	ACGIH: HAL	BS EN	CTD-RAM	ISO 11226	ISO/TS 20646-1	LUBA
Title	American Conference of Governmental Industrial Hygienists Threshold Limit Value for Hand Activity Level	British Standard BS EN 1005-3:2002	Cumulative Trauma Disorder – Risk Assessment Model	International Standard Ergonomics – Evaluation of working postures	Ergonomic procedures for the improvement of local muscular workloads – Part 1: Guidelines for reducing local muscular workloads	Loading on the Upper Body Assessment
Overview	Hand activity assessment tool.	Design tool to assess the risk of using machinery.	Upper limb assessment tool for predicting injury incidence rates.	Work posture assessment tool.	Method for reducing WMSDs	Upper limb assessment tool. Intervention information included.
Type	Risk Assessment	Standard	Risk Assessment	Standard	Standard	Risk Assessment
Stated Purpose	• The ACGIH recommend the threshold limit value for exposure to 4 or more hours of repetitive handwork (hand, wrist, forearm) per day. • This value is intended to protect most workers from MSDs for the hand, wrist, and forearm. This assessment can use biomechanical methods of measurement or more objective ones. This permits the assessment to be used with variable levels of expertise.	• The purpose of this standard is to decrease the risk of musculoskeletal disorders for machine operators. • Another purpose of this standard is to increase the size of the population that can operate machines by making their design and use more flexible. • As well, this standard will help machine manufacturers control machine design to minimize MSDs.	• This assessment model predicts injury incidence rates and assesses job risk. It further quantifies risk factors by strength, fatigue, and posture. • To specify acceptable limits on work design for a given individual.	• An approach used to determine whether a working posture is acceptable. Acceptability is based on current ergonomic knowledge. • Recommended limits for static working postures with varying amounts of external force exertion. • Allows evaluation of the task risk to a worker. • Applies to the adult population. Recommendations give protection to most healthy adults.	• Procedure for reducing work-related musculoskeletal disorders., including a risk assessment checklist.	• Technique for assessing postural loading on the upper body. • Postural classification scheme based on the angular deviation from a neutral posture for joint deviation. **Kee and Karwowski. Applied Ergonomics. 2001.**

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Body Parts Assessed		*Distal Upper Limb*	*Hand, arm*, legs, trunk	*Upper Limb*, shoulders, low back	Trunk, lumbar spine posture, neck, *shoulder, forearm, hand*, legs	Lower back, *lower limbs*, upper limbs, neck	*Wrist, elbow*, shoulder, neck, back
Measurement of Risk Factors	Force	• Normalized peak hand force is measured qualitatively or quantitatively on a scale of 0-10 where 0 means "no effort" and 10 means "maximal effort" • The effort required is rated qualitatively by the subject or the observer. **Marras et al, Fundamentals and Assessment Tools for Occupational Ergonomics, 2006**	• The maximum safe force for several hand, arm, leg and whole body postures is available for comparison in a table or through calculations. • This data is available for specific populations.	• The percent of maximum voluntary contraction is determined. This is collected by grip or pinch dynamometer measurements. • The percent force factor is calculated as a function of the wrist posture and grip span factor. • The percentage of maximum voluntary strength is determined by grip type, span and width.	• No force measurements are made in this standard. Other standards such as ISO 11228: Lifting and Carrying, Pushing and Pulling include additional force measurements.	• The checklist considers lifting, carrying, and work requiring high physical force.	
	Posture	• The angle of deviation of the arm from neutral is observed and compared with given values. • Grip postures are observed and incorporated in the choice of strength data. • Awkward postures of wrist and forearm are considered separately in the determination of acceptable peak hand forces.	• The posture is qualitatively observed to determine if is restricted, whether or not it allows flexible and frequent changes of the working posture, and the prevalence of extreme joint postures.	• A point level posture rating system of gross postures (shoulders, elbows, neck and back) is used to quantify posture.	• The posture is evaluated for the trunk, head, both limbs of the upper and lower extremities.	• The checklist considers awkward postures such as frequent stretching up, repeated lifting extreme joint positions when reaching for something.	• Perceived discomfort gathered for varying postures of 5 joints in upper body. Discomfort score of 1 assigned for neutral position. • Target postures for assessment chosen should be those with the greatest stress, postures held for the longest period of the work cycle, or those which the worker says are most stressful. • The discomfort is measured at 5 levels of range of motion (0, 25, 50, 75, 100%).

