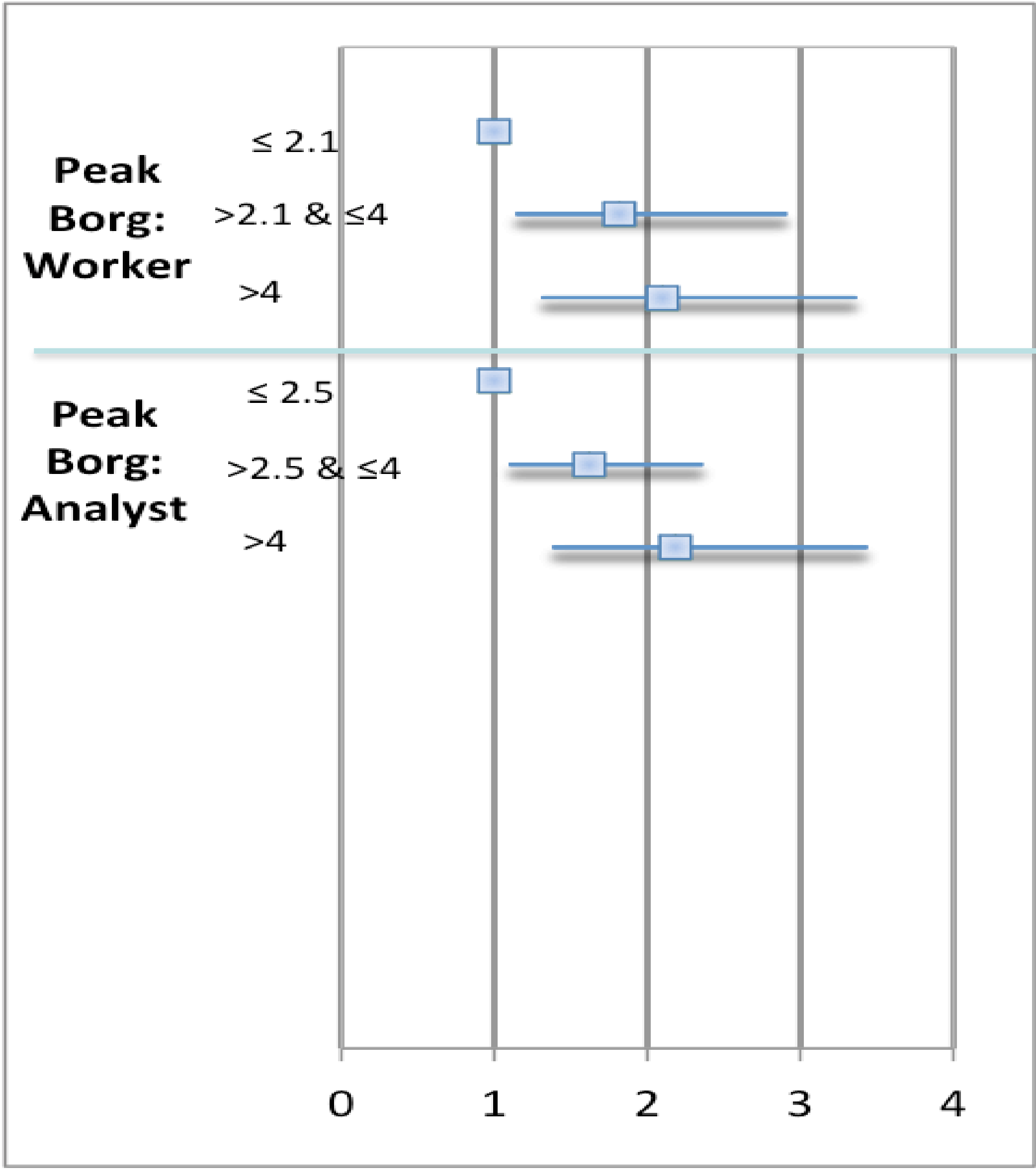
[Harris C et al. OEM 2015]



*Adj. for age, gender, BMI, Study site and non-overlapping exposures

Hazard Ratios: Peak Hand Force*

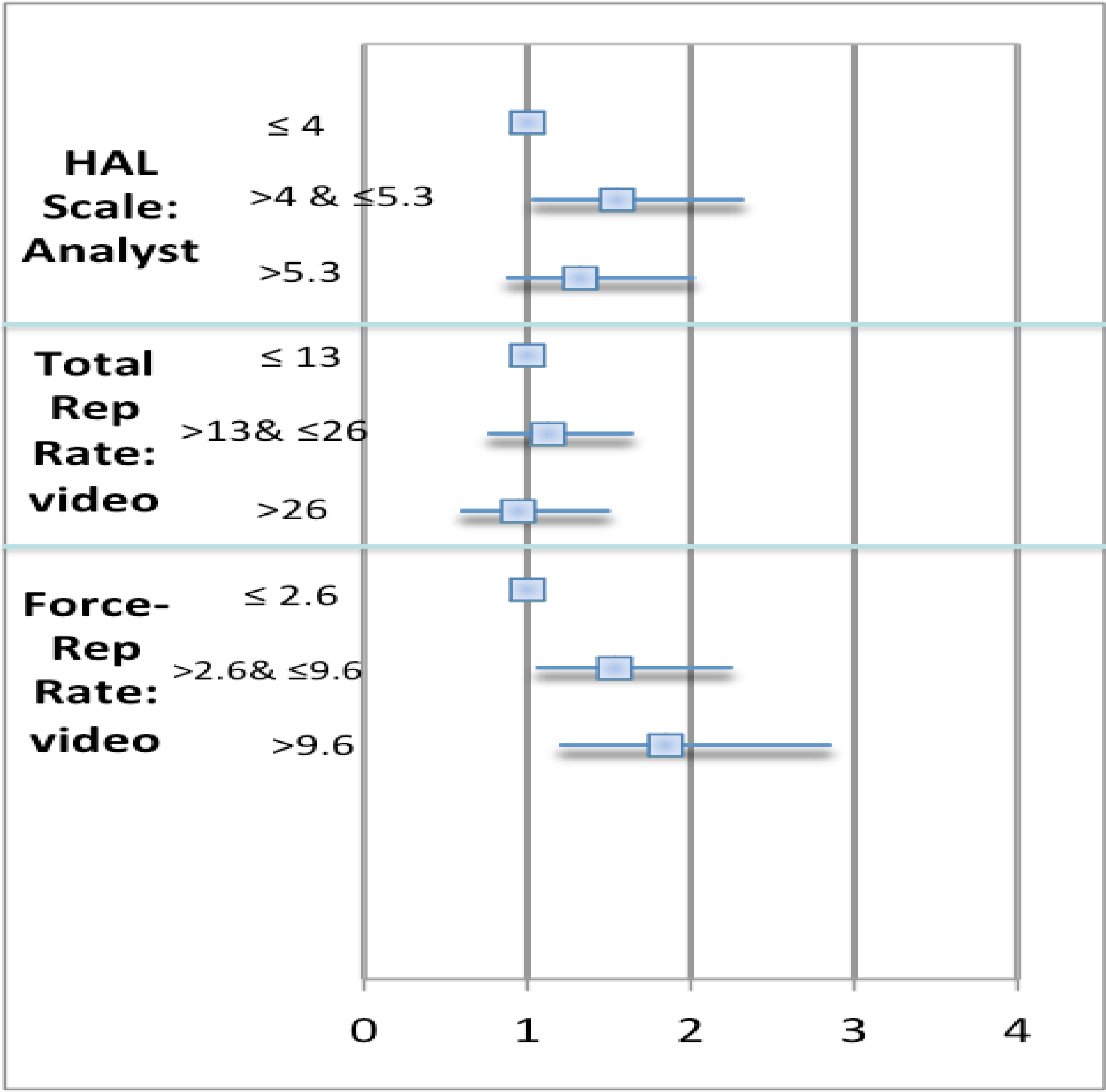
*Adj. for age, gender, BMI, Study site and non-overlapping exposures



