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A Cross-Sectional Assessment of the ACGIH TLV for Hand Activity Level

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The ACGIH Worldwide Threshold Limit Value (TLV) for hand activity "considers average hand activity level or "HAL" and peak hand force." We report cross-sectional data that assess the validity of the TLV with respect to symptoms and selected upper extremity musculoskeletal disorders among workers. The prevalence of symptoms and specific disorders were examined among 908 workers from 7 different job sites in relation to the TLV. Worker exposures were categorized as above the TLV, above the TLV Action Limit but below the TLV, or below the TLV Action Limit. Symptoms in the distal upper extremities did not vary by TLV category. Tendonitis in the wrist/hands/fingers did not vary by TLV category, but elbow/forearm tendonitis was significantly associated with TLV category. All measures of carpal tunnel syndrome were associated with TLV category. In all instances, prevalence of symptoms and specific disorders were substantial in jobs that were below the TLV action limit, suggesting that even at "acceptable" levels of hand activity, many workers will still experience symptoms and/or upper extremity musculoskeletal disorders, which may be important in the rehabilitation and return to work of injured workers. Future analyses need to examine the incidence of symptoms and upper extremity musculoskeletal disorders prospectively among workers in relation to the TLV for hand activity.

KEY WORDS: threshold limit value; hand activity level; ergonomics; musculoskeletal disorders.

INTRODUCTION

Upper extremity musculoskeletal disorders (UEMSDs) are common, and there is evidence that these disorders can be caused or aggravated by physical activities in the workplace

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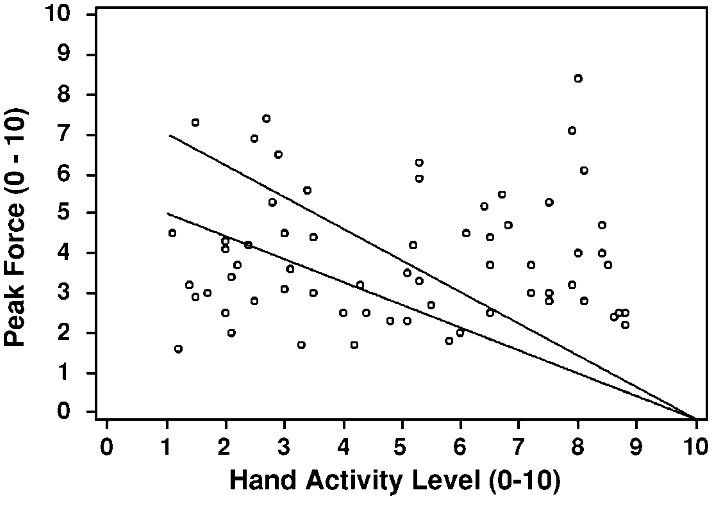

Fig. 1. Plot of jobs with respect to normalized peak hand force and hand activity. Note: The upper line is the threshold limit value (TLV), and the lower line is the action limit. Each circle in the graph represents a job; the number of workers in each job varied.

(1–3). A number of specific workplace risk factors have been identified, including hand repetition or hand activity, forceful exertions, non-neutral postures, contact stress, vibration and low temperatures (2, 3). These same workplace risk factors are likely to be important for rehabilitation and return to work of injured workers. Furthermore, these workplace risk factors have been documented to exist at some level in nearly all industries (1, 4). In response to these challenges, a number of agencies and organizations have issued regulations or guidelines in an effort to control exposures and/or reduce work-related musculoskeletal disorders (WRMSDs). The approaches have varied.

The ACGIH Worldwide, a private, non-profit professional organization, issued a Threshold Limit Value (TLV) or guideline for Hand Activity Level ("HAL") in 2001 (5). The ACGIH TLV provides an explicit criterion for what is the maximum recommended ergonomic exposure. The guideline is based on the joint assessment of average hand activity and normalized peak hand force, and includes both a TLV and a lower 'action limit' for which general controls are recommended (see Fig. 1). There are a number of approaches ranging from ratings based on observations to computational methods described in the TLV documentation that can be used to quantify average hand activity and normalized peak hand force (5).

