

The ACGIH 2018 TLV for Hand Activity: Recent research findings and the revised TLV

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SCHOOL OF MEDICINE

ACGIH®

- ACGIH® Recommends Threshold Limit Values (TLVs®) – Safe exposure limits for chemical, physical and biological agents
- TLVs® – based on published data - not political consensus.

www.acgih.org

ACGIH Hand Activity TLV[®] (Revised 2018)

- For prevention of work-related hand, wrist and forearm MSDs.
- Based on epidemiological, psychophysical and biomechanical studies
- Goal: set TLV below which nearly all workers may be repeatedly exposed without adverse health effects
- Applies to mono-task job performed ≥ 4 hours per day

Other ACGIH Ergonomic TLVs

- Upper limb fatigue (2018)
- Hand-Arm Vibration (revised 2017)
- Whole-Body Vibration (revised 2017)
- Lifting

Why study CTS?

- Most common entrapment neuropathy – compression of median nerve in carpal tunnel
- Common upper extremity ambulatory surgery: almost twice as common as rotator cuff repair among people aged 45-64
- Associated with large financial burden in compensation systems, significant disability
- Estimates vary widely depending on how CTS is defined and counted (passive vs. active surveillance)
- Model for other UE MSD

Risks for CTS

- Strong support in the literature for increased risk of CTS associated with
 - *Personal factors* including age, BMI, gender, some diseases (diabetes, arthritis)
 - *Work exposures* including forceful grasp, pinch, repeated hand/wrist exertion, vibration
- Exposure response relationships, attributable risk continue to be defined

NIOSH Upper Extremity Consortium Studies:

- Prospective studies
- Assess personal and work factors
- Quantify relationship between exposures and outcomes
- Rigorous case definitions
- Individual level exposures



55 Companies 4321 Workers

**Production, food processing, health care,
Construction, service, technical**



Studies collected similar (but not identical) data

- Questionnaire / Interview
- Individual level exposure information
- Structured physical examination
- Nerve Conduction Studies
 - Median nerve at wrist
 - Ulnar nerve at wrist
- Measures repeated over time
- Subjects followed 3-7 years

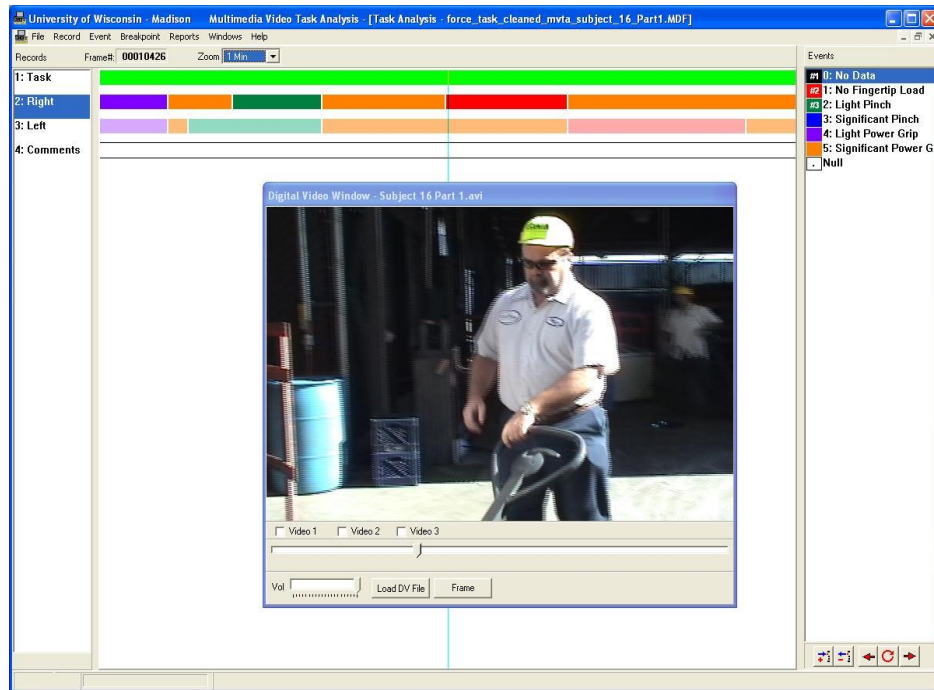
Common case definition for CTS required symptoms and abnormal nerve conduction

- 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° Flex?	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 = $\geq 9\text{N}$ (1 kg) pinch force or $\geq 45\text{N}$ (4.5 kg) of power grip



MVTA used to estimate:

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

Borg CR-10 Scale

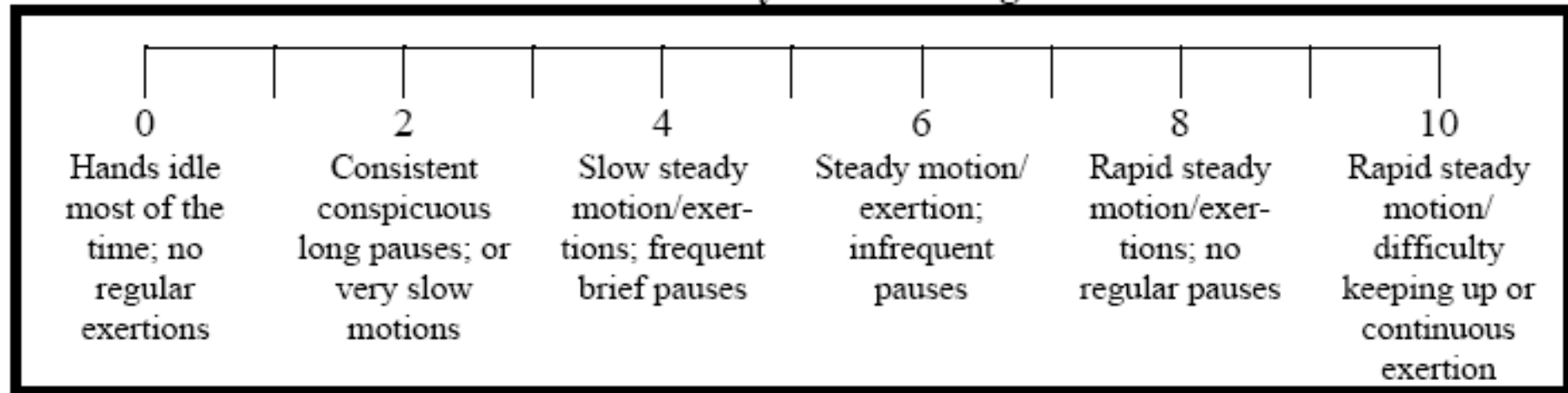
Estimated Intensity of Task Peak Hand Force