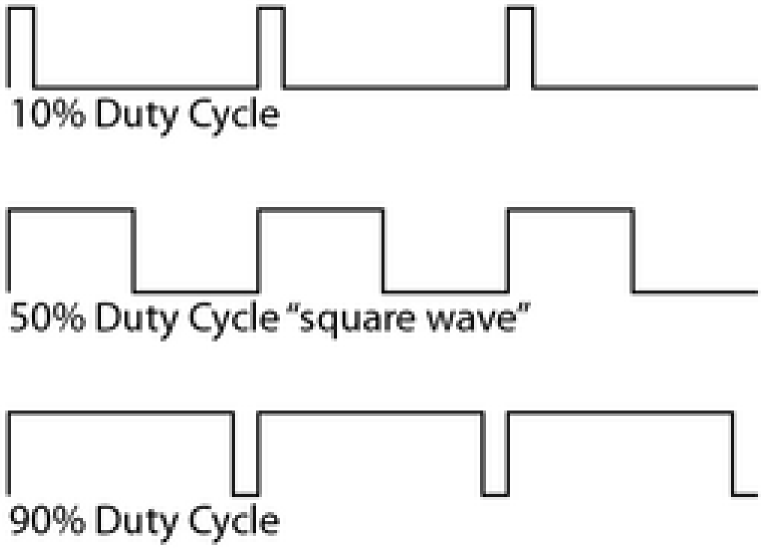
Hazard Ratios: Hand Repetition*

*Adj. for age, gender, BMI, Study site and non-overlapping exposures

Forceful = ≥9N pinch force or ≥45N of power grip



Duty Cycle ≈
% Time in Hand Exertions

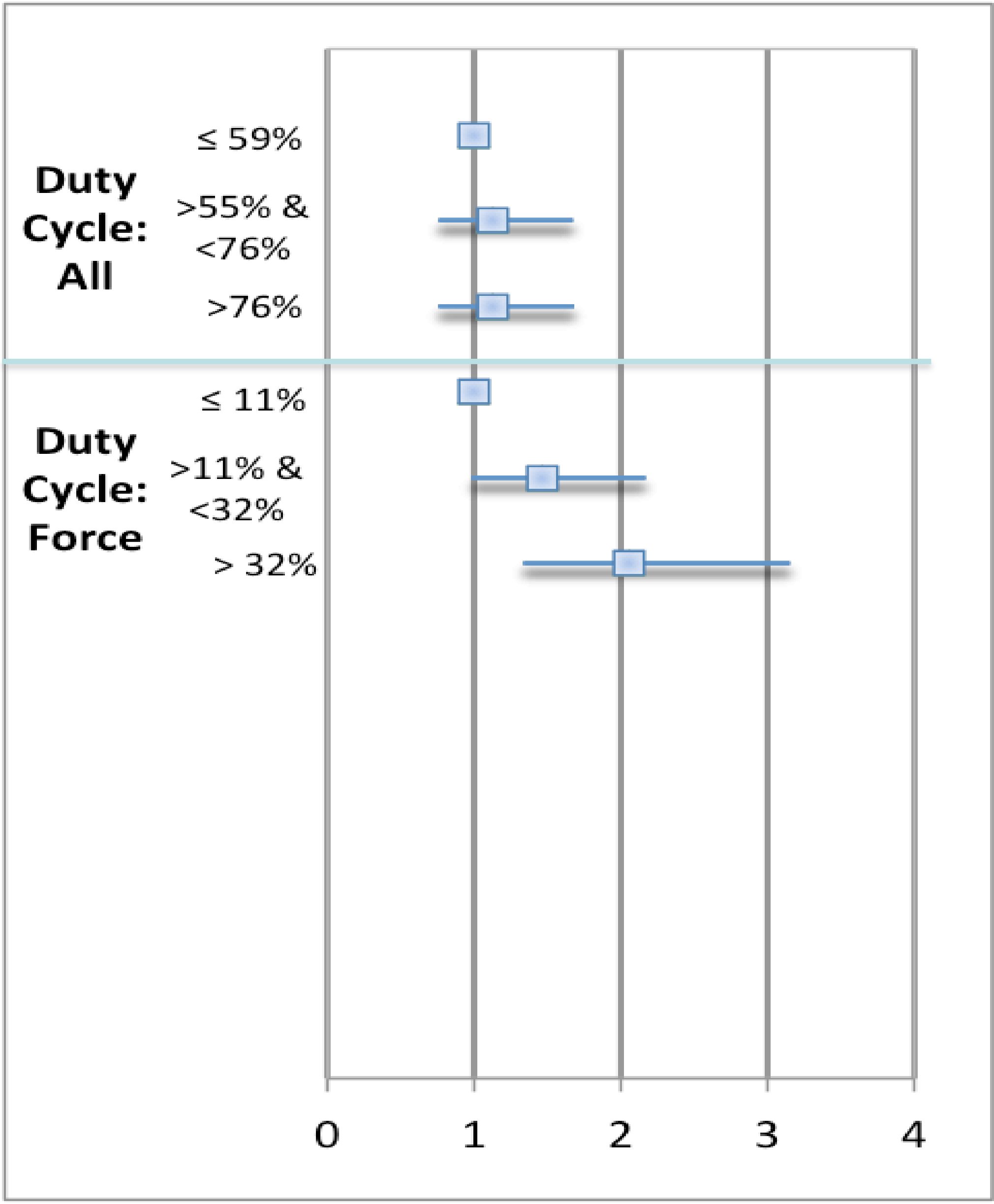


same repetition rate !
same peak force !