The ACGIH TLV is more narrowly focused than previously proposed or promulgated ergonomic standards in that it is designed only to control exposures that impact the risk of MSDs of the hand, wrist and forearm. Also, the TLV is only intended to apply to "mono-task jobs" performed four or more hours per day. A "mono-task job" is defined as one that "involves performing a similar set of motions or exertions repeatedly, such as working on an assembly line or using a keyboard and mouse." The TLV "is set for conditions to which it is believed that nearly all workers may be repeatedly exposed without adverse health effects" (5). The TLV was not designed explicitly for use in rehabilitation and return to work of injured workers, but there is a need for acceptable exposure guidelines to assist health care providers to establish rehabilitation goals and to determine design of jobs to accommodate persons with work-related MSDs. Determination of acceptable exposure limits and health expectations for healthy or active workers is a starting point for determining acceptable exposures for injured workers. In the present study we report cross-sectional data that assess the validity of the ACGIH TLV with respect to symptoms and selected distal UEMSDs among active workers from a variety of workplaces and jobs with a broad range of ergonomic job exposures.

METHODS

Data for this study were collected from among 985 out of 1315 eligible workers (75%) at seven independent companies. The companies included four manufacturing operations (office furniture manufacturing, industrial container manufacturing, automobile parts manufacturing, and spark plug manufacturing), and three employers involving office or computer-related jobs (an insurance claims processing center and two government computer data entry facilities). Prior to participation, all subjects were made aware of the medical survey protocol, and each provided written informed consent that had been approved by the University Institutional Review Board. All medical survey procedures were performed on 'company time' during each worker's regular shift, except at the automobile parts manufacturing site. The management at this site required that survey evaluations be performed before or after workers' shifts and without pay. No data were collected pertaining to the 330 eligible workers who chose to not participate in the study so it is not possible to assess quantitatively the potential for response bias in relation to demographic or other covariates.

The medical survey was the same at all study sites and included: ulnar and median sensory nerve conduction studies across both wrists; completion of a self administered questionnaire with hand diagrams; and a physical examination specific to the upper extremities. Detailed descriptions of these methods and assessment of the reliability and/or validity have been described elsewhere (6–11). Each participant received a confidential written summary of his or her medical survey results (including electrodiagnostic results), an interpretation of the results, and recommendations for medical follow-up, if warranted. Personally identifiable results were not provided to employers or unions.

A variety of outcomes were employed in analyses, including distal upper extremity symptoms in the wrist/hand/fingers or elbow/forearms, tendonitis in the wrist/hands/fingers or elbow/forearms (similar to Latko *et al.*, 1999) (9), and carpal tunnel syndrome (CTS) defined using hand diagrams and/or electrodiagnostic criteria consistent with established consensus criteria (12). All outcomes were defined bilaterally, meaning a subject was considered to be 'positive' if the outcome was present in either or both extremities. Details of diagnostic criteria are summarized in Table I.

An observational method was used to classify exposure to work-related risk factors of upper extremity musculoskeletal disorders. Ergonomic exposures associated with the jobs of the subjects in this study were rated by a team of four university faculty and research staff members who were experienced in ergonomic job analysis in general and specifically, the observational rating technique used for assessing physical stress (9) and Latko (1997) and Latko *et al.* (1997) (13,14). The raters viewed videotape of a representative worker for each of the jobs and listened to a presentation of job documentation information. Next,