<u>Score</u>	<u>Worker Verbal Estimate</u>	<u>Observer Estimate</u> (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)	

HAL Scale

Hand Activity Level Rating



Hazard Ratios for Demographic Factors

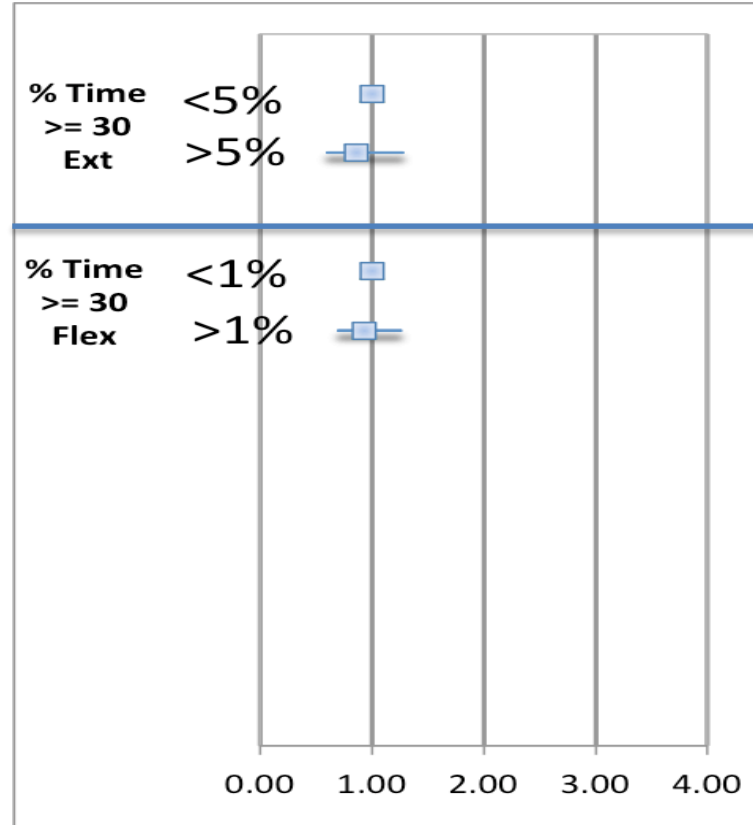
[Harris C et al. OEM 2013; 70:529]

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]
Non-occupational hand activity > 3h/w	0.58 [0.41-0.82]

Hazard Ratios: Wrist Posture*

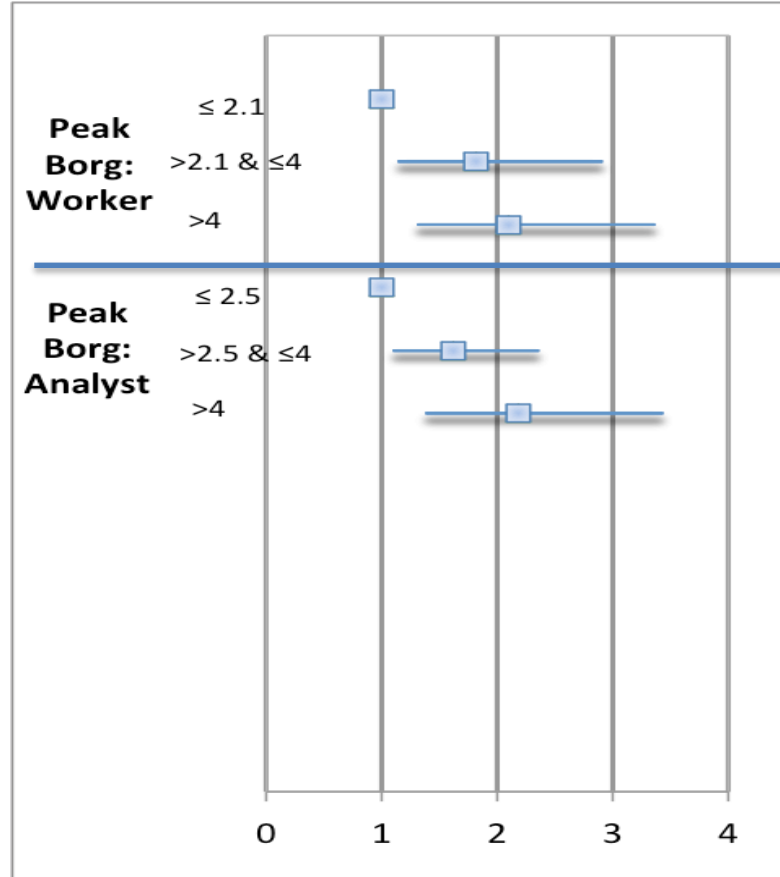
[Harris C et al. OEM 2015;72:33-41]