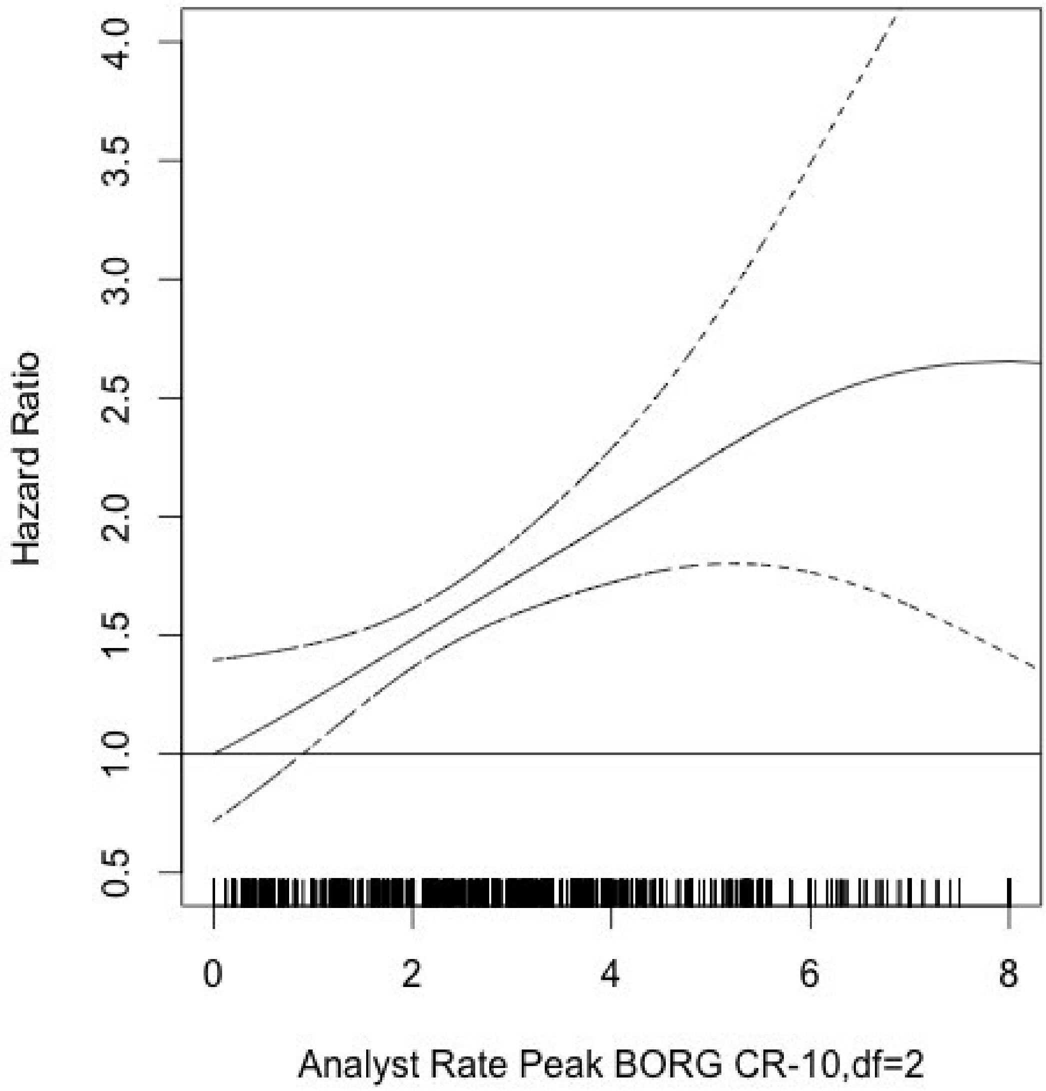
Hazard Ratios: Duty Cycle*

*Adj. for age, gender, BMI, Study site and non-overlapping exposures

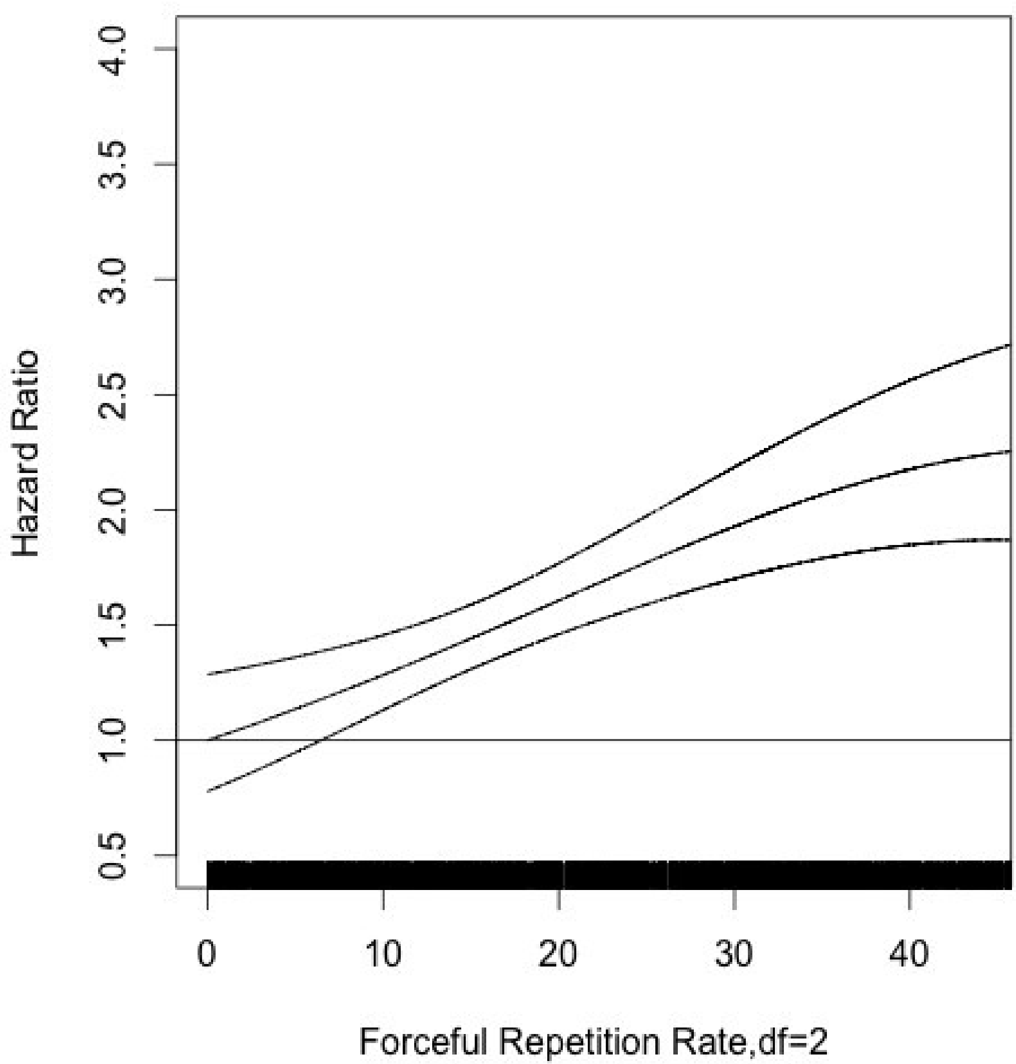
Forceful = ≥9N pinch force or ≥45N of power grip