Table I. Criteria for Defining Medical Survey Outcomes

Outcome categories	Abbreviation	Definition
Wrist/hand/finger symptoms	WHF Sx	Any symptoms in the wrist, hands and/or fingers lasting one week up to one year prior to survey *or* occurring on three or more occasions up to one year prior to survey
Elbow/forearm symptoms	EF Sx	Same as WHF Sx, but localized to the elbow and/or forearm
Wrist/hand/finger tendonitis	WHF-T	WHF Sx (e.g., pain, stiffness, burning, tightness, aching, or soreness) plus physical exam findings consistent with tendonitis in the wrist, hand, or fingers (e.g., pain with resisted motion, tenderness, or positive finding on appropriate test maneuver, e.g., Finkelstein's maneuver)
Elbow/forearm tendonitis	EF-T	Same as WHF-T, but with symptoms and findings localized to the elbow and/or forearm
Carpal tunnel syndrome, hand diagrams	HD	A hand diagram score of "classic" or "probable"[a]
Carpal tunnel syndrome, median mononeuropathy	MM5	A median minus ulnar peak latency difference $\geq$0.5 ms
Carpal tunnel syndrome, median mononeuropathy	MM8	A median minus ulnar peak latency difference $\geq$0.8 ms
Carpal tunnel syndrome, hand diagrams & MM5	HD & MM5	A hand diagram score of "classic" or "probable" and a median minus ulnar peak latency difference $\geq$0.5 ms in the ipsilateral extremity
Carpal tunnel syndrome, hand diagrams & MM8	HD & MM8	A hand diagram score of "classic" or "probable" AND a median minus ulnar peak latency difference $\geq$0.8 ms in the ipsilateral extremity

[a]Hand diagrams were scored as "unlikely," "possible," "probable" and "classic" according to likelihood of representing symptoms consistent with carpal tunnel syndrome; see Franzblau *et al.* (1994) (6).

each rater independently rated 52 physical stress variables using 10-cm visual analog scales with written guidelines. After all team members had completed their individual ratings, ratings were discussed in order to reach consensus (see Latko *et al.*, 1999 (9) for a complete description of consensus and a list of the 52 rated physical stressors). The ACGIH HAL TLV (5) incorporates the "repetition" and "peak hand force" ratings. The observational methods used to assess exposure in the present study are among those that are described and endorsed in the ACGIH documentation for the HAL TLV (5). No other ergonomic exposure assessment procedures were performed, so it is not possible to compare the HAL results with other ergonomic exposure methodologies.

The test/re-test reliability and validity of this observational rating method have been investigated (13, 14). The same 12 jobs were rated by a group of analysts on two separate occasions seven weeks apart to examine the test/re-test reliability. No systematic differences were found between the two sets of ratings using a paired *t*-test analysis (Latko, 1997 (13)). The validity of this observational method was examined in an epidemiological study (Latko *et al.*, 1999 (9)) and in laboratory study (Latko, 1997 (13)). The epidemiological results showed that repetitiveness of work, as defined using this observational method, was significantly associated with the prevalence of reported discomfort in the wrist, hand, or fingers, tendonitis in the distal upper extremity, and symptoms associated with carpal tunnel syndrome. Validity of this observational method was compared to traditional instrumental techniques in a laboratory study (Latko, 1997 (13)). In the laboratory study, subjects performed a hand transfer task at specified frequencies while EMG and electrogoniometer data were collected. In addition, the sessions were videotaped so analysts could rate each transfer task using the observational technique. Eighty-eight percent of the variance in the observational repetition ratings was explained when the ratings were modeled using average wrist movement speed and amount of finger recovery time. Seventy-eight percent of the variance in the observational peak force ratings was explained when the ratings were modeled using measured peak EMG. The results from the epidemiological study demonstrate that the observational rating method is able to classify work factors that are related to prevalence of symptoms and disease among workers, and the results from the laboratory study demonstrate that ratings by analysts with extensive ergonomics training and familiarity with the rating method agree with instrumental methods in describing exposure to work-related risk factors of upper extremity musculoskeletal disorders.

The exposure assessment variables discussed in the present study include HAL and peak hand force. The hand activity level or "HAL" was rated on a scale that ranges from 0 to 10 where 0 corresponds to "hands idle most of the time; no regular exertions" and 10 corresponds to "rapid, steady motion/difficulty keeping up or continuous exertion." Peak hand force was also rated on a 0 to 10 scale where 0 corresponds "no force" and 10 corresponds to "greatest imaginable force or 100% MVC" for a given population (ACGIH TLV (5)).