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



Hazard Ratios: Peak Hand Force*

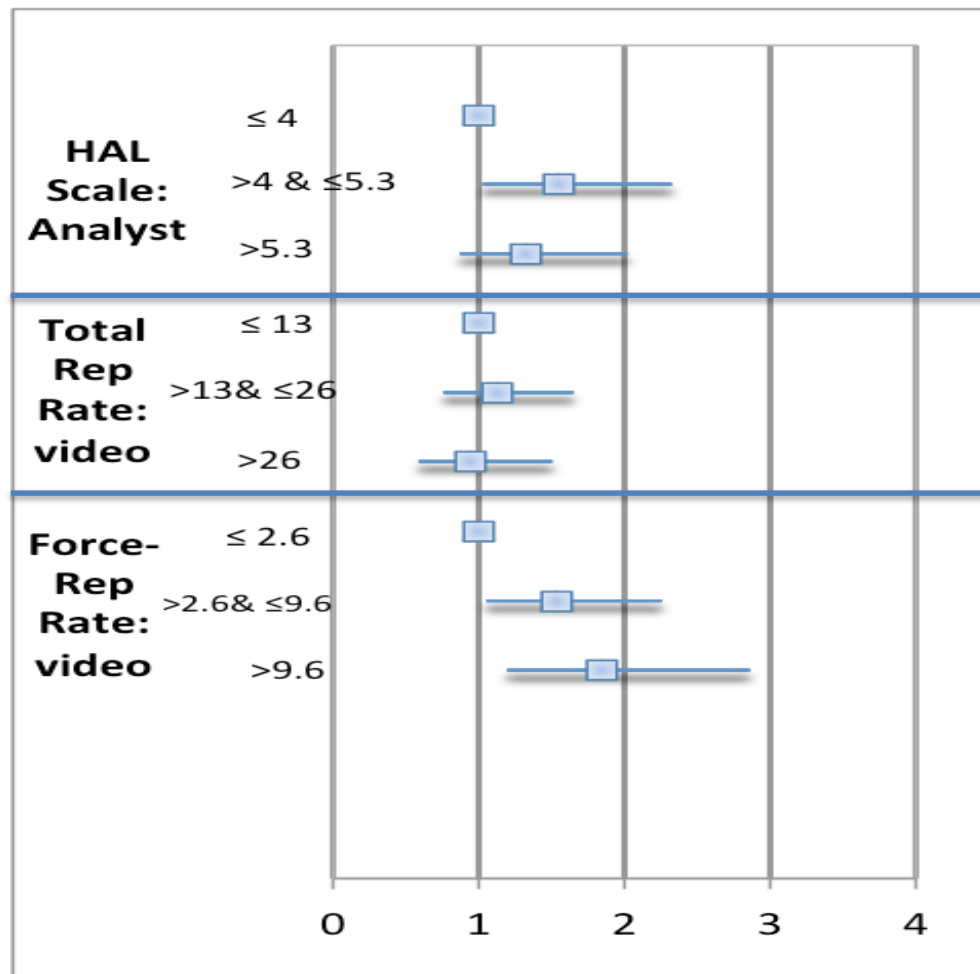
*Adj. for age, gender,
BMI, Study site and
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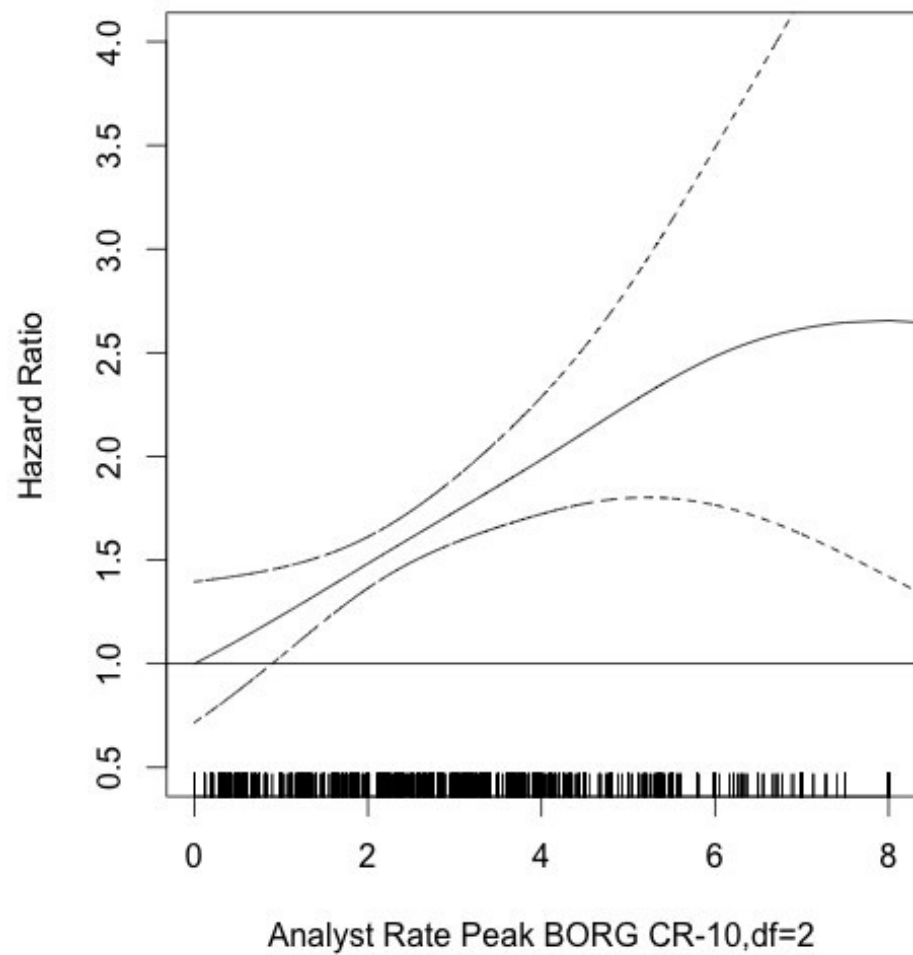