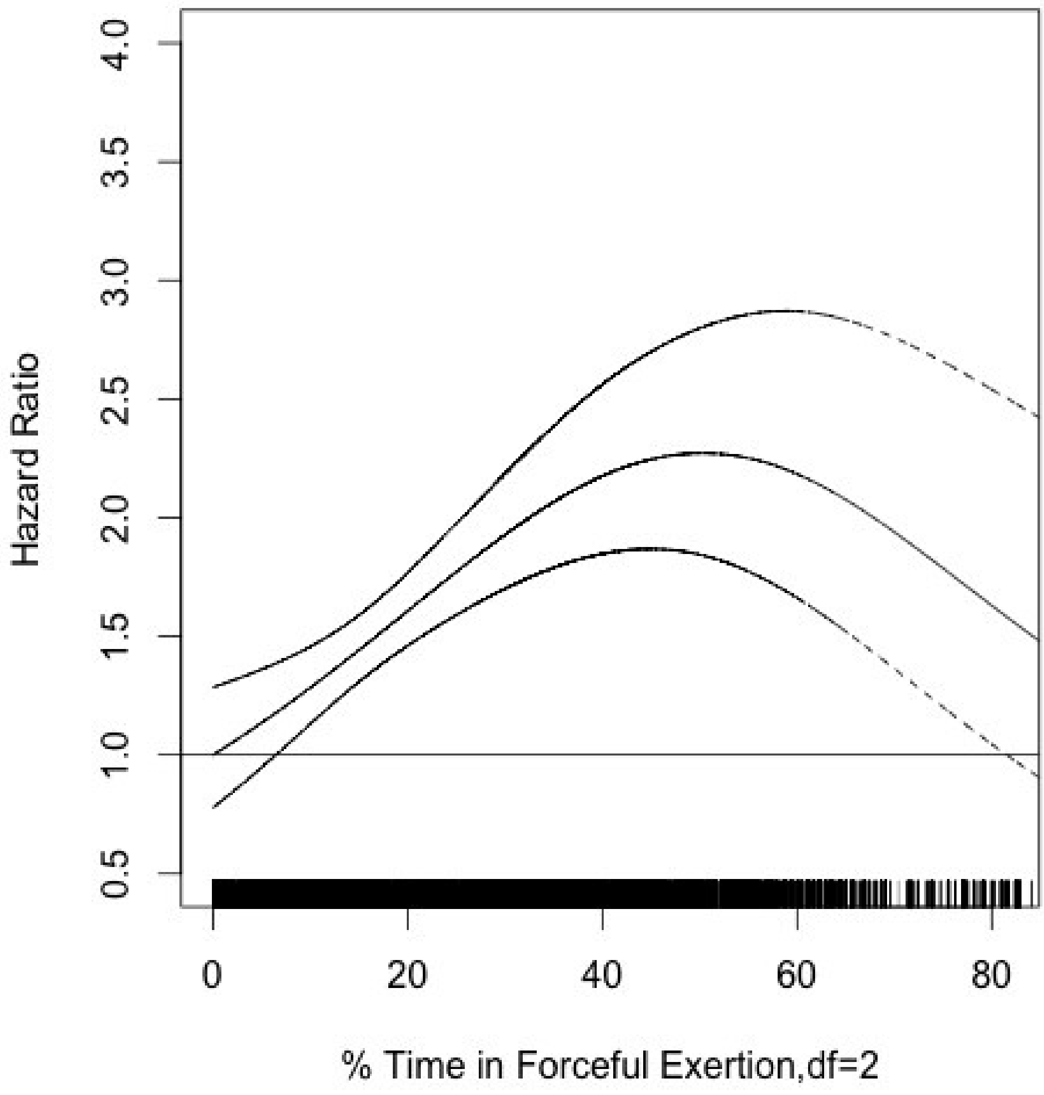
HR for Peak Force



HR for Forceful Repetition Rate

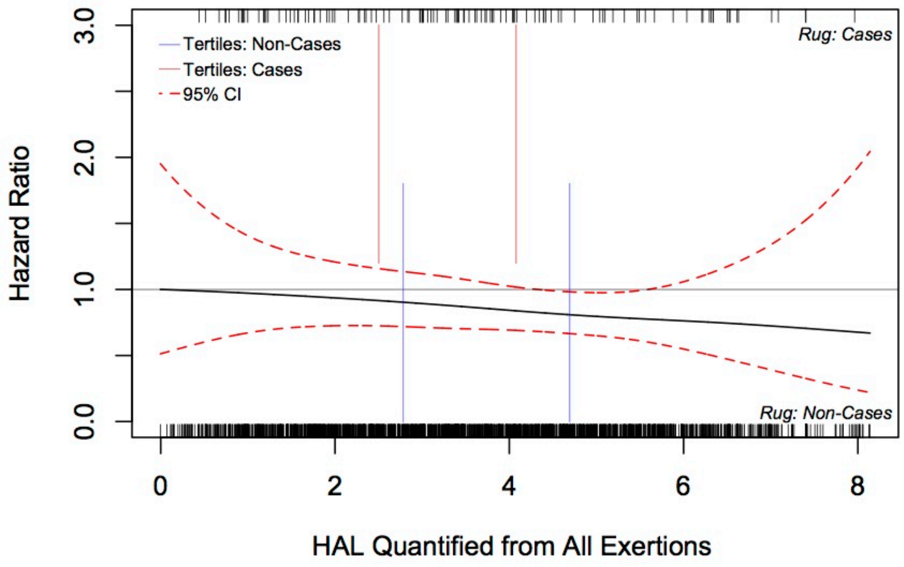


HR for % Time in Forceful Exertion

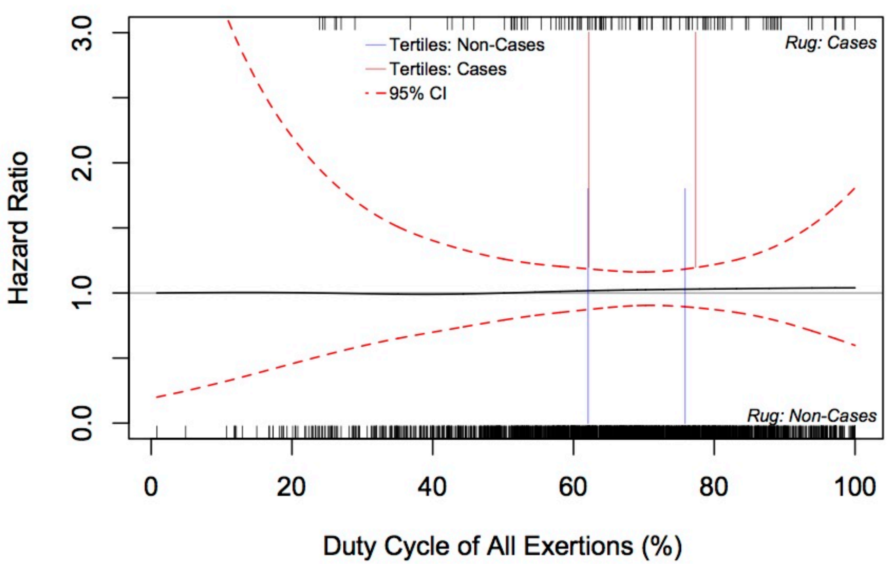


Repetition Alone

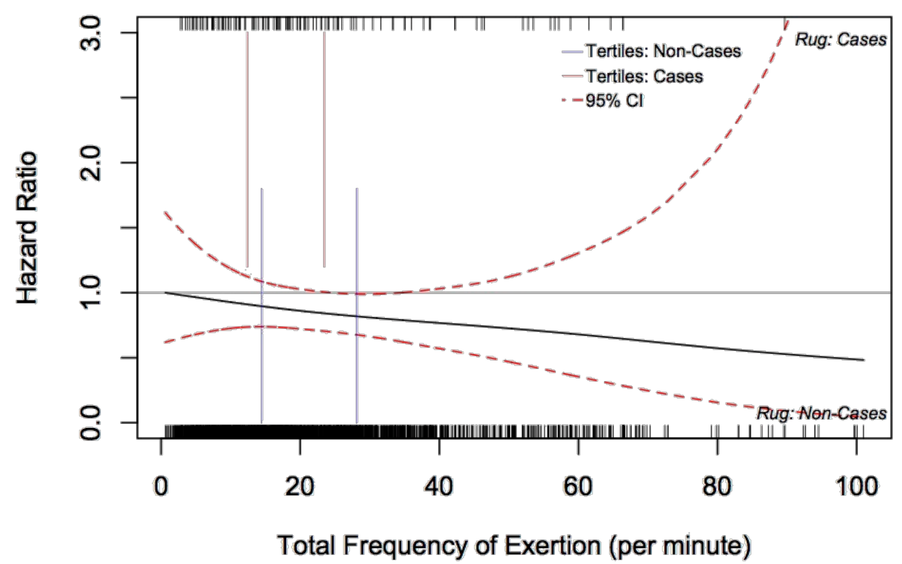
HAL (Computed)