After data collection was completed it was determined that only 908 of the 985 subjects were in jobs that were rated and met the eligibility criteria for the TLV to be applicable. The distribution of eligible jobs with respect to the TLV and the action limit is shown in Fig. 1.

Members of the medical field study teams were masked to data collected by other study team members or via the questionnaire, and also to electrodiagnostic test results. Members of the medical survey teams were also masked to ergonomic assessments of jobs, and members of the ergonomic exposure assessment teams were masked to medical survey results.

Like most other 'criterion standards,' the ACGIH TLV for HAL does not explicitly account for individual risk factors, although it does acknowledge their contribution to UEMSDs. For UEMSDs individual risk factors include gender, age, anthropometry (e.g., body mass index or BMI), past medical history of individual workers, workplace or individual psychosocial factors, and other possibly individual covariates that have been shown to influence the risk of UEMSDs among workers (1–3). The TLV also does not attempt to explicitly integrate other widely cited workplace risk factors for UEMSDs, such as non-neutral postures, contact stresses, vibration and low temperatures. However, if these latter workplace factors are present, the TLV documentation states that "Professional judgment should be used to reduce exposures below the action limits recommended in the HAL TLVs," but no explicit, quantitative approach for "professional judgment" is described in the documentation (5). Given these features of the TLV, it was decided that for the present analyses it would be most realistic to assess outcomes with respect to the guidelines without any adjustments for individual or other workplace factors since such factors do not enter into the TLV in an explicit, quantifiable manner. The analyses and results are based on the 908 subjects for which there are medical survey data and who were employed in jobs for which the TLV was applicable.

Statistical analyses (i.e., descriptive statistics, ANOVA, Chi-square test) were performed with STATA 7 (15). The statistical significance of linear trends of count data was assessed via the Mantel-Haenszel Chi-square test of linear trend (16). Statistical tests were considered significant if the p-value was less than or equal to 0.05 (i.e., $\alpha = 0.05$).

RESULTS

The hand activity level ratings ranged from 1.1 to 8.8 on the scale from zero to 10, with a mean rating of 5.86 (standard deviation = 1.89 rating units) (see Fig. 1). Ratings for peak finger force ranged from 1.6 to 8.4, with a mean rating of 3.15 (standard deviation = 1.38 rating units). Of the 908 workers in jobs that qualified for rating under the TLV guideline, 279 (30.7%) were in jobs that were above the TLV, while another 424 (46.7%) were in jobs that exceeded action limit, but were below the TLV. There were 205 workers (22.6%) employed in jobs that were below the action limit.

Table II displays the results of age, gender and body mass index (BMI, kg/m^2) in relation to the action limit and TLV. Mean age ranged from 35 to 40.9 years. The prevalence of males in each group varied from 25 to 44%, and the mean BMI varied from 27.6 to 28.5 kg/m^2. Age and gender differed significantly by TLV category, but BMI did not.

The main results are summarized in Table III. The prevalence of symptoms in the wrist/hand/fingers differed significantly among the three job rating categories, but there was no linear trend with increasing ergonomic exposure. Similarly, prevalence of symptoms in the elbow/forearm also did not show a trend with increasing ergonomic exposure.

In contrast to symptoms alone, tendonitis in the wrist/hand/fingers was not related to ergonomic exposure category, but tendonitis in the elbow/forearm showed a highly significant linear trend in association with increasing ergonomic exposure (see Table III).

The linear trend for hand diagrams alone in relation to the TLV did not achieve statistical significance ($p = 0.0669$), but the trend for most other CTS-related outcomes demonstrated a statistically significant relationship with the TLV categories (i.e., below the action limit, above the action limit but below the TLV, and above the TLV). The latter outcomes included nerve test outcomes (MM-0.5: $p = 0.0003$ for test of linear trend; MM-0.8: $p = 0.0001$ for test of linear trend), and outcomes that combined hand diagrams and electrophysiologic test results to define CTS (MM-0.5 & HD: $p = 0.0372$ for test of linear trend; MM-0.8 & HD: $p = 0.0594$ for test of linear trend) (see Table III).