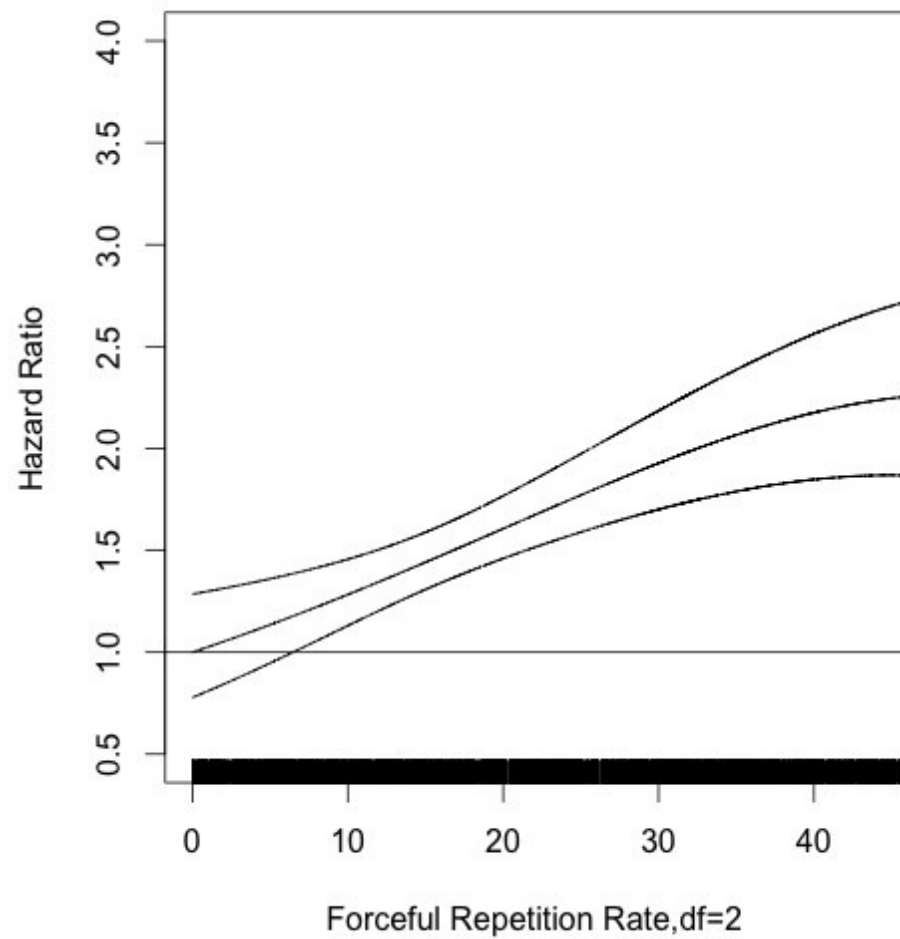
Hazard Ratios: Hand Repetition*

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

**Forceful = $\geq 9\text{N}$
pinch force or
 $\geq 45\text{N}$ of power
grip





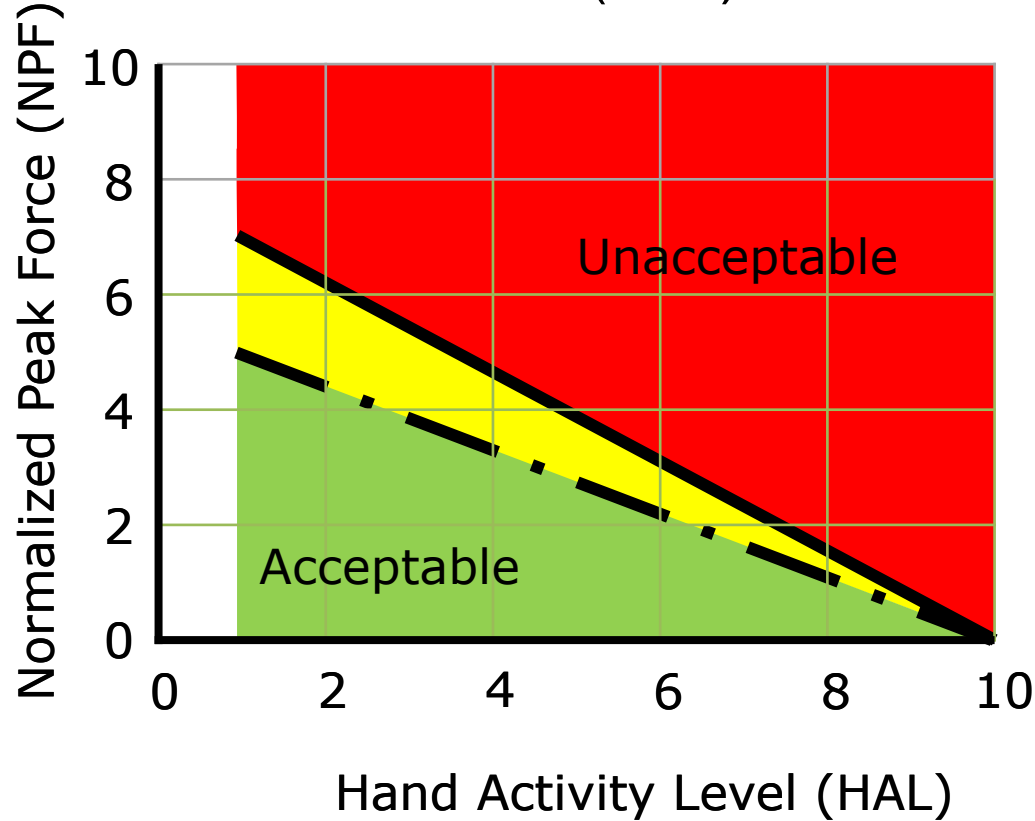


Summary of Consortium Findings

- Biomechanical factors associated with CTS
 - Peak hand force (Borg CR10 ≥ 3)
 - Forceful* hand repetition rate (>3 exertions/min)
 - % time in forceful* hand exertions ($> 11\%$)
- Biomechanical factors not associated with CTS
 - Total hand repetition rate
 - % time any hand exertions
 - Wrist posture

*Forceful = $\geq 9\text{N}$ pinch force or $\geq 45\text{N}$ of power grip

ACGIH Threshold Limit Value (TLV) for Hand Activity Level



Top line - TLV

Lower line - Action limit (surveillance and training)