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	Time	• The Hand Activity Level (HAL) is rated qualitatively by the subject or an observer. • HAL considers repetition and force applied to monotask hand work performed for 4+ hours per day. • The duty cycle is considered and consists of the work to rest ratio. • The exertion frequency is considered as well as recovery time, percent duty time and speed of motion. **Marras et al, Fundamentals and Assessment Tools for Occupational Ergonomics, 2006**	• The frequency of actions is measured by determining the time required per action and the rate of repetition. • The duration of the activity is measured.	• The time taken by a motion, the rest period between motions, and the hours worked in one day are considered.	• The duration of time that postures of the trunk, head, upper and lower extremities are held for is evaluated and compared to the maximum holding time for a static working posture that can be held continuously from a resting state. • The amount of recovery time is evaluated and includes the time that a body segment is maintained in a neutral posture or is fully supported.	• The checklist considers long-duration walking or stair climbing. • Constrained postures held for long durations are also considered. • Continuous and frequent changes to joint angles are also considered.	• The maximum amount of time that a static posture is held for is required. **Kee and Karwowski. Applied Ergonomics. 2001.**
	Other	• TLV considers HAL and peak finger force. Other characteristics (vibration, wrist posture, contact stresses) should be considered especially near the TLV limit. **Marras et al, Fundamentals and Assessment Tools for Occupational Ergonomics, 2006**	• The velocity of the action is observed simply by determining if the action shows evident movement or not. • Vibration is considered by determining whether machine vibrations reach the operator. • Man-machine interaction is	• Miscellaneous factors (Vibration, temperature) arbitrarily assigned weighting factors of 7.5 and 3 compared to the presence of other factors such as use of gloves, job rotation, training and incentive pay.	• Variation in task is considered.	• The checklist also considers work hours, work using vibrating tools, precision work requiring high mental loads, the characteristics of the work space and objects handled. • Also considered is the work environment including the surface, temperature and noise.	

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		• Documentation suggests that sustained non-neutral postures (flexion, extension, pron/sup), contact stresses, low temperatures, vibration, hand moisture, gloves, lack of breaks, lack of task variety must also be considered. **Hand Activity Level. 2001. ACGIH.**					
Evaluation of Single Risk Factors	Force	• Peak hand force is rated on a scale from 0 (none) to 10 (greatest imaginable). • Effort required is rated qualitatively by either an observer or the subject. The Hand Activity Level (HAL) is rated qualitatively by an observer or the subject. • The normalized peak force can be measured qualitatively by the subject or an observer or quantitatively using EMG. **Potvin et al, IOES Conference, June 2002**	• The maximum safe force is determined for an action. The acceptable force depends on the user population, force distribution and relevant action. • The safe force can be determined using tables, by simple calculation or by an advanced calculation.	• The percent of maximum voluntary contraction (%MVC) is rated • The percent force factor is also rated as well as the force frequency and posture score.		• The checklist considers only the presence or absence of lifting, carrying, and work requiring high physical force.	
	Posture	• Postural deviation from neutral is rated according to Table 6. **Potvin et al, IOES Conference, June 2002**	• The posture is evaluated by considering whether machinery allows for unrestricted movement, whether working postures are flexible and frequent changes are permitted and whether extreme joint postures are avoided.		• The posture of the trunk, head, upper and lower extremities is rated. •	• The checklist considers only the presence or absence of awkward postures such as frequent stretching up, repeated lifting extreme joint positions when reaching for something.	• Joint posture is given a relative discomfort score.