It is notable that all outcomes were present in all hand activity rating categories, including below the action limit for the TLV. For example, 88 (42.9%) of the 205 workers in jobs rated below the action limit nevertheless reported symptoms in the wrist, hands and/or fingers, and these 88 workers represented 18.3% of all workers who reported such symptoms. The prevalence of outcomes in jobs rated below the action limit varied considerably, depending on the outcome, with symptom-based outcomes being most prevalent. The prevalence of outcomes for CTS in jobs rated below the action limit were 3.4% (MM-0.5 & HD) and 2.4% (MM-0.8 & HD) (see Table III). Another way of looking at the same results is to consider the sensitivity and specificity of the TLV with respect to presence or absence of the outcomes as benchmarks (see Table III). Overall, the sensitivity of the TLV was weak, ranging from 0.29 to 0.59, and the specificities were also modest (0.67–0.73).

Table II. Summary of Age, Gender, and Body Mass Index (BMI) by TLV Job Exposure Category

	TLV = 1[a]	TLV = 2	TLV = 3	
Age: years mean (SD)	37.8 (10.3)	35.0 (9.3)	40.9 (10.7)	ANOVA, $F = 29.82$, $p < 0.0001$
Gender (% male)	39	25	44	Chi square (2 df) = 31.1, $p < 0.0001$
BMI, kg/m^2 mean (SD)	27.6 (6.3)	28.1 (7.3)	28.5 (5.9)	ANOVA, $F = 1.02$, $p = 0.3619$

[a]TLV = 1 - below TLV action level; TLV = 2 - above TLV action level but below TLV; TLV = 3 - above TLV.

Table III. Summary of Outcomes by TLV Job Exposure Category

Outcomes[a] (N^b)	TLV = 1[c] ($n = 205$)	TLV = 2 ($n = 424$)	TLV = 3 ($n = 279$)	Statistics	Sensitivity/ specificity[d]
Any WHF Sx ($N = 907$)	88 (43%)/117 (57%)[e]	254 (60%)/169 (40%)	140 (50%)/139 (50%)	χ^2 (df = 2) = 17.67 ($p = 0.0001$) χ^2 linear trend = 1.35 ($p = 0.2453$)	0.29/0.67
Any EF Sx ($N = 907$)	48 (23%)/157 (77%)	137 (32%)/286 (68%)	81 (29%)/198 (81%)	χ^2 (df = 2) = 5.38 ($p = 0.0678$) χ^2 linear trend = 1.29 ($p = 0.2563$)	0.30/0.69
WHF Tendonitis ($N = 908$)	14 (7%)/191 (93%)	21 (5%)/403 (95%)	20 (7%)/259 (93%)	χ^2 (df = 2) = 1.73 ($p = 0.4213$) χ^2 linear trend = 0.09 ($p = 0.7711$)	0.36/0.70
EF Tendonitis ($N = 908$)	11 (5%)/194 (95%)	13 (3%)/411 (98%)	34 (12%)/245 (88%)	χ^2 (df =2) = 23.82 ($p < 0.0001$) χ^2 linear trend = 11.68 ($p = 0.0006$)	0.59/0.71
Positive HD ($N = 908$)	25 (12%)/180 (88%)	65 (15%)/359 (85%)	51 (18%)/228 (82%)	χ^2 (df = 2) = 3.36 ($p = 0.1865$) χ^2 linear trend = 3.36 ($p = 0.0669$)	0.36/0.70
MM-0.5 ($N = 907$)	39 (19%)/166 (81%)	60 (14%)/363 (86%)	86 (31%)/193 (69%)	χ^2 (df = 2) = 28.98 ($p < 0.0001$) χ^2 linear trend = 13.12 ($p = 0.0003$)	0.46/0.73
MM-0.8 ($N = 907$)	17 (8%)/188 (92%)	19 (4%)/404 (98%)	48 (17%)/231 (83%)	χ^2 (df = 2) = 32.63 ($p<0.0001$) χ^2 linear trend = 14.52 ($p = 0.0001$)	0.57/0.72
CTS (MM-0.5 & HD) ($N = 907$)	7 (3%)/198 (97%)	15 (4%)/408 (96%)	20 (7%)/259 (93%)	χ^2 (df = 2) = 5.88 ($p = 0.0528$) χ^2 linear trend = 4.34 ($p = 0.0372$)	0.48/0.70
CTS (MM-0.8 & HD) ($N = 907$)	5 (2%)/200 (98%)	7 (2%)/416 (98%)	14 (5%)/265 (95%)	χ^2 (df = 2) = 7.00 ($p = 0.0302$) χ^2 linear trend = 3.56 ($p = 0.0594$)	0.54/0.70

