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Inter-rater reliability of cyclic and non-cyclic task assessment using the hand activity level in appliance manufacturing

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ABSTRACT

This study evaluated the inter-rater reliability of the American Conference of Governmental Industrial Hygienists (ACGIH®) hand activity level (HAL), an observational ergonomic assessment method used to estimate physical exposure to repetitive exertions during task performance. Video recordings of 858 cyclic and non-cyclic appliance manufacturing tasks were assessed by sixteen pairs of raters using the HAL visual-analog scale. A weighted Pearson Product Moment-Correlation Coefficient was used to evaluate the agreement between the HAL scores recorded by each rater pair, and the mean weighted correlation coefficients for cyclic and non-cyclic tasks were calculated. Results indicated that the HAL is a reliable exposure assessment method for cyclic ($\bar{r}$-bar$_w$ = 0.69) and non-cyclic work tasks ($\bar{r}$-bar$_w$ = 0.68). When the two reliability scores were compared using a two-sample Student's *t*-test, no significant difference in reliability ($p = 0.63$) between these work task categories was found. This study demonstrated that the HAL may be a useful measure of exposure to repetitive exertions during cyclic and non-cyclic tasks.

Relevance to industry: Exposure to hazardous levels of repetitive action during non-cyclic task completion has traditionally been difficult to assess using simple observational techniques. The present study suggests that ergonomists could use the HAL to reliably and easily evaluate exposures associated with some non-cyclic work tasks.

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1. Introduction

Musculoskeletal disorders (MSDs) continue to be one of the leading sources of impairment and lost work time in the United States and elsewhere. In 2011, occupationally-related MSDs in the United States accounted for 32.8% of all cases of injuries and illnesses requiring time away from work and resulted in a median of 11 lost work days (Bureau of Labor Statistics, 2012). The development of MSDs is linked to a variety of physical work exposures, such as awkward postures, excessive forces, prolonged vibration, and high repetition (Bernard, 1997; NRC/IOM, 2001). In particular, repetitive hand activity has been identified as one of the primary occupational risk factors associated with upper extremity MSDs (Bernard, 1997; Latko et al., 1999; Silverstein et al., 1986, 1987). Exposure assessment tools, such as the American Conference of Governmental Industrial Hygienists (ACGIH®) Hand Activity Level (HAL) Threshold Limit Value (TLV®) (ACGIH, 2005) have been developed to quantify these physical risk factors (Latko et al., 1997). In 2001, the National Research Council and the Institute of Medicine (NRC/IOM) reported that additional occupational risk factor exposure assessment tools should be developed or improved (NRC/IOM, 2001). As a measure of physical exposure to repetitive exertion, the utility of the HAL would be improved if it could be used to assess non-cyclic tasks. Non-cyclic tasks in a manufacturing, construction, agriculture, healthcare, service, and general office/administrative industries may expose workers to repetitive exertions that repeatedly stress their musculoskeletal systems, and the associated MSD hazard exposure should be assessed (Fethke et al., 2012; Paquet et al., 2005; Punnett and Wegman, 2004).

Exposure assessment tools are used to quantify physical exposure and estimate the risk of developing a work-related MSD.

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Ergonomists investigating exposures that may increase MSD risk use a variety of metrics, including those based on self-report (e.g., work diaries), expert observation (e.g., HAL or Strain Index), and direct measurement (e.g., push/pull force sensors, electrogoniometry, or surface electromyography) (David, 2005; Dempsey et al., 2005; Kilbom, 1994). The choice of assessment tools depends on the characteristics of the work task, but may also depend on training, familiarity, practicality, cost, and time required to use the tool (Dempsey et al., 2005; Li and Buckle, 1999).

Some investigators have quantified repetitive hand activity in the field using direct measures of muscle activity or wrist deviation frequencies (Chen et al., 2010; Fethke et al., 2012; Hansson et al., 1996; Jones and Kumar, 2007; Spielholz et al., 2001). These data intensive methods produce quantitative estimates with better accuracy than observational or self-report assessment tools (David, 2005; Spielholz et al., 2001). However, analyzing and interpreting direct measurement results is time intensive and requires considerable technical expertise. Furthermore, the cost of instrumentation and software required to perform direct measures can be prohibitively expensive (Anton et al., 2003; David, 2005). Observational methods are frequently employed in industry because they cost less and are more time efficient than direct measures, and are generally more accurate and reliable than self-reports (Ebersole and Armstrong, 2002; Garg and Kapellusch, 2011; Kilbom, 1994; Takala et al., 2010).