OCTOPUS study

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

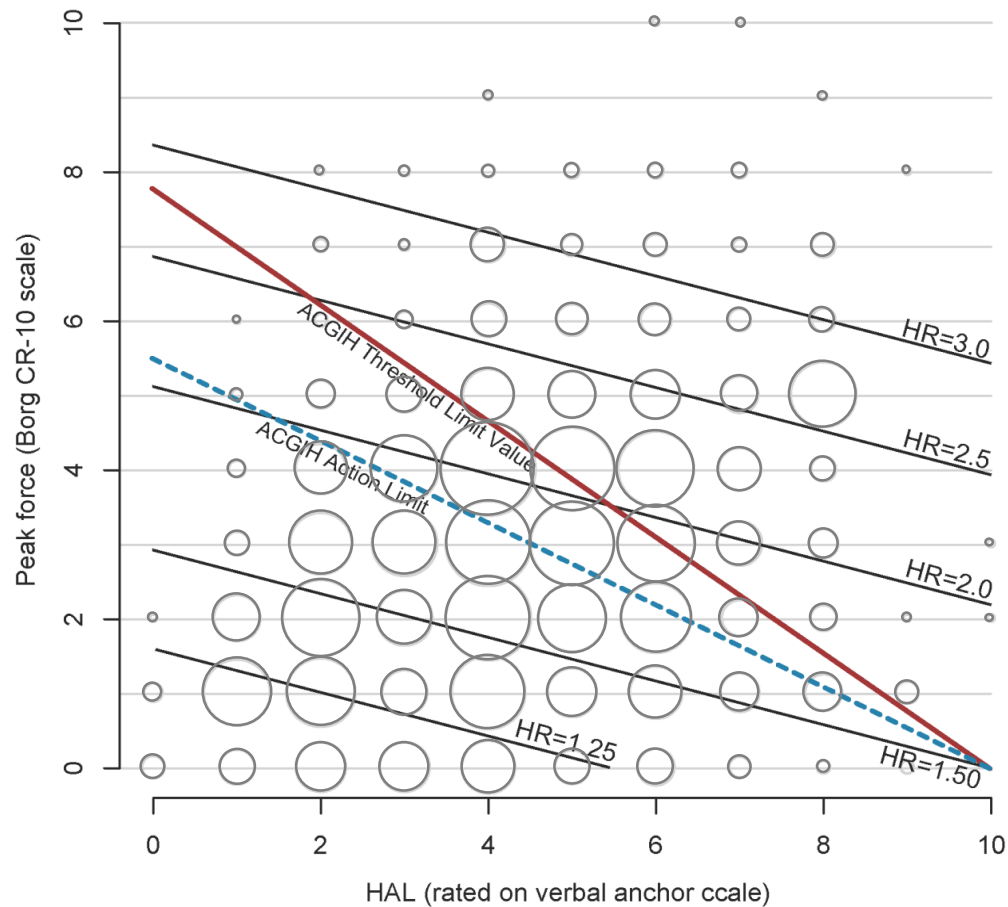
- Prospective cohort study in manufacturing and service workers
- 4232 in cohort
- Ratings of Peak Force and Hand Activity Level performed by trained observers
- Case definition for Carpal Tunnel Syndrome (CTS) required symptoms and slowing of median nerve conduction

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

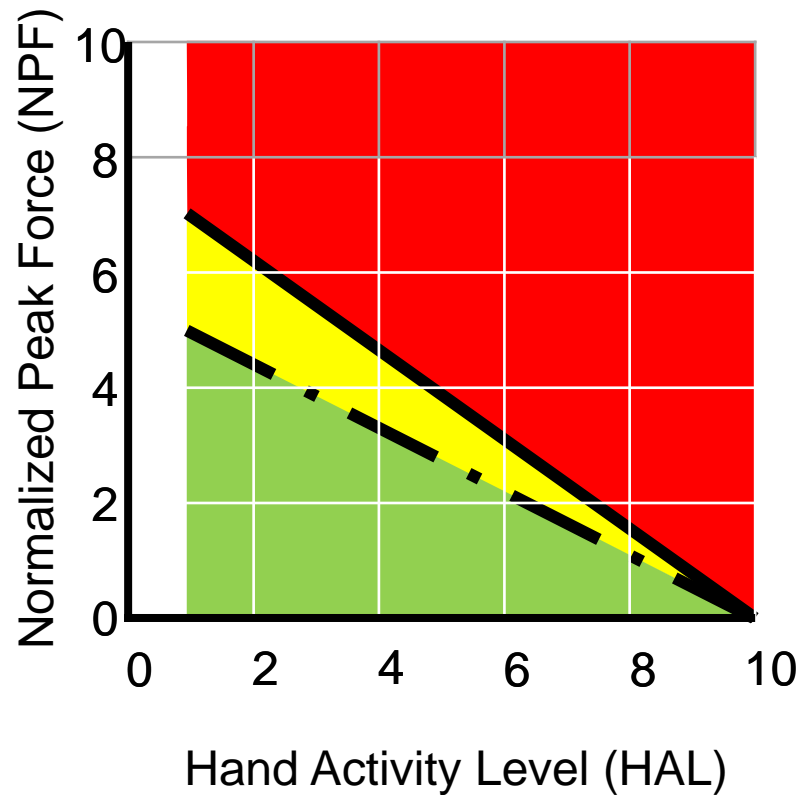
score = PF + 0.3*HAL (Kapellusch et al. 2014)



