Evidence on Work-related Causation of Carpal Tunnel Syndrome

David Rempel, MD, MPH, FACOEM

Professor, Occupational and Environmental Medicine
University of California, San Francisco
Professor, Bioengineering
University of California, Berkeley

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Question

What are the relative contributions of the following risk factors to CTS?

a. Hand repetition
b. Pinch force
c. Power grip force
d. Wrist posture
e. Dissatisfied with job
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**Question**

What are the relative contributions of the following risk factors to CTS?

a. Hand repetition 20 exertions/min  
b. Pinch force 15 N  
c. Power grip force 40 N  
d. Mean wrist posture 30 degrees extension  
e. Dissatisfied with job dissatisfied or very d.

**Systematic Review: Work & CTS**

[van Rijn RM et al. SJWEH 2009; 35:19-36]  

Average hand force  
> 40 N [ > 10 N]  
Repeated rapid motions  
> 50% cycle same motions  
Cycle<10s  
Vibration  
>3.9 m/s  
Prolonged or repeated wrist flexion or extension  
Psychosocial (negative)  
Computer use (mixed)

1. Roquelaure et al. SJWEH 1997; 23:364  
3. Bovenzi et al Int Arch Occup Environ H 2006; 78:303-10

**Force, Repetition and CTS**

CTS and Workplace Risks

- No prospective studies with...
  - CTS based on narrow criteria using NCS
  - Detailed exposure assessment at individual level
  - Adequate power
- Exposure-response relationships are not well known
  - Linear, hocky-stick, threshold?
  - Biomechanical factors
  - Work psychosocial factors

Causation Criteria

[Bradford Hill 1980]

- Strength of Association
  - Magnitude of effect (RR, OR, HR)
- Temporality of Association
  - Exposure precedes outcome (prospective vs. cross-sectional)
- Consistency of Association
  - Similar findings across different studies
- Specificity of Association
  - A factor is associated with one outcome
- Dose-response Relationship
  - Individual level exposure assessment
- Biological Plausibility
  - Animal and human models of disease

Overview

- Animal models
- Human physiology
- Epidemiology – 5 Prospective Studies
- Potvin Fatigue Curves
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Ischemia – Reperfusion Injury Model
[Rempel, Dahlin, Lundborg. JBJS 1999; 11:1600]

- Repeated grasping or sustained postures
- Extraneural pressure elevations
- Ischemia – reperfusion injury
- Edema - endoneurial and synovial
- Persistent pressure elevation
- Demyelination, axonal degeneration
- Epineural fibrosis

Alternate Hypotheses

- Direct mechanical contact
- Nerve traction
- Amyloid deposits in synovium
- Inflammatory pathway with collagen deposition

Animal Models - CTS

- Rat - cuff
  - Powell and Meyers. Lab Invest 1986
- Rabbit – balloon
- Primate – volitional repetitive gripping
- Rat – volitional repetitive gripping
  - Barbe M et al. 2003-2013

2 h/day, 3 days/wk x 12 wks
LR = 2 /min
HR = 4 /min
LF = 15 % max
HR = 60 % max
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**Human Physiology – Carpal Tunnel Pressure**


Side view  
Palmar view

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**CTP vs Wrist extension/flexion (N=37)**


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**Pinch Force and CTP**

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### Pathophysiology

1. **High CT Pressure**
   - Image of hand with high carpal tunnel pressure.

2. **Low CT Pressure**
   - Image of hand with low carpal tunnel pressure.