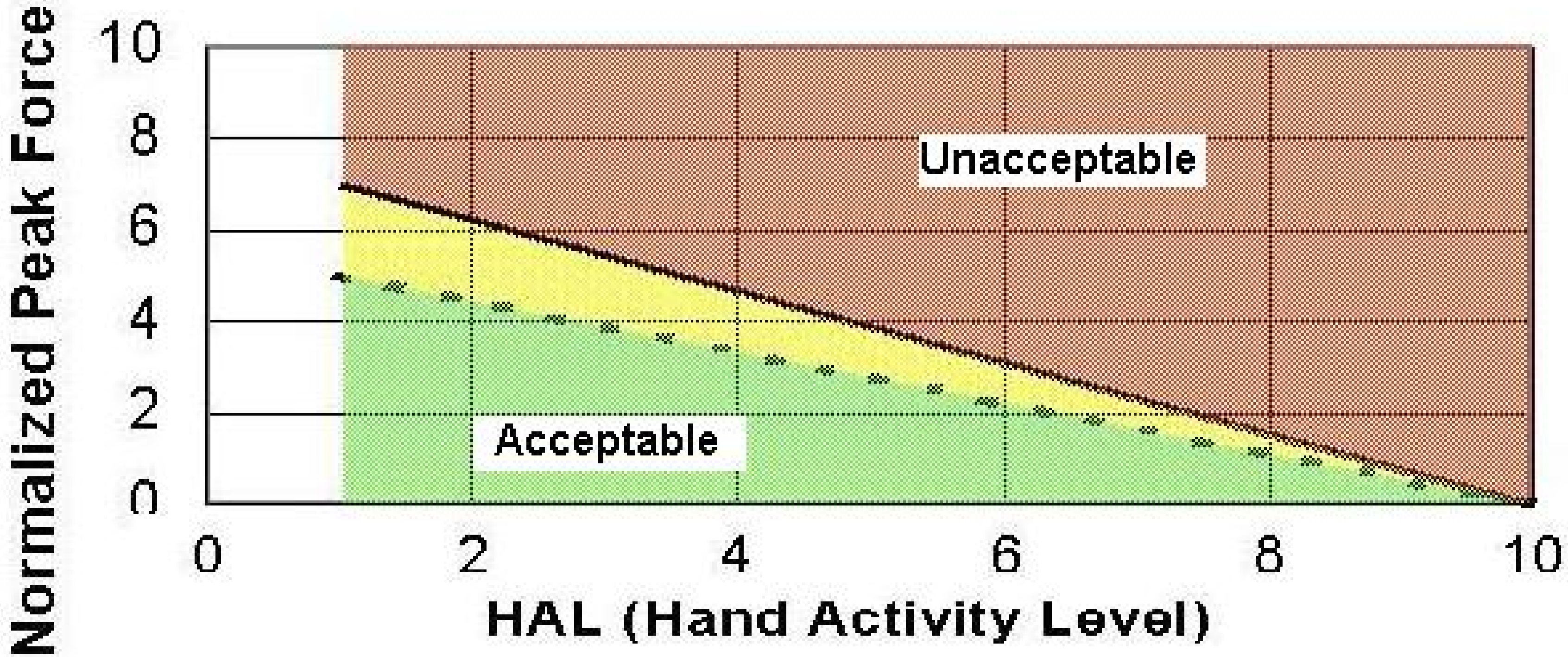
Duty Cycle



Frequency



Threshold Limit Value for Hand/Wrist Exposures (ACGIH, 2001)



TLV for HAL score = PF/(10-HAL)

OCTOPUS study

[Bonfiglioli R, et al. OEM 2013; Violante et al. SJWEH 2016]

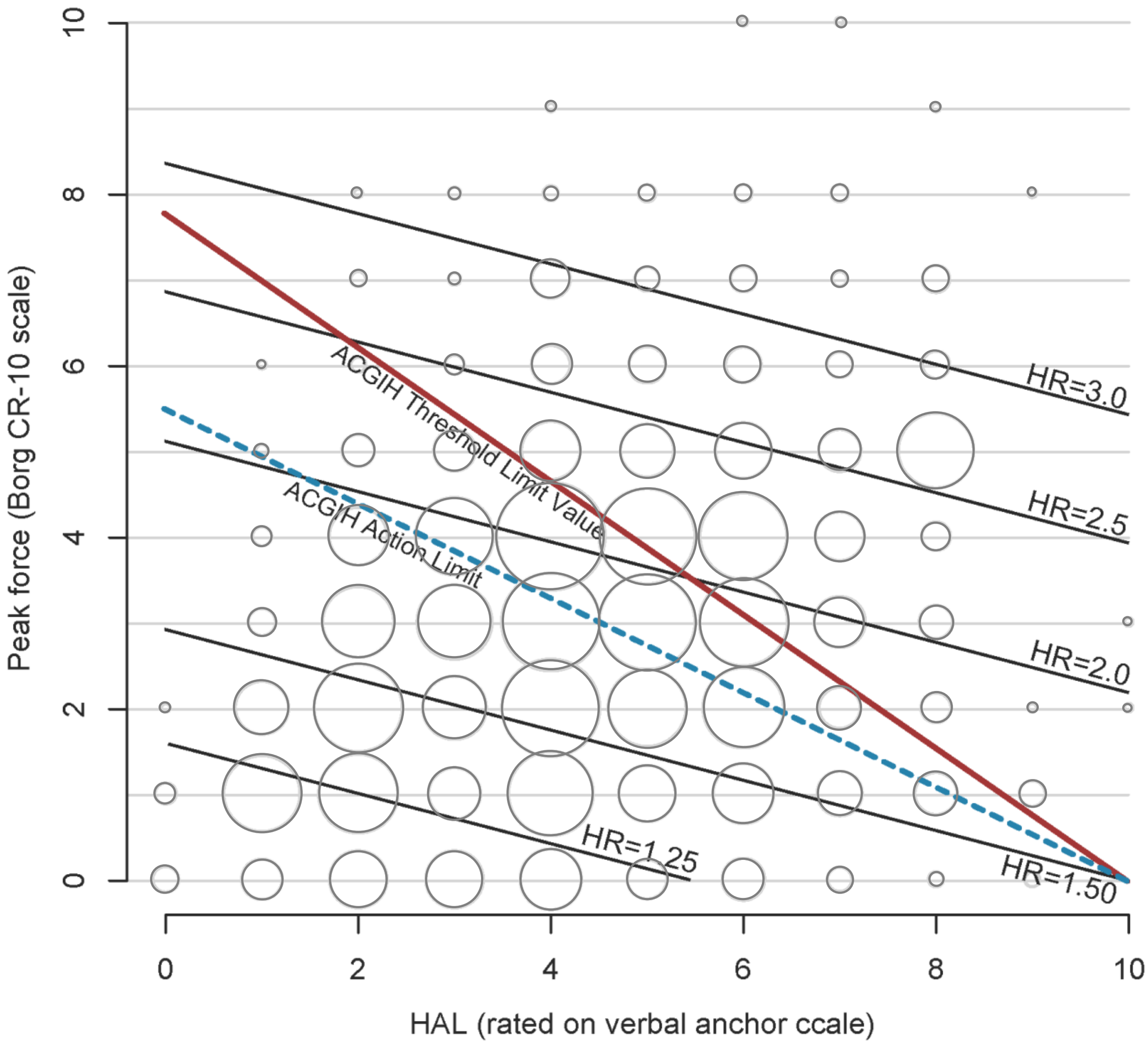
- Prospective cohort study in manufacturing and service workers
- 4232 in cohort; study population 3131
- Ratings of Peak Force and Hand Activity Level performed at task level by trained observers
- Case definition including CTS symptoms and slowing of median nerve conduction
- 126 cases of CTS observed in 8883 person years