[a] See Table I for key to abbreviation of outcomes.
[b] N = number of subjects in the model.
[c] TLV = 1 - below TLV action level; TLV = 2 - above TLV action level but below TLV; TLV = 3 - above TLV.
[d] Assessing prevalence of outcome above versus below TLV.
[e] #with trait (%)/# without trait (%).

DISCUSSION

This study assesses the prevalence of UEMSDs and upper extremity symptoms in relation to the new hand activity TLV for monotask handwork promulgated by the ACGIH. It is important to note that this was a cross-sectional study, not a prospective study. The ACGIH TLV is a 'criterion' guideline, in that it establishes an absolute level or cutoff for the acceptable combination of hand activity and peak force, similar to other criterion guidelines or standards that seek to protect workers from adverse consequences, like isocyanates and asthma. Also, like other criterion guidelines and standards, the TLV does not incorporate any formal, quantitative mechanism for making adjustments that might relate to the simultaneous presence of other exposures, or personal risk factors. For example, many persons smoke, have atopy, and/or may have a prior history of asthma, and each of these personal factors may impact one's risk of developing isocyanate-induced asthma, yet the TLVs for isocyanates do not incorporate adjustments for these factors. For these reasons, we intentionally did not make adjustments for known covariates in our analyses.

In the context of rehabilitation, these results provide some limited insight into what might be reasonable expectations for rehabilitation and/or return to work of injured workers. In this large cohort of active workers, the prevalences of wrist/hand/finger symptoms and elbow/forearm symptoms among workers in jobs below the TLV action limit were very common (43 and 23%, respectively). These results might be helpful to health care providers and to patients in that they suggest that some degree of upper extremity symptoms may be 'normal.'

In addition to regulations issued by public agencies, a number of investigators have proposed methods for analysis of work-related MSD work factors. Some examples of these include: RULA (17); REBA (18); the Strain Index (19); and OCRA (20). While the purpose of this paper is only to examine the prevalence of selected UEMSDs among workers in jobs below and above the ACHIG TLV it is worth noting some of the similarities between the ACGIH TLV and other exposure metrics. All of the metrics include repetition and force. The repetition metrics are based on cycle times, recovery times and frequency of motions. Forces on the body are estimated from observations, measurements or identification of related task factors.

Sensitivities and specificities of metrics with respect to the identification of risk factors have not been established, but interpretation of sensitivity and specificity in this context should be cautious. It is known that upper limb MSDs are highly prevalent. Thus some cases can be expected in jobs with low work exposures. Also, the ACGIH only directly considers force and repetition. Other factors, such as posture and vibration exposure are also known to be associated with MSDs. For example, Armstrong *et al.*, reported that the risk of CTS was approximately two times higher in workers performing high-force and high-repetition jobs who had vibration exposure than in those who performed similar jobs without vibration exposure (21). Further work is required to determine how other work factors should be incorporated into the ACGIH TLV.

The distribution of workers and ergonomic job exposures among all workers is unknown, and so it is unknown whether the distribution of jobs and ergonomic exposures among workers in our study is representative of all workers and jobs. However, our study involved a large number of workers in many jobs with a wide range of ergonomic exposures, thus ensuring adequate representation of all ergonomic exposure categories relevant to the TLV (i.e., below the action limit, above the action limit and below the TLV, and above the TLV).