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	Time	• The duty cycle consisting of the work to rest ratio is rated. • The Hand Arm Activity ranges from 0 (hands idle for most of the time) to 10 (rapid steady motion/exertion, difficulty keeping up). **Potvin et al, IOES Conference, June 2002**	• The frequency of the action is related to a 'frequency multiplier' that considers the time required per action and the frequency of actions. • The amount of time that an action is performed relates to a 'duration multiplier'.		• The duration of time that postures are held for is evaluated.	• The checklist considers only the presence or absence of factors such as long-duration walking or stair climbing, postures held for long durations and continuous and frequent changes to joint angles.	
	Other		• The velocity of action is evaluated in the form of a 'velocity multiplier'. This value varies from a value of 1.0 for actions with slow to no movement at all, to 0.8 for actions with evident movement. • The tolerability and risk of a population to the required action is considered in the form of a 'tolerability and risk multiplier'.			• The checklist also considers only the presence or absence of work hours, work using vibrating tools, precision work requiring high mental loads, the characteristics of the work space and objects handled. • The presence or absence of work environment factors such as the objects surface, temperature and noise as well.	

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Evaluation of Combined Risk Factors	• HAL and normalized peak hand force are combined on a graph. They're compared to the Threshold Limit Value (TLV) and the Action Limit (AL). **Marras et al, Fundamentals and Assessment Tools for Occupational Ergonomics,2006**	• The maximum safe force is recalculated using the frequency, duration and velocity multipliers. • The risk of the movement is evaluated by considering the working posture, the acceleration in movement and precision, vibration, man-machine interaction, personal protective equipment and external environment. • The risk assessment force is calculated using the maximum safe force and the tolerability and risk assessment.	• Force and frequency are combined into a Force Frequency Score (combines the effect of different grip strengths on different hand motions) • Posture and duration of task are combined into a Posture Score • The Force Frequency Score and Posture Score are combined to give an Overall Job Task Grand Score	• The trunk inclination is compared with the maximum acceptable holding time. • The head inclination is compared with the maximum acceptable holding time. • The upper arm elevation is compared with the acceptable holding time.		• The postural discomfort scores for the wrist, elbow, shoulder, neck and back are combined with the joint motion to give a postural load index.
Validity	• TLV provides a valid and reliable method of determining average injury risk across a range of users when EMG is used to measure the peak effort and observers are used to measure HAL. **Potvin et al, IOES Conference, June 2002**. • Elbow and forearm tendonitis and carpal tunnel syndrome were found to be associated with the TLV category of the worker. • Repetitiveness of work was found to be associated with upper limb discomfort. **Franzblau et al, Journal of Occupational Rehabilitation 2005.**		• The frequency, posture and other scores were compared with cumulative trauma disorder rates of incidence from the location of the study. The score determined by the assessment methods correlates with actual injury.			• Posture holding times correlated negatively with posture or postural loading. **Kee and Karwowski. Applied Ergonomics. 2001.**

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Limit or Guideline Level Proposed?	• TLV is the condition to which all workers may be exposed without adverse health effects. AL is the limit for which general controls are recommended. Work that falls within this range should trigger a proactive program.	• The calculation of the risk multiplier defines a risk zone for the activity. If the risk zone is within a certain range the risk of disease and injury is unacceptable.	• Gives an Overall Job Task Grand Score that predicts incidence rates	• For each combination of posture and acceptable holding time, a range of acceptable values is given. Anything that falls outside of this range is considered unacceptable and action should be taken to improve either the posture or the holding time.	• Factors that are present require farther examination.	• An overall postural load index is calculated based on joint posture. • The load index corresponds to one of 4 action categories. Depending on the category, intervention may be required.
Study Base/ Generalizability Used in: Developed in:	• 280 automotive manufacturer line operators from seven different plants. • 10 men and women. **Potvin et al, IOES Conference, June 2002** • 985 workers from 7 companies. Workers included car parts, office furniture and industrial containers manufacturers, and office/computer work at three different companies. **Franzblau et al. Journal of Occupational Rehabilitation, 2005.**		• Based on 24 industrial jobs (11 in garment sewing industry, 13 in printing industry), subjects were male and female b/w 18 to 65 years			• 20 male subjects with no history of musculoskeletal disorders.
Equipment Required	• EMG useful for determining the peak effort required.		• Grip or pinch dynamometer for MVC measurements, (CTD Risk Assessment model software), stopwatch	• Measuring joint angles from pictures is more easily accomplished. • A goniometer would be useful to determine the joint angles.		• Video camera to record the task being performed. • A goniometer would be useful to determine joint angle but is not necessary.