### Human Physiologic Studies

**Carpal tunnel pressure and hand activities**

Four recent, large, prospective, work-place epidemiologic risk assessment studies for CTS

- CTS criteria: media symptoms plus abnormal NCS
- Exposure data at the individual level

### 429 manufacturing workers in US followed for 1350 PY


- 35 incident CTS cases [2.6 cases/100 p-y]
  - Age
  - BMI [HR=1.06 (1.02-1.11)]
  - Other MSDs [HR=2.66 (1.30-5.45)]
  - Rheumatoid arthritis [HR=4.14 (1.48-11.59)]
  - Gardening outside work [HR=3.17 (1.34-7.46)]
  - TLV HAL Score [normalized peak force & repetition] (up to unit score of 1.25) [HR=3.8 (1.00-14.86)]
  - Strain Index [force, repetition, % duty cycle, posture, speed, shift duration] [HR=2.5 (1.00-6.13)]

### 347 health care and manufacturing workers followed for 694 PY

[Burt S et al. OEM 2013; 70:568]

- 29 incident CTS cases [5.1 cases/100 p-y]
  - Model 1
    - % time in forceful exertion
      - <20% 1.00
      - 20 to 60% 2.83 (1.18 – 7.79)
      - >60% 19.57 (5.96-64.24)
    - BMI (30 kg/m3) 3.19 (1.28 – 7.98)
  - Model 2
    - TLV for HAL ratio 1.40 (1.11 – 1.78)
    - BMI (30 kg/m3) 3.26 (1.45 – 7.31)
    - High job strain 2.13 (1.00 – 4.54)
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**347 health care and manufacturing workers followed for 694 PY**
[Burt S et al. OEM 2013; 70:568]

**2299 industrial and service workers in Italy followed for 3825 PY**

**2299 industrial and service workers followed for 3825 PY**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Incident Rate Ratios*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>2.85 [1.51-5.37]</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>1.07 [1.04-1.14]</td>
</tr>
<tr>
<td>Age</td>
<td>1.06 [1.05-1.08]</td>
</tr>
<tr>
<td>Co-morbidities</td>
<td>1.91 [1.26-2.91]</td>
</tr>
<tr>
<td>HAL TLV (&gt;AL, &lt;TLV)</td>
<td>1.95 [1.21-31.6]</td>
</tr>
<tr>
<td>HAL TLV (&gt;TLV)</td>
<td>2.70 [1.48-4.91]</td>
</tr>
<tr>
<td>HAL (unitary increase, 1-7)</td>
<td>1.37 [1.19-1.57]</td>
</tr>
<tr>
<td>Peak Force (unitary increase, 1-7)</td>
<td>1.31 [1.08-1.59]</td>
</tr>
</tbody>
</table>

*adjusted for sex, age, bmi, & co-morbidities (DM, gout, thyroid, RA, SLE, tendinitis)
Personal and Workplace Psychosocial Risk Factors for Carpal Tunnel Syndrome: A Pooled Study Cohort (N=3513) followed for 8833 PY
Harris C et al. OEM 2013; 70(8):529
Dale AM et al. SJWEH 2013 (Epub)

- Carisa Harris-Adamson, PhD
- Ellen A Eisen, ScD
- Ann Marie Dale, PhD
- Bradley Evanoff, MD
- Kurt T. Hegmann, MD
- Matthew S. Thiene, PhD
- Jay Kapellusch, PhD
- Arun Garg, PhD
- Susan Burt, ScD
- Stephen Bao, PhD
- Barbara Silverstein, PhD
- Fred Gerr, MD
- Linda Merlino, MS
- David Rempel, MD

Demographic Factors (N=3500)