Hazard Ratios for TLV

TLV for HAL	Bonfiglioli et al 2013	Violante et al 2016	Kapellusch et al 2014
≤ AL	1.00	1.00	1.00
>AL ≤ TLV	1.95 (1.21 – 3.16)	1.93 (1.38-2.71)	1.73 (1.19-2.50)
>TLV	2.70 (1.48 – 4.91)	1.95 (1.27 – 3.00)	1.48 (1.02-2.13)

Contour Plot for PF + HAL Model

score = PF + 0.3*HAL (Kapellusch et al. 2014)



ACGIH TLV (HAL & PF)

- Consistent results from two large cohorts
- TLV predicts CTS; different calculations using HAL and PF are even more predictive
- Current Action Limit and TLV are too high to adequately protect workers
- Non-linearity of risk; highest exposures sometimes associated with lower risk than “intermediate” exposures (survivor effect?)
- Higher rates of CTS among newer workers (NIOSH); higher rates among those that decreased exposures during study (OCTOPUS)

Consortium Study Strengths

- Prospective design
- Large cohort
- Varied workplaces – generalizable findings
- High participation rate (>80%)
- Specific CTS case criteria using nerve conduction
- Quantitative individual exposure measures
- Both personal and workplace factors measured
- Exposure response modeling

Limitations

- Six individual studies with different designs
- Exposure based on limited windows of observation
- Relatively few low exposure or variable exposure jobs included in pooled analyses
- Limited data on vibration exposure
- Few workers with long duration of exposure in extreme flexion or extension

Summary of Consortium Findings

- Biomechanical factors associated with CTS
  - Peak hand force (Borg CR10 ≥ 3)
  - <u>Forceful</u> hand repetition rate (>3 exertions/min)
  - % time in <u>forceful</u> hand exertions (> 11%)
- Biomechanical factors not associated with CTS
  - <u>Total</u> hand repetition rate
  - % time <u>any</u> hand exertions
  - Wrist posture
- Interventions for CTS in production workers should focus on reduction in peak force and duration of forceful hand activity

Next Steps

- Analyze other endpoints:
  - Wrist tendinitis
  - Elbow and shoulder disorders
- Evaluate functional outcomes
- Combine data with other large cohorts
- Revise TLV for HAL (ACGIH)
- Revise the Strain Index

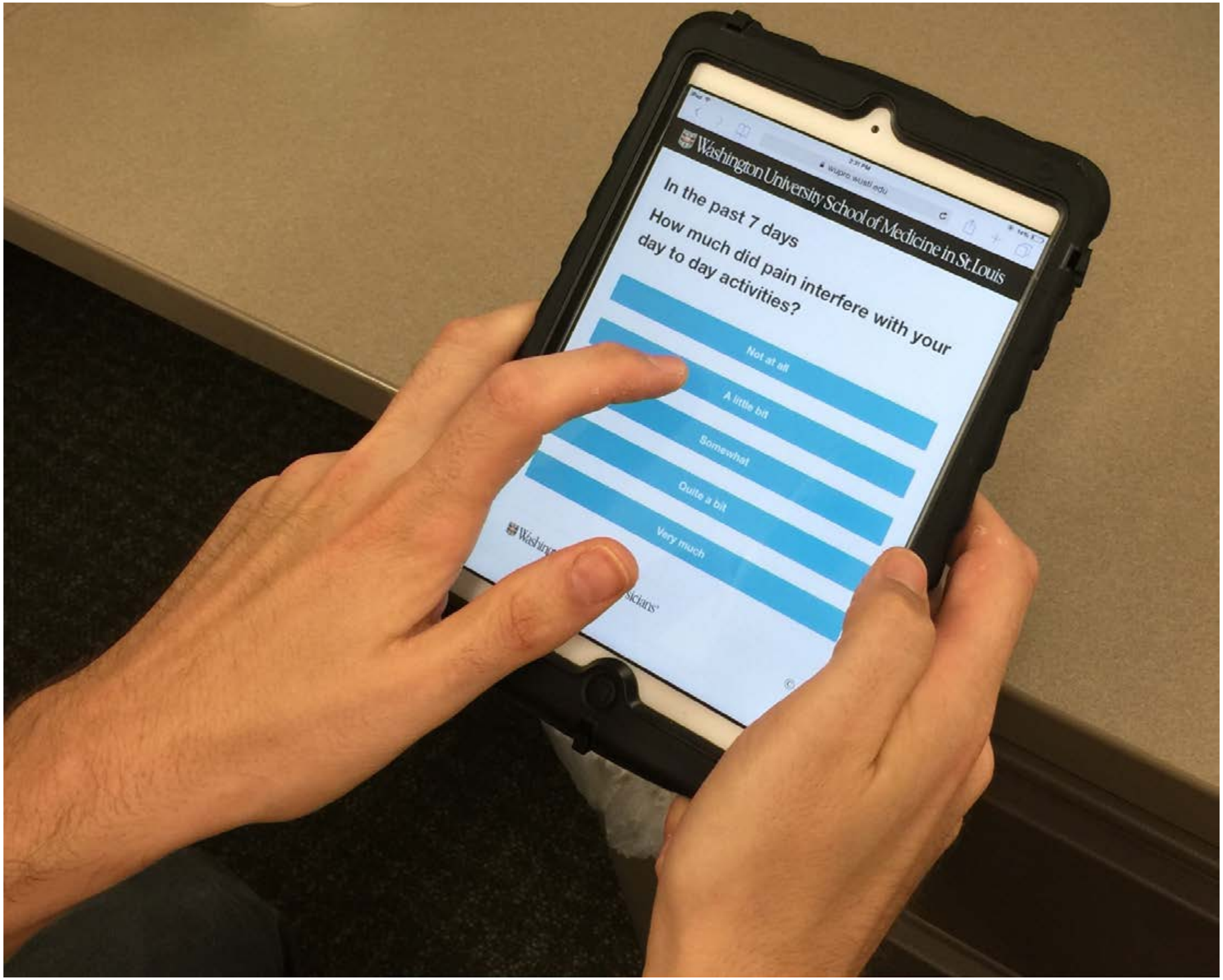
What should we do now? Outcomes, Exposures, Interventions

- Longitudinal studies
  - Expensive, labor intensive
- Outcome assessment
  - Are we measuring the most important outcomes?
- Exposure assessment
  - Expensive, labor intensive
  - Variable jobs an issue
- Interventions – design for dissemination

Outcomes

- Most case definitions centered on clinical diagnosis: symptoms, physical signs
- Research should incorporate more worker-centered outcomes (pain, function, work limitation) and employer-centered outcomes (productivity, cost, quality)
- More use of registry studies; electronic health records and Workers’ Compensation
- Link EHR to SOC codes

PROMIS: Patient-Reported Outcomes



Embrace New Approaches to Exposure Assessment

- New technologies – wearable sensors
- Automated coding of videos (Radwin)
- Job Exposure Matrix (JEM) allows exposure estimation for large registry and cohort studies based on job titles
- TLV for HAL, other less labor intensive assessment tools (JEM) appear valid and usable for workplace prevention

Approaches to intervention

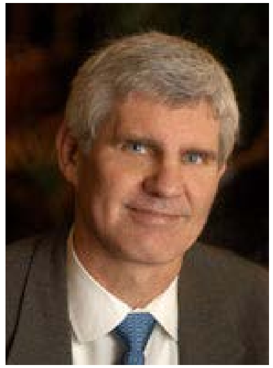
- Build case for urgency – MSD are a major source of morbidity, disability, cost
- Provide practitioners with better tools to identify and reduce the exposures associated with disease (design for dissemination)
- Validate usable exposure assessment tools
- Test practical interventions for exposure reduction
- Focus on the most important exposures in high risk groups– prolonged and repeated forceful hand exertions

Translate our work into prevention

"If we wait until we're ready, we'll be waiting for the rest of our lives."