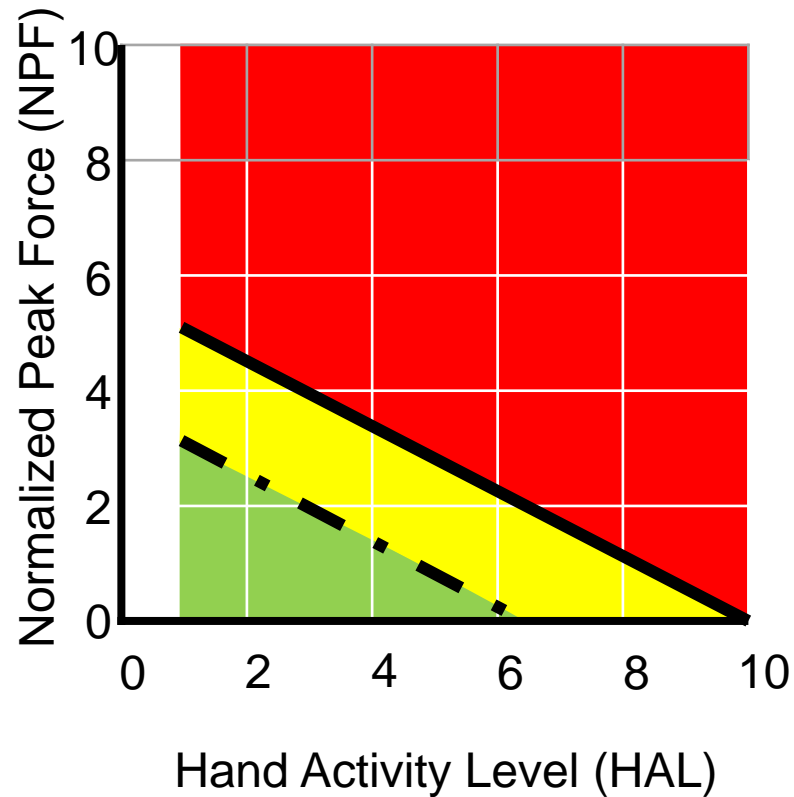
ACGIH TLV (HAL & PF)

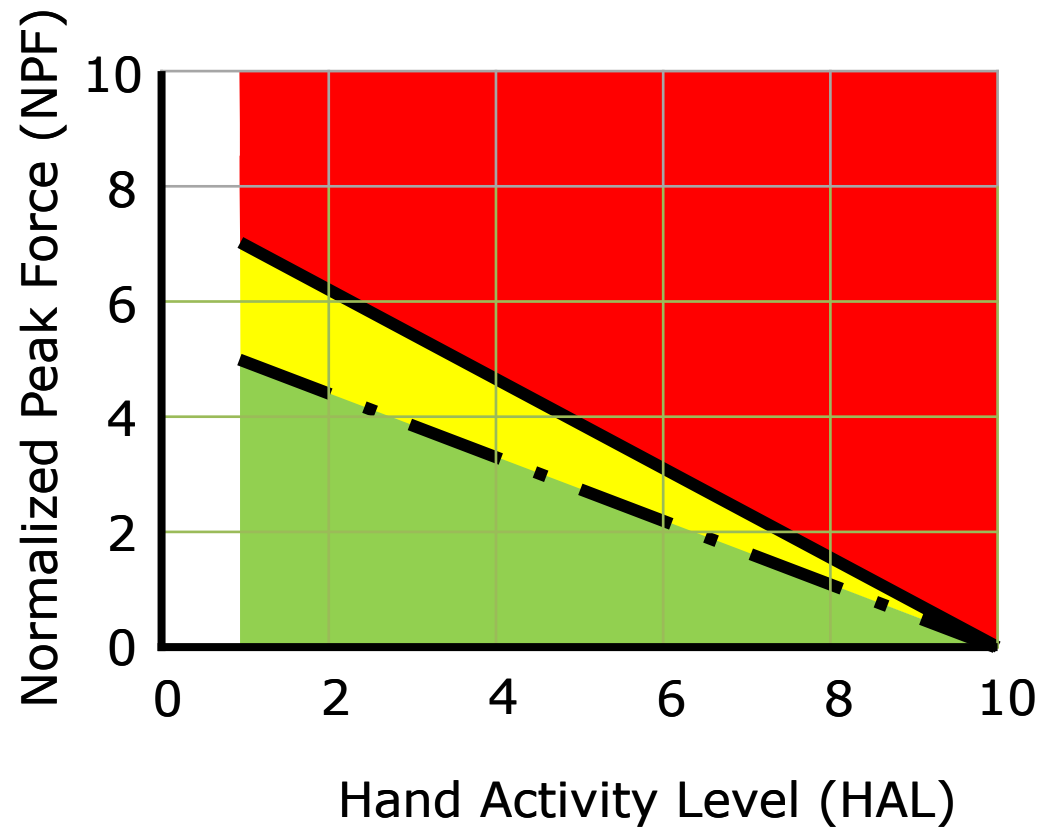
- Consistent results from two large cohorts
- TLV predicts CTS
- Different calculations using HAL and PF are even more predictive
- 2001 Action Limit and TLV were too high to adequately protect workers
- The ACGIH used these data to revise the TLV!