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Measurement Characteristics	• HAL and effort scores had a demonstrated 'good' inter-rater reliability. • The average number of injuries and discomfort ratings were within the range of TLV risk and HAL scores. • Ranking of TLV scores varied widely between methods. For example, operators overestimated the TLV, and observers generally chose a value slightly higher than that obtained using EMG. • Good between-rater reliability between HAL scores and effort scores. **Potvin et al, IOES Conference, June 2002** • This observational method is valid when compared to instrumental techniques in laboratory studies. • The test-retest reliability of this assessment method was found to have 'no systematic differences'. **Franablau et al. Journal of Occupational Biomechanics, 2005.**		• Possibility for inter-observer errors due to expertise or rating of miscellaneous factors (b/c of subjectivity)			
Information for Intervention?	• Use professional judgment to reduce exposures below recommended HAL and TLV action limits if any of the following are present: o Vibration o Low temperatures o Contact stresses o Sustained, non-neutral postures (wrist flexion, extension, deviation, forearm rotation)	• The risk multiplier corresponds to a risk zone. This risk zone recommends three possibilities: no intervention, increased risk analysis and if the risk zone is high enough, intervention.	• Postural/force scores can be used to identify areas for improvement.	• A range of acceptable postures and duration times is given. Tasks that fall outside of this range required intervention. Intervention consists of altering the posture so that it is more neutral (upright trunk, upper arms hanging freely,	• If risk factors are noted to be present in the workplace, the opinion of members of the workplace risk reduction taskforce determine if an intervention is required.	• Using the postural load index, the posture can be fitted into one of four categories. If the index is high, the category type may require action.

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	• Graph of Normalized Peak Force vs. HAL outlines acceptable, and unacceptable regions. Peak Force and HAL are directly related. Intervener must find ways to reduce Peak Force and /or HAL to be in the acceptable range. **ACGIH TLV for Mono-task Hand Work and Prevention of WRMSDs**			head posture according to Frankfurt plane).		
Limitations	• Many factors are deferred to professional judgment. • This assessment does not account for sustained non-neutral postures, contact stresses, low temperatures, vibration exposure. • Considers repetition and force applied to monotask hand work performed for 4+ hours per day. • It considers exertion frequency, recovery time, percent duty time and speed of motion. **Marras et al, Fundamentals and Assessment Tools for Occupational Ergonomics,2006** • TLV scores put operators within a general risk severity category but cannot predict injuries to individual operators. • Using video, the effort required is more difficult to discern. Cues such as sound and facial expression are not as easy to see. **Potvin, IOES Conference, June 2002**	• This method does not consider that actual force required to perform a task. This method considers only acceptable forces for specific populations.	• Poor predictor of incidence injury rates of jobs with cycle times below 4 seconds	• The force applied during a given posture is not considered. This would affect the length of time a posture could be held for and is a necessary element of the analysis that is missing.	• This method is a method of minimizing work related musculoskeletal disorders in the workplace. It includes managing a committee to identify and minimize risks.	• Only predicts action category for either the left or right upper limb. The more stressful of the two should be chosen. • Does not consider vibration, load, duration of action or repetition.

