Association between the ACGIH TLV for HAL and incidence of CTS in a pooled prospective study

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Introduction: Recent prospective cohort studies have shown an association between the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for Hand Activity Level (HAL) and incidence of carpal tunnel syndrome (CTS). However, there has been only one study that included a large working population (Bonfiglioli et al. 2013). The aim of this presentation is to demonstrate the validity of the TLV for HAL using pooled data from 6 coordinated prospective studies.

Method: Prospective data on 3515 workers from 50 companies were enrolled in studies conducted by 6 research groups and followed for up to 7 years. These data were pooled in order to determine associations between physical exposure and CTS with greater statistical power for a more diverse group of workers from production and service sectors (Dale 2013). Data on analyst rated peak force (PF) and verbal anchor HAL were collected by all 6 research groups, and 4 research sites collected additional information on frequency and duration of all exertions performed (Kapellusch 2013). Thus two measures of HAL were available: (i) verbal anchor HAL (V-HAL), and HAL calculated using an equation provided by Chen (2012) (C-HAL). Symptom reports consistent with CTS and electrophysiological measures of median nerve function were collected at regular intervals during the follow-up period by researchers blinded to physical exposures. A CTS case definition that required symptoms of numbness, tingling, burning or pain in at least one of the first three digits of the hand plus abnormal median nerve latency was used to identify cases of CTS. Subjects with CTS or polyneuropathy at baseline were excluded from analysis. Models were a priori adjusted for age, gender and BMI which had been shown to be associated with CTS in this cohort (Harris-Adamson 2013). In addition, models included job tenure at the current employer to adjust for healthy worker survivor effect (HWSE), and research site to account for any systemic variation in measurements between sites. Proportional hazards regression with time-varying covariates was used to model the association between TLV for HAL (as a continuous measure calculated as peak force + 10-HAL) and time-to first event of CTS. Penalized splines (p-splines) were used to visualize exposure-response relationships; however, linear models were used to provide hazard ratio (HR) estimates provided in Table 1. HR estimates were also calculated for the ACGIH recommended Action Limit (AL), and threshold limit value (TLV).

Results: A total of 2,385 workers had both peak force and V-HAL measurements, and were eligible to develop an incident case of CTS. Similarly, a total of 1,864 had peak force and C-HAL. From these two groups, there were 171 and 137 incident cases of CTS, respectively. As a continuous variable, TLV for HAL score was strongly associated with incident cases of CTS regardless of whether V-HAL or C-HAL was used. Using ACGIH limits, both C-HAL and V-HAL models were associated with CTS; however, only C-HAL showed evidence of a monotonic relationship (Table 1). P-spline graphs show that V-HAL based TLV for HAL score had a linear relationship with CTS, but with relatively modest HRs (Figure 1), whereas C-HAL based TLV for HAL had relatively larger HRs, but showed some evidence of HWSE (Figure 2).

Discussion: Consistent with recent prospective studies, this study cohort showed an exposure-response relationship between TLV for HAL and incidence of CTS. The C-HAL based model showed a stronger association and monotonic relationship using the ACGIH prescribed limits, but is time-consuming to calculate. The V-HAL based model with ACGIH showed increased risk above the AL.
but no further increase above TLV; however, the continuous model showed a steady increase in risk as scores increased, and V-HAL is easily determined from observation alone. Consistent with prior studies, the ACGIH TLV for HAL is associated with risk of CTS, and a potentially useful tool in industrial surveillance programs.

**Keywords:** Epidemiology, physical exposure, injury prevention, surveillance

Table 1: Hazard ratios for ACGIH TLV for HAL models adjusted for age, gender, BMI, company tenure, and research site.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (cases)</th>
<th>HR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV for HAL score using V-HAL (HR per unit increase)</td>
<td>2,385 (171)</td>
<td>1.33 (1.13 – 1.57)</td>
<td>≤ 0.01</td>
</tr>
<tr>
<td>TLV for HAL using V-HAL ≤ AL</td>
<td>1,200 (108)</td>
<td>1.00</td>
<td>...</td>
</tr>
<tr>
<td>&gt; AL &amp; &lt; TLV</td>
<td>429 (27)</td>
<td>1.94 (1.33 – 2.82)</td>
<td>≤0.01</td>
</tr>
<tr>
<td>≥ TLV</td>
<td>756 (36)</td>
<td>1.58 (1.10 – 2.28)</td>
<td>0.03</td>
</tr>
<tr>
<td>TLV for HAL score using C-HAL (HR per unit increase)</td>
<td>1,864 (137)</td>
<td>1.55 (1.19 – 2.03)</td>
<td>≤ 0.01</td>
</tr>
<tr>
<td>TLV for HAL using C-HAL ≤ AL</td>
<td>583 (45)</td>
<td>1.00</td>
<td>...</td>
</tr>
<tr>
<td>&gt; AL &amp; &lt; TLV</td>
<td>293 (15)</td>
<td>1.63 (0.90 – 2.96)</td>
<td>0.11</td>
</tr>
<tr>
<td>≥ TLV</td>
<td>988 (77)</td>
<td>2.30 (1.52 – 3.50)</td>
<td>≤ 0.01</td>
</tr>
</tbody>
</table>
Figure 1: p-Spline of TLV for HAL calculated from verbal anchor HAL [95% CI (dashed lines), exposure distribution (bottom), and case distribution (top)].
Figure 2: p-Spline of TLV for HAL calculated from frequency and duration of exertion from all efforts performed [95% CI (dashed lines), exposure distribution (bottom), and case distribution (top)].
References:


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