Overall, the unadjusted relationship of the various outcomes with ergonomic exposure categories was mixed; sensitivities and specificities were weak or modest. Some outcomes showed no relationship with ergonomic exposure, while others were significantly 'positively' associated with increasing ergonomic exposure. None of the outcomes showed a significant 'negative' association with exposure. For those UEMSDs for which there is a positive and significant trend, adherence to the TLV might have resulted in a reduction in morbidity corresponding to the fraction of disease risk that might be attributable to the exposure. For example, if the ergonomic exposures of workers in jobs above the TLV had been below the action limit, and the prevalence of elbow-forearm tendonitis changed accordingly (5% instead of 12%, see Table III), then the number of workers with elbow-forearm tendonitis among those workers in jobs above the TLV might have been reduced by about 7%, or almost 20 of the 34 (59%) cases might have been prevented in this instance. One must exercise caution in generalizing this result, however, since the distribution of job exposures (and the associated attributable risk) may differ in other circumstances.

As suggested by the significant results in Table II, some important covariates may be acting as confounders in our data. The potential impact of confounding from, for example, gender, is unclear from the results shown. However, while gender is observable to an employer, government inspector, or consultant, and therefore may be used to 'adjust' data, many other potential confounders are not so easily observable, and are unlikely to be known to such parties (e.g., personal medical history). More importantly, as with most other exposure standards and guidelines, there is no quantitative method for adjusting the HAL TLV for gender, personal medical history, or other factors that may influence an individual worker's risk of developing an upper extremity disorder, which is why we chose to present our results in this manner (i.e., without adjustments for possible confounders). We believe that this presentation provides a more realistic appraisal of how application of the HAL TLV will operate in practice.

In all instances, the prevalence of symptoms and specific UEMSDs were substantial in jobs that were below the TLV action limit, suggesting that even at "acceptable" levels of hand activity, many workers still experience symptoms and/or UEMSDs. Despite the substantial prevalence of UEMSDs below the TLV action limit, this does not imply that the TLV is not protective for many workers. UEMSDs are common, and not all UEMSDs are work-related. By analogy, most asthma is not related to occupational exposures, and so even in workplaces with exposures that may cause asthma one would expect to find the prevalence of asthma to not be zero among subjects with little or no exposure to asthma-causing agents. Furthermore, the substantial prevalence of symptoms and UEMSDs in the lowest ergonomic exposure category may also reflect 'selection' or 'transfer' by workers with musculoskeletal problems from 'higher' to 'lower' ergonomic exposure categories. Since this was a cross-sectional study, the impact of this latter hypothesis can only be conjectured and not tested.

In contrast to the results described here, other studies, such as Latko *et al.* (1999), have examined the relationship between ergonomic factors, in particular hand repetition, and various UEMSDs (9). This latter study was designed to isolate and focus on the relationship between repetition and UEMSDs so as to better define the exposure–response relationship, and not to assess the efficacy of a particular mandated threshold for maximum acceptable exposures. Numerous multivariate models were constructed that included other ergonomic factors, demographic factors, past medical history, and even psychosocial covariates. Subjects were selected based on employment in jobs that met strict exposure criteria with regard to hand repetition (i.e., ‘low,’ ‘medium,’ and ‘high’ hand repetition categories), and so it was assured that there was heterogeneity of exposure with respect to hand repetition, but not other ergonomic factors. Latko *et al*. (1999) found significant, positive dose–response associations (with adjustment for covariates) between repetition and many, but not all UEMSD outcomes (9).

CONCLUSIONS AND RECOMMENDATIONS

The present cross-sectional analysis provides limited support concerning the potential effectiveness and validity of the TLV for hand activity. Health care providers and workers recovering from UEMSDs may benefit from knowing that symptoms are not rare among workers in jobs below the TLV action limit. A more complete assessment of the validity and potential benefit of the ACGIH TLV for hand activity will require prospective studies of active workers and workers recovering from injuries that observe the *incidence of new cases* of symptoms and/or UEMSDs in relation to the TLV.

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