<table>
<thead>
<tr>
<th>Factor</th>
<th>N</th>
<th>%CTS (n)</th>
<th>OR</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Male</td>
<td>1895</td>
<td>81</td>
<td>1.00</td>
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<tr>
<td>Female</td>
<td>1604</td>
<td>127</td>
<td>1.50</td>
<td>0.96</td>
<td>2.32</td>
<td>0.09</td>
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<tr>
<td>Diabetes Mellitus</td>
<td>1102</td>
<td>166</td>
<td>1.60</td>
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<tr>
<td>No Diabetes</td>
<td>2475</td>
<td>193</td>
<td>1.00</td>
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<tr>
<td>Smoker</td>
<td>122</td>
<td>7</td>
<td>0.84</td>
<td>0.50</td>
<td>1.40</td>
<td>0.27</td>
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<tr>
<td>Rheumatoid Arthritis</td>
<td>1135</td>
<td>127</td>
<td>1.00</td>
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<tr>
<td>No Rheumatoid</td>
<td>2365</td>
<td>193</td>
<td>1.00</td>
<td></td>
<td></td>
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<tr>
<td>RA</td>
<td>66</td>
<td>9</td>
<td>1.13</td>
<td>0.50</td>
<td>2.57</td>
<td>0.77</td>
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<tr>
<td>Thyroid Disease</td>
<td>1467</td>
<td>201</td>
<td>1.00</td>
<td></td>
<td></td>
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<tr>
<td>No Thyroid Disease</td>
<td>2320</td>
<td>196</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyroid Disease</td>
<td>1119</td>
<td>105</td>
<td>1.54</td>
<td>0.72</td>
<td>3.32</td>
<td>0.44</td>
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<tr>
<td>Monthly Absentee Activity</td>
<td>1554</td>
<td>90</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-19 days</td>
<td>1033</td>
<td>127</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20+ days</td>
<td>541</td>
<td>44</td>
<td>0.92</td>
<td>0.55</td>
<td>1.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Monthly Heavy/Manual Activity (Non-Occupational)</td>
<td>2112</td>
<td>144</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-19 days</td>
<td>1216</td>
<td>127</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20+ days</td>
<td>396</td>
<td>61</td>
<td>0.99</td>
<td>0.51</td>
<td>2.02</td>
<td>0.89</td>
</tr>
</tbody>
</table>

HR for CTS by age (N=3500)

[Graph showing hazard ratios for CTS by age]
HR for CTS by BMI (N=3495)

<table>
<thead>
<tr>
<th>BMI Range</th>
<th>n (mean)</th>
<th>HR 1</th>
<th>Lower CI</th>
<th>Upper CI</th>
<th>p-value 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>100</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>High</td>
<td>390</td>
<td>1.10</td>
<td>1.05</td>
<td>1.15</td>
<td>0.00</td>
</tr>
</tbody>
</table>
| Psychosocial Risks (N=3080)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>n (mean)</th>
<th>HR 2</th>
<th>Lower CI</th>
<th>Upper CI</th>
<th>p-value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>671</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>High</td>
<td>401</td>
<td>1.10</td>
<td>1.05</td>
<td>1.15</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Seven Upper Extremity
Psychophysics Studies

Jim Potvin Fatigue Curves

[Potvin J. Human Factors 2012; 54(2):175]
Duty Cycle =
\% Time in High Force Pinch or Grip

\% Time in High Force Grip vs Repetition Rate
(N=2594, 12,000 observations)

Correlation: 0.29

UE Psychophysics Studies
[Potvin J. Human Factors 2012: 54(2):175]
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**UE Psychophysics Studies**

[Potvin J. Human Factors 2012; 54(2):175]

![Graph showing duty cycle vs. maximum acceptable effort]

**Causation Criteria**

[Bradford Hill 1980]

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### Conclusions: Demographic Factors & CTS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Consistency</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Age</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>BMI</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>Co-morbidity</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Home - hand hobbies:</td>
<td>+/-</td>
<td></td>
</tr>
</tbody>
</table>

### Conclusions: Psychosocial Factors & CTS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Consistency</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>High demand &amp; low control</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Feeling depression</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Low social support</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Job dissatisfaction</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Conclusions: Biomechanical Factors & CTS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Consistency</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV for HAL</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Strain Index</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>% time high force grip</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Repetition</td>
<td>+/-</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions: CTS Causation

- Recent evidence for multifactorial causation
- Linear risk for age and BMI
- Risk for workplace psychosocial: high demand & low control
- Risk for TLV for HAL and Strain Index
- Risk for duration of high force pinch
- Role of repetition less certain; consider duty cycle
- Other important papers will be published next year

Questions?

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