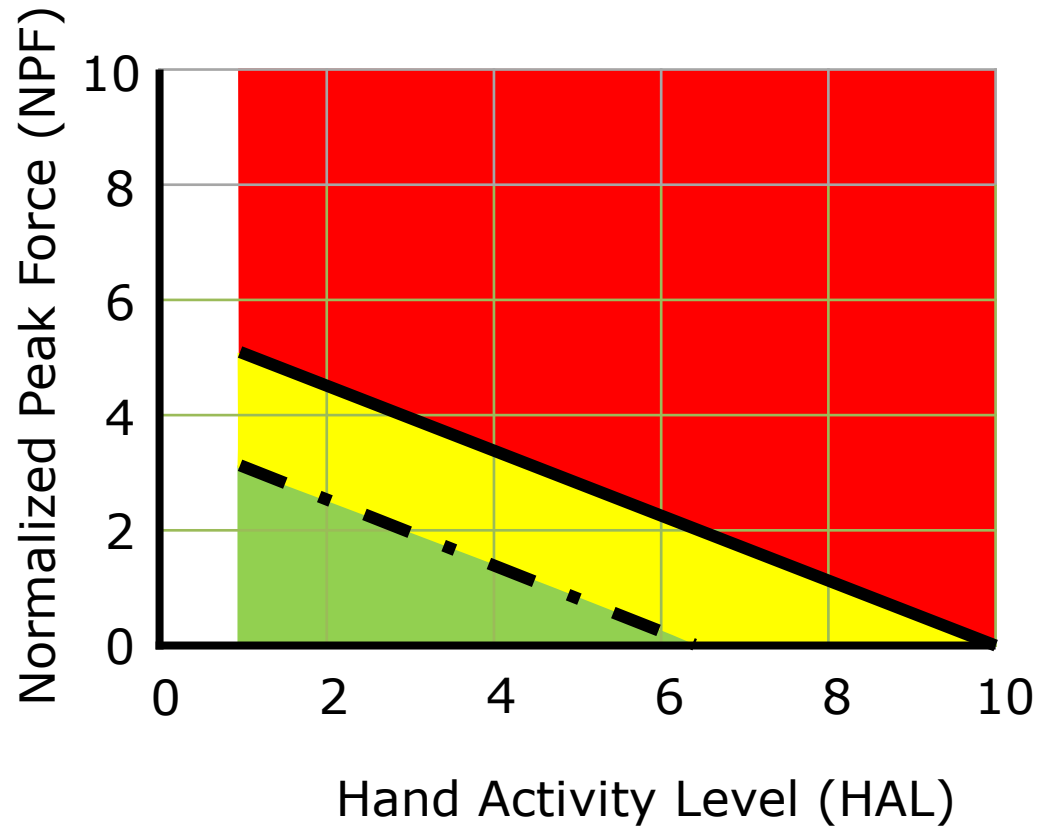
ACGIH TLV for Hand Activity - 2001



ACGIH TLV for Hand Activity - 2018







How many cases of CTS could be prevented by application of the new Hand Activity TLV?

- Modeled the 2,751 workers with full data in NIOSH Consortium (6,282 person years)
- For both the 2001 and 2018 HA TLV, workers characterized as:
- Below the AL **GREEN**
- Between the AL and TLV **YELLOW**
- Above the TLV **RED**

Percentage of workers exposed at different TLV thresholds

2,751 workers (6,282 person years)

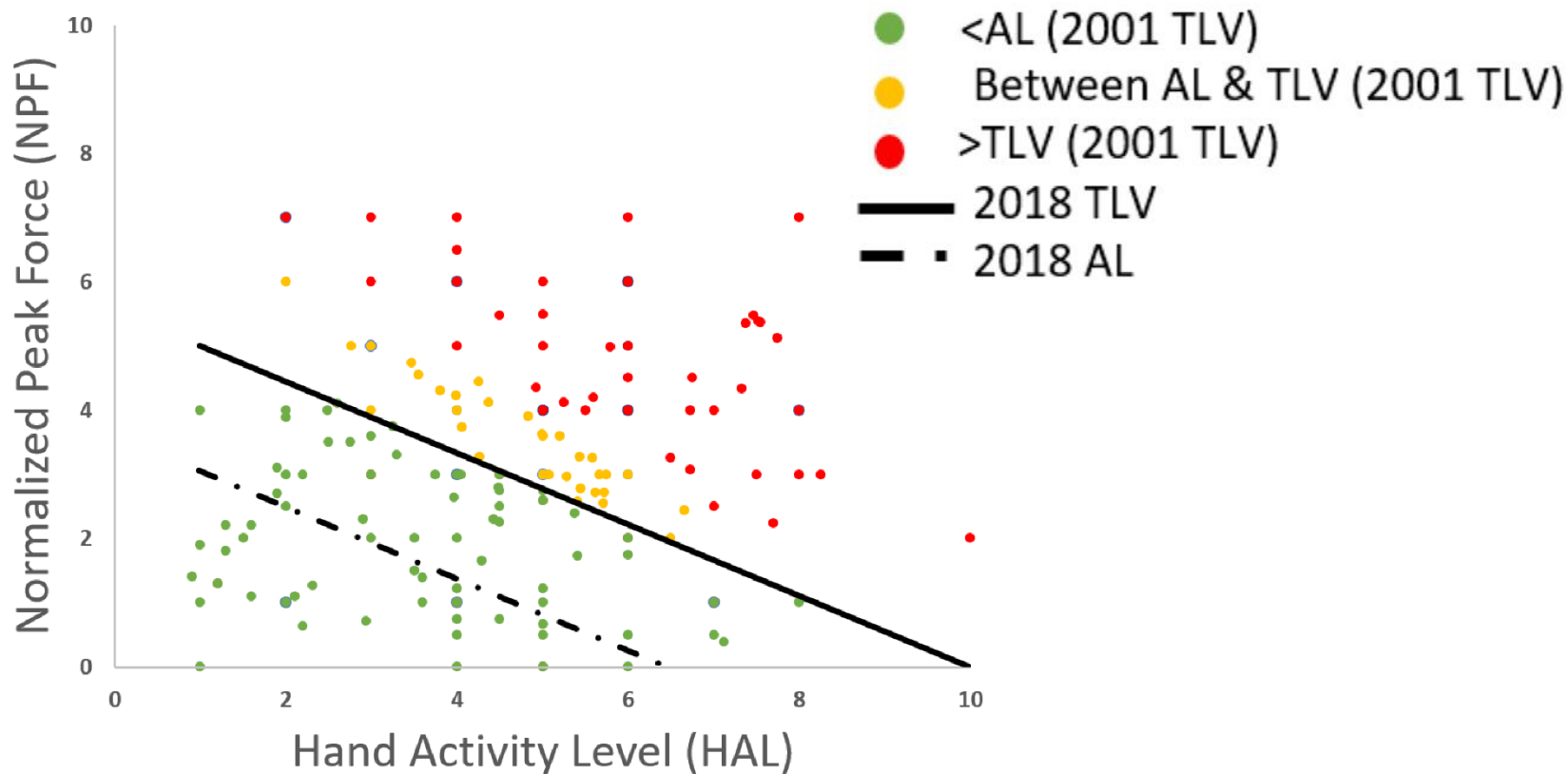
Exposure category	2001 HA TLV	2018 HA TLV
<AL	58%	24%
≥AL, <TLV	19%	34%
> TLV	23%	42%