— Lemony Snicket


B. Silverstein


D. Rempel


S. Burt


A. Garg


F. Gerr

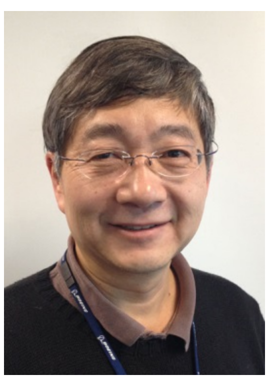

K. Hegmann


J. Kapellusch


C. Harris-Adamson


E. Eisen


A.M. Dale


S. Bao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ZJ Fan

Work-related Psychosocial Risk Factors for Low Back Pain Evidence from 2015 NHIS Data

June 22, 2017

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Impact of Low Back Pain

- Burden:
  - Low back pain (LBP) is a common health problem (~1 in 4 adults)
  - Tremendous economic burden ($119-238 Billion per year).
  - Leading cause of disability
    - #1 Years Lived with Disability (YLDs) in the US
    - #1 in YLDs Globally
- Need:
  - >85% of LBP are non-specific abnormality. Need research.
  - Understanding of interactions between risk factors for LBP is poor.
- Impact:
  - All walks of life, in particular 3.7 million workers involving repetitive manual materials handling (MMH) as part of their regular job.
  - Top impacted industries: Manufacturing, warehousing, retail trade and transportation; and health care.

Background

- Workplace psychosocial factors play some role in the development of back pain.
- Interactions of psychosocial factors with other risk factors are poorly understood.
- Insight into the interactions may provide information needed for effective LBP prevention strategies.

National Health Interview Survey

- NHIS is a questionnaire-based cross-sectional health survey of a nationally representative population of the US.
- NHIS covers a broad range of health questions, demographic, personal behavior and work-related factors.
- NHIS has core and occupational health supplement (OHS) questions.
- Final sample adult response rate was 55.2% in 2015.

Methods

- Selected variables from 2015 NHIS dataset.
- Respondents aged 18 and over, employed and worked at least 20 hours per week (N=17,911).
- Multivariable logistic regression analyses: full model; sex or age (“young”=18-40; “old”=41-64 and over) stratified model.
- Tree analysis (Breiman et al., 1984) as a supplementary analysis for a deeper understanding of interactions of risk factors.

Tree Analysis

- Recursive partitioning of data to minimize impurity of tree nodes (Breiman et al., 1984).
- Tree model set up
  - Model construction rule: Gini algorithm
  - 80% learn and 20% test samples
  - Tree selection: minimal cost
    - Δ Gini (Y, x) = Gini (Y)- p (Y_L)Gini (Y_L)- p (Y_R)Gini (Y_R)
    - (1-sensitivity)+(1-specificity))
  - Minimal size below which node will not be split: 100
  - Minimal size for end node: 50

Variables

- Dependent variable: Self-reported LBP in the past three months (Yes or No).
- Independent variables:
  - Personal: sex, age, race/ethnicity, education, obesity (BMI≥30), leisure-time physical activity, serious psychological distress
  - Workplace psychosocial: job demand, job control, supervisory support, work-life interference, exposure to hostile work, job insecurity
  - Work organizational: job arrangement, shiftwork, work hours, occupation category, earnings.
  - Workplace physical: physical exertion, sedentary work

Independent Variables

- Most independent variables were dichotomized by the mid point of the 4-point frequency Likert scale (i.e., low exposure: 1-2; high exposure: 3-4).
- Independent variables dichotomized by other methods:
  - Shiftwork: Regular shift vs. other shifts.
  - Physical exertion and sedentary work: 5-point frequency Likert scale: categories 1-2 (low) vs. 3-5 (high)
  - Psychological distress was measured by the Kessler 6 Scale. Sum of score for the 6 scales was calculated. A score > 13 was used to indicate psychological distress (Pratt et al., 2007)
  - Obesity: Yes if BMI≥30

Independent Variables (cont.)

- Other multi-level categorical independent variables:
  - Age: 18-25; 26-40; 41-55; 55-64; 65 and over
  - Work hours (20-39; 40; 41-45; 46-59; 60 and over)
  - Occupation (22 categories)
  - Earnings (5 categories)
  - Education (5 categories)
  - Race/Ethnicity (white, black, Asian, Hispanic, Others)
- All categorical variables were used in the tree analysis except age (continuous).

Results:

Logistic Regression Analysis (full model)

	OR	CI
	All	N=14,580
Workplace psychosocial factors		
Work family interference	**1.21**	(1.07,1.35)
Hostile work environment	**1.67**	(1.37,2.04)
Job insecurity	**1.39**	(1.2,1.61)
High demand	**1.25**	(1.08,1.44)
Low control	0.95	(0.83,1.09)
Lack of supervisor support	1.1	(0.95,1.28)
Physical risk factor		
Physical exertion	**1.33**	(1.19,1.5)
Sedentary work	0.94	(0.83,1.05)
Health behaviors		
Leisurely Active	0.92	(0.82,1.03)
Serious psychological distress	**2.51**	(2.09,3.03)
Obesity (BMI≥30)	**1.19**	(1.08,1.31)
Sex		
Female	1.06	(0.95,1.17)
Age group		
18-25	1	
26-40	**1.36**	(1.13,1.65)
41-55	**1.78**	(1.48,2.14)
56-64	**1.73**	(1.41,2.14)
65 and over	**1.68**	(1.29,2.2)

Note: OR adjusted for race/ethnicity, education, earnings, job arrangement, shiftwork, work hours, occupation

OR in bold font indicates a statistical significance (P<0.05)

Results:
Logistic Regression Analysis (Sex-stratified)

	OR Male	CI N=7,335	OR Female	CI N=7,245
Workplace psychosocial factors				
Work family interference	**1.19**	(1.02,1.38)	**1.22**	(1.01,1.48)
Hostile work environment	**1.63**	(1.2,2.2)	**1.71**	(1.34,2.19)
Job insecurity	**1.49**	(1.19,1.87)	**1.26**	(1.01,1.57)
High demand	1.13	(0.91,1.39)	**1.36**	(1.13,1.64)
Low control	0.92	(0.75,1.12)	1	(0.82,1.21)
Lack of supervisor support	1.17	(0.94,1.45)	1.05	(0.85,1.29)
Physical risk factor				
Physical exertion	**1.31**	(1.1,1.57)	**1.32**	(1.12,1.56)
Sedentary work	0.98	(0.83,1.16)	0.92	(0.77,1.1)
Health behaviors				
Leisurely Active	0.79	(0.67,0.94)	1.06	(0.9,1.25)
Serious psychological distress	**2.18**	(1.63,2.92)	**2.79**	(2.18,3.57)
Obesity (BMI≥30)	**1.08**	(0.93,1.25)	**1.32**	(1.13,1.53)
Sex				
Female				
Age group				
18-25	1		1	
26-40	**1.31**	(1,1.71)	**1.44**	(1.11,1.87)
41-55	**1.81**	(1.39,2.36)	**1.81**	(1.41,2.32)
56-64	**1.59**	(1.18,2.15)	**1.96**	(1.47,2.61)
65 and over	**1.57**	(1.05,2.35)	**1.89**	(1.32,2.71)