In performing a HAL assessment, an ergonomist typically uses a standard scale to judge the magnitude of worker exposure to repetitive and forceful exertions. Because the estimation of HAL values is based on observer judgment, establishing the reliability of the HAL method is important for interpreting HAL results, whether the aim is for research, hazard mapping, or intervention evaluation (Kilbom, 1994; Streiner and Norman, 2008). Multiple studies report that the HAL inter-rater reliability ranges from moderate to good when assessing cyclic tasks (Ebersole and Armstrong, 2006; Spielholz et al., 2008; Takala et al., 2010). However, the inter-rater reliability of non-cyclic task assessment has not been estimated, in part because the HAL was designed to assess cyclic, mono-task jobs (Armstrong, 2006; Latko et al., 1997), but also because of the difficulty assessing non-cyclic tasks given the absence of an inherent task completion pattern (Punnett and Wegman, 2004).

In some of the earlier literature, the distinction between cyclic and repetitive tasks is unclear (Bao et al., 2009; Latko et al., 1997). This is primarily because some ergonomic researchers have used the concept of cycle-time to define tasks as repetitive or non-repetitive (Armstrong et al., 1987; Buchholz et al., 1996; Chiang et al., 1993; Colombini, 1998; Silverstein et al., 1986). In the present study, appliance assembly line tasks were evaluated regardless of whether they were expected to be classified as repetitive according to the HAL or any other type of exposure assessment. The aim of this was to determine if a repetitive task could be estimated reliably regardless of whether the work was cyclic or non-cyclic. Further, classification of tasks as cyclic or non-cyclic was entirely based on whether the work conformed to easily identifiable patterns of subtask or work element procedures lasting no more than 3 min.

Further confusion arises from the inconsistent usage of the terms “mono-task,” “single-exertion,” and “complex task” (Bao et al., 2009; Kapellusch et al., 2013). The HAL was designed to assess repetitive force exposures during mono-task work performance lasting at least 4 h (Armstrong, 2006). The developers of the assessment defined mono-task work as a predictable pattern of work elements (or subtasks) reoccurring throughout the work shift (ACGIH, 2005; Latko et al., 1997). This definition of mono-task work differs from the one presented by Moore and Garg (1995) during their description of a similar assessment tool, the Strain Index, where they equated mono-tasks with single exertion tasks (Moore and Garg, 1995). More often than not, tasks are comprised of subtasks requiring different levels of exertion rather than a single level of exertion, and these are called complex tasks (Bao et al., 2009; Garg and Kapellusch, 2011; Kapellusch et al., 2013). In the present study, the HAL was applied to single exertion and complex exertion tasks. Some of these tasks were characterized by unpredictable subtask performance patterns (i.e. non-cyclic tasks), so they would not be considered mono-tasks according to the HAL developers. Nonetheless, these non-cyclic tasks may still expose workers to predictable patterns of repetitive force exertions. The purpose of the present study was to compare the inter-rater reliability of the HAL assessments used to estimate worker exposure to repetitive hand exertions during cyclic and non-cyclic task performance in the appliance manufacturing industry.

2. Materials and methods

2.1. Study context

The present study obtained previously recorded videos of cyclic and non-cyclic work tasks performed by adult (≥18 years aged) workers in a household appliance manufacturing facility. The videos were recorded during a large prospective cohort study (Gerr et al., 2013) focused on associations between physical exposures and MSD incidence among manufacturing workers.

The appliance manufacturing facility employed approximately 2000 workers on multiple assembly lines. The research team observed manual tasks performed on multiple assembly lines representing all stages of appliance production—from materials fabrication to product assembly and packaging. For the present study, “tasks” were defined as assembly, inspection, or packaging procedures performed at a specific workstation, such as “assemble wire harness” or “install ice maker.” Tasks were categorized as cyclic if they were performed according to an identifiable work cycle lasting 3 min or less. Otherwise, tasks were categorized as non-cyclic. University faculty members in ergonomics determined *a priori* whether tasks were cyclic and non-cyclic. An appliance product quality inspection task is a good example of one that is non-cyclic. This task involved use of hand tools requiring various levels of grip strength to operate, manual handling of materials of varying weights, intermittent inspection of control panels, and the making of assembly line adjustments as needed. The subtasks or work elements comprising the quality inspection task did not proceed according to a clearly identifiable procedure, and inspections could last longer than 3 min.

Digital video cameras were arranged within the manufacturing facility to grossly record the frontal and sagittal planes of the workers’ upper extremities during task completion. One video camera was mounted on a tripod for a consistent, stable viewing angle, while another researcher operated a hand-held camera. Camera views were continuously adjusted in an attempt to fill the frame with the worker’s upper body. Dynamic control of the second camera improved tracking of the upper limbs when work materials or equipment obstructed the view of the workers. Workers were videotaped for a minimum of 30 min for each task that they performed. Prior to the HAL rating sessions the two video recordings were synchronized, providing raters with two simultaneous views of each worker.

In the present study, video recordings of 385 workers performing their standard assembly-line tasks were observed, and a total of 858 tasks were evaluated with the HAL. The mean worker age was 42.3 years (SD = 10.6), and on average they had worked at

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