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	• Workers doing jobs below their TLV level were found to develop symptoms and disorders. At 'acceptable' levels of hand activity workers still experience symptoms and MSDs. • This method does not account for individual risk factors including gender, age, or medical history. • Some risk factors are not accounted for in the method (cold, vibration, non-neutral postures, contact stresses). 'Professional judgment' should be used to reduce these risk factors below the TLV but no guidance is given regarding how this should be done. **Franzblau et al. Journal of Occupational Rehabilitation, 2005.**					
Core Reference	**Hand Activity Level, ACGIH TLV, 2001**	**Safety of machinery – Human physical performance. Part 3: Recommended force limits for machinery operations. *British Standard*, January 2002.**	**Seth V, Weston RL, Freivalds A. 1999. Development of a cumulative trauma disorder risk assessment model for the upper extremities. *International Journal of Industrial Ergonomics* 23:281-291.**	**ISO11226. 2000 Ergonomics – Evaluation of static working posture, International Standard. *International Organization for Standardization*.**	**ISO/TS 20646-1:1004(E). 2004. Ergonomic procedures for the improvements of local musculoskeletal workloads – Part 1: Guidelines for reducing the local muscular workloads. *International Organization for Standardization.***	**Marras, W., Karwowski W. (eds.) 2006. An Assessment Technique for Postural Loading on the Upper Body (LUBA). *Fundamentals and Assessment Tools for Occupational Ergonomics*. pp. 43-1 to 43-8.**

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Other References	**ACGIH TLV for Mono-task Hand Work and Prevention of Work Related Musculoskeletal Disorders, MSDs. Accessed May 2006. http://umrerc.engin.umich.edu/jobdatabase/RERC2/HAL/ACGIHTLV.htm** **American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values and biological exposure indices for 2001. Cincinnati: ACGIH, 2001.** **Franzblau, A., Armstrong, T., Werner, R., Ulin, S. 2005. A Cross-Sectional Assessment of the ACGIH TLV for Hand Activity Level. *Journal of Occupational Rehabilitation*. 15(10): pp 57 to 67.** **Marras, W., Karwowski W. (eds.) 2006. Assessment Tools, The ACGIH TLV for Hand Activity Level. *Fundamentals and Assessment Tools for Occupational Ergonomics*. pp. 34-9 to 34-10 and 41-1 to 41-14.** **Potvin, J., Dawson, D., Jones, J., Macpherson, M., and Joseph, B. 2002. Comparing Risk Scores from the ACGIH TLV Guideline When Obtained from Live Observation and Video Records. Proceedings of the XVI Annual International Occupational Ergonomics and Safety Conference, Toronto, Ontario, Canada. June 10-13. 6pp.** **Potvin, J., Dawson, J., MacPherson, M., Joseph, B. 2002. evaluating the ACGIH TLV Guideline for Low Force/High Frequency**			**Delleman, N. 2000. Upper Limb Assessment According to ISO/CEN Standards. *Proceedings of the IEA 2000/HFES 2000 Congress*.** **Kilbom, A. 1994. Repetitive Work of the Upper Extremity: Part I – Guidelines for the Practitioner. *International Journal of Industrial Ergonomics*. 14: pp 51 to 57.**		**Armstrong, T., Buckle, P., et al 1993. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scandinavian Journal of Work, Environment & Health*. pp. 73 to 81.** **Kee, D., Karwowski, W. 2001. LUBA: an assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time. *Applied Ergonomics*. 32(4): pp 357 to 366.**

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Example Worksheet	Worksheet **ACGIH Threshold limit values and biological exposure indices for 2001**	Worksheets **Worksheets are available through British Standard, BSI Standards.**	Software	Worksheets **Worksheets are available through ISO.**	Worksheets **Worksheets are available through ISO.**	Worksheet **Marras et al. Fundamentals *and Assessment Tools for Occupational Ergonomics 2006.***
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