Note: OR adjusted for race/ethnicity, education, earnings, job arrangement, shiftwork, work hours, occupation

OR in bold font indicates a statistical significance ($P<0.05$)

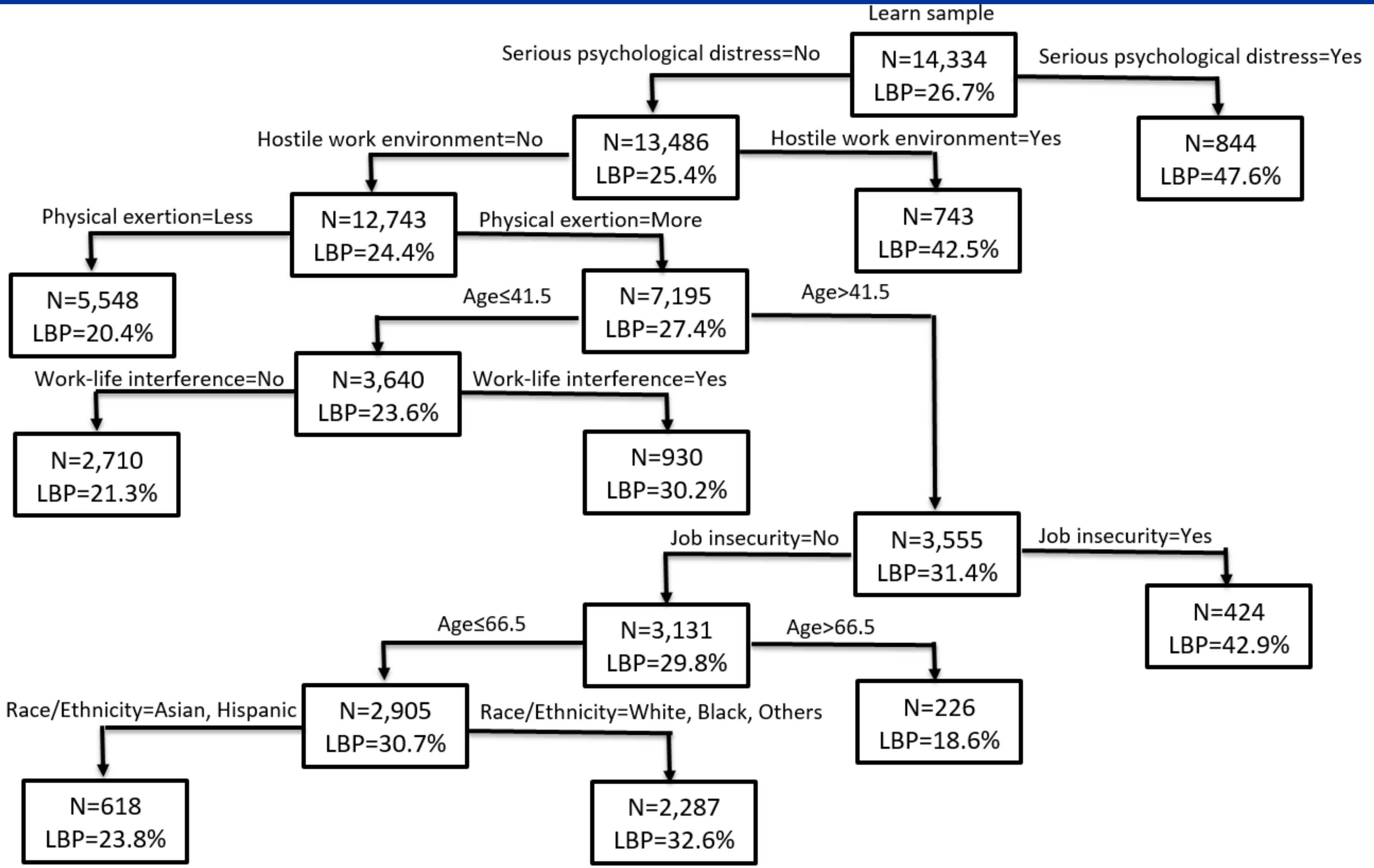
Results:
Logistic Regression Analysis (Age-stratified)

	OR Young	CI N=6,981	OR Old	CI N=6,877
Workplace psychosocial factors				
Work family interference	**1.38**	(1.2,1.6)	1.07	(0.9,1.26)
Hostile work environment	**2**	(1.47,2.72)	**1.45**	(1.12,1.88)
Job insecurity	**1.27**	(1,1.61)	**1.51**	(1.24,1.83)
High demand	**1.29**	(1.04,1.62)	**1.23**	(1.02,1.48)
Low control	0.87	(0.71,1.08)	1.01	(0.83,1.24)
Lack of supervisor support	1.01	(0.81,1.27)	1.17	(0.95,1.45)
Physical risk factor				
Physical exertion	**1.24**	(1.02,1.51)	**1.42**	(1.22,1.66)
Sedentary work	0.97	(0.8,1.19)	0.9	(0.76,1.05)
Health behaviors				
Leisurely Active	1.04	(0.87,1.25)	0.84	(0.72,0.99)
Serious psychological distress	**2.5**	(1.95,3.2)	**2.44**	(1.86,3.2)
Obesity (BMI≥30)	**1.19**	(1.02,1.39)	**1.19**	(1.05,1.36)
Sex				
Female	**1.21**	(1.03,1.42)	0.97	(0.84,1.13)

Note: OR adjusted for race/ethnicity, education, earnings, job arrangement, shiftwork, work hours, occupation

OR in bold font indicates a statistical significance (P<0.05)

Results: Tree Analysis



Highlights of Results

- Per NHIS data, the 3-month prevalence of LBP in the US working population was 26.7%.
- Serious psychological distress had the highest odds (OR=~2.5 or 150% increased risk) of LBP.
- High physical exertion, work-life interference, hostile work environment, job insecurity were associated with LBP.

Discussion (Regression Models)

- Female workers aged between 18-40 may have an increased risk (20%) of LBP.
- Age was associated with LBP in both sexes.
- Psychosocial job demands were not associated with LBP for male workers.
- Work-life interference was associated only with workers aged 40 and younger.

Discussion (Tree Analysis)

- Under no serious psychological distress and hostile work environment, job insecurity was a risk factor for workers older than 42 involving increased job physical exertions; while work-life interference was a risk factor for workers younger than 42 involving increase job physical exertions.
- Among workers without serious psychological distress, exposure to a hostile work environment had an increased rate (42.5%) of LBP vs. the rate (24.4%) without the exposure.
- Sex was not a significant factor in moderating the risk associations.

Limitations

- Cross-sectional design. No causal implications.
- Frequency and intensity of pain was not analyzed although available.
- Single item risk assessments for both workplace psychosocial and physical factors were likely to be less reliable.

Take-Home Messages

- Sex may not be a significant factor moderating various risk factors for LBP.
- Age may play a more important role in developing LBP than sex.
- Psychological distress, hostile environment and physical exertion were three main risk factors for LBP.
- The tree analysis that simulates human decision making may be more practical for implementing or prioritizing interventions for reducing risk factors.

Questions?

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