Number of cases by TLV threshold

186 incident cases of CTS (2.96 cases/ 100 P-Y)

Exposure category	2001 TLV	2018 TLV
<AL	86	34
≥AL, <TLV	48	52
> TLV	52	100

CTS cases by 2018 TLV; color = 2011 TLV



Crude and adjusted associations between TLV categories and incident CTS

	2001 ACGIH for Hand Activity		2018 ACGIH HA TLV	
Variable	HR	(95%CI)	HR	(95%CI)
<AL	1.00		1.00	
≥AL and ≤TLV	1.80	(1.27–2.57)	1.12	(0.72–1.72)
>TLV	2.01	(1.41–2.84)	2.03	(1.37–3.00)
Adjusted for BMI, age, gender, research site				
<AL	1.00		1.00	
≥AL and ≤TLV	1.88	(1.30–2.72)	1.16	(0.73–1.85)
>TLV	1.73	(1.20–2.49)	1.99	(1.28–3.10)

Attributable Risk Fraction and Prevention

- If exposures were reduced to below the 2018 TLV, the incidence of CTS in the overall cohort would decrease from 2.96 cases / 100 P-Y to 2.11 cases / 100 P-Y
- 25% of all cases of CTS could have been prevented
- Additional reductions if exposures reduced to <AL
- **Many workers are exposed above recommended limits (both new and old!)**
- **This exposure above TLV would not be ignored for chemical exposures**

Limitations

- Workers had average of 7.6 years in their current jobs at baseline – likely a survivor cohort
- 683 workers changed jobs and were assigned TWA exposures

Challenge

- Illustrates a need to move from etiology studies to effective interventions that reduce exposure
- Need to better implement recommendations

National Occupational Research Agenda for Musculoskeletal Disorders 2018

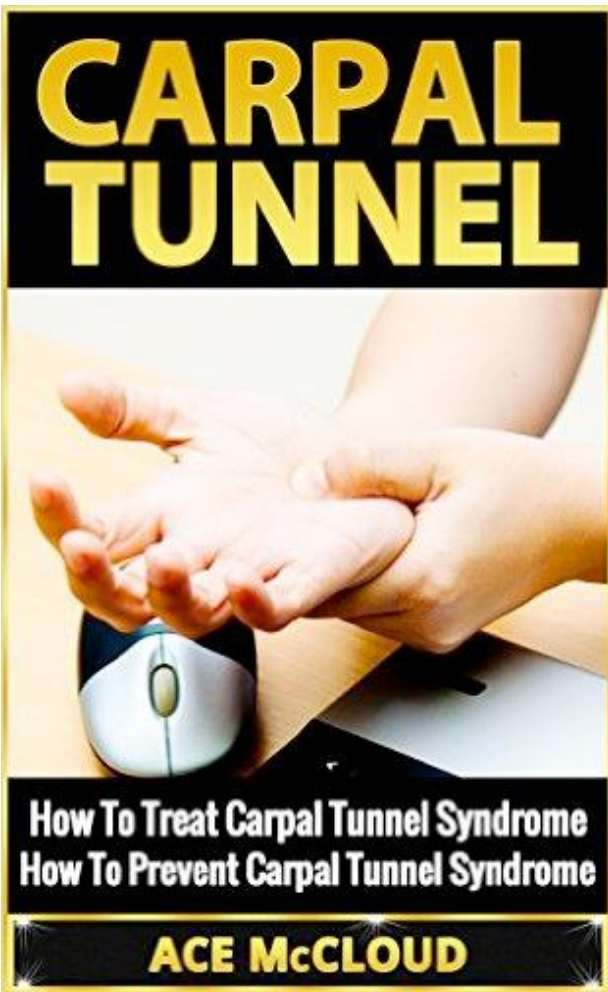
- Define the incidence and impact of WMSDs
- Understand the risk factors for WMSDs
- Describe the underlying mechanisms for MSDs
- Develop and evaluate interventions to prevent WMSDs and limit disability
- Disseminate and implement interventions

Embrace New Approaches to Exposure Assessment

- New technologies – wearable sensors
- Job Exposure Matrices allow exposure estimation for large registry studies, longitudinal cohorts
- TLV for HAL, other less labor intensive assessment tools appear valid and usable for workplace prevention

Approaches to intervention

- Identify and reduce the exposures associated with disease
- Provide usable exposure assessment tools
- Offer practical suggestions for exposure reduction
- Build case for urgency – MSD are a major source of morbidity and disability
- Focus on the most important exposures



FOCUS ON WHAT'S IMPORTANT

- Minimal evidence that computer use is a risk factor
- High risk jobs are those associated with prolonged or repeated forceful grip and pinch

Carpal tunnel syndrome and computer exposure at work in two large complementary cohorts

- Compared new cases of CTS among workers with highest computer use to other workers in two large prospective studies: PrediCTS and Cosali.
- Adjusted OR for CTS
 - 0.16 (PrediCTS)
 - 0.39 (Cosali)
- Compared to industrial and service workers, odds of CTS very low among computer users

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[Workplace Resources](#)

Attributing Work-Relatedness of CTS

[Franklin 2015]

- Evidence based expert panel in Washington State
 1. Forceful use, particularly if repeated
 2. Repetitive hand use **combined with some element of force**, especially for prolonged periods
 3. Constant firm gripping of objects
 4. Moving or using the hand and wrist against resistance or with force
 5. Exposing the hand and wrist to strong regular vibrations
 6. Intensive computer, keyboard, or mouse use of at least 12 to 20 h/wk

Modeling the Effect of the 2018 Revised ACGIH® Hand Activity Threshold Limit Value® (TLV) at Reducing Risk for Carpal Tunnel Syndrome

**Yung M, Dale AM, et al. Journal of
Occupational and Environmental Hygiene,
2019**

DOI: 10.1080/15459624.2019.1640366



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