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# The Relationship Between Hand and Wrist Musculoskeletal Disorders and Hand Activity and Posture

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Public Health
with a concentration in Occupational Exposure Science
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ABSTRACT

Musculoskeletal disorders are common in many industries such as automotive, manufacturing and line assembly. Risk factors include high frequency or hand repetition, long duration of work activities with short rest periods, unsustainable postures which put strain on the body and muscles, and activities that require significant force to fulfill duties. The current ACGIH TLV for hand activity uses hand activity level (HAL) and normalized peak force (NPF) to assess an individual's risk of developing an MSD. The purpose of this study is to propose the use of Posture as an alternative to NPF and couple it with HAL to assess the risk of an MSD.

The data used in this paper come from an automotive study conducted at four automotive manufacturing plants. An estimated 50 interviews were conducted at each of the four plants in an effort to document if any worker had recently experienced an MSD which would then be termed as a case. A case was determined by one of two methods, the first being if the employee visited the plant clinic for pain experienced while on the job, the second occurred through an interview conducted by a USF investigator in which the employee answered yes to having pain or discomfort that interfered with work, play or sleep and there was a treatment-seeking behavior. The analysis revealed HAL and Posture can be used to assess potential MSD development in exposed workers. Logistic regression was conducted, and it showed statistical significance when using HAL and Posture to assess MSDs developing in workers exposed in occupational settings. In place of NPF, Posture can be used with HAL to assess MSDs in occupational settings.

# CHAPTER ONE: INTRODUCTION

Musculoskeletal disorders (MSDs) are soft tissue injuries that effect the joints, tendons, ligaments and muscles of the body, which may lead to decreased functionality and limit mobility (WHO, 2018). Upper limb MSDs may involve the shoulders, arm, forearm, wrist, elbow and hand. Common examples of upper limb MSDs include rotator cuff tendonitis, tension neck syndrome and carpal tunnel syndrome (ACGIH, 2018). In the manufacturing sector, a total of 115,550 days away from work (DAFW) cases were reported for 2017 (BLS, 2017). MSDs accounted for 34 percent (38,950) of the DAFW cases in the manufacturing sector (BLS, 2017). The incidence rate for MSDs in the manufacturing sector was 31.4 cases per 10,000 full time equivalent (FTE) workers in 2017 (BLS, 2017). The BLS reported sprains and strains as the most prevalent injury type in the manufacturing sector during 2017 (BLS, 2017).

Industries that have an elevated risk for MSDs include automotive, manufacturing, assembly work and nursing (Anderson et al., 1997; T. J. Armstrong et al., 1999; BLS, 2017; Burt et al., 2011, 2013). Force, posture and frequency elevate levels of hand activity and overexertion. Workers may experience these factors individually or in a combined form which increases the risk of muscle and tendon fatigue and may lead to development of an MSD (Anderson et al., 1997; Antonucci, 2019; T. Armstrong, J. et al., 1993; T. J. Armstrong et al., 1999; T. J. Armstrong et al., 2015; T. J. Armstrong & Ebersole, 2006; Burt et al., 2013; Finneran & O'Sullivan, 2013).

The ACGIH proposed a threshold limit value (TLV) for work related MSDs of the hand and wrist that is inclusive of force, posture and frequency. The TLV of the hand and wrist uses hand activity level (HAL) for frequency and normalized peak force (NPF) to account for the force and posture. To assess force, you need information on the posture and population being studied. Accessing this information can be very difficult. As such, the indicators posture and hand activity can be used to assess the likelihood of an MSD.

This purpose of this study is to determine if hand activity and posture can be used to assess the development of an MSD.

# CHAPTER TWO: LITERATURE REVIEW

Force, posture and frequency are well known risk factors for MSDs. The ACGIH TLV for hand activity has identified an increased risk of MSDs when these risk factors are present. Peak Force is the force used to accomplish a task while in a specific posture. Posture refers to body positions in which there may be increased strain on muscles and tendons in the body. Frequency includes repetitive motions and duration of activity.

The ACGIH developed a TLV for determining potential over exposure risk to the hand, wrist and forearm (ACGIH, 2018). Hand Activity Level (HAL) was first introduced by Latko, et al (1997), since then, it has been incorporated into the development of the HAL TLV. The hand activity TLV is comprised of two factors which are HAL and normalized peak force (NPF).The TLV specifically addresses mono-task jobs that have periods of rest and are conducted for four or more hours daily (ACGIH, 2018; Allee et al., 2010; T. J. Armstrong et al., 2015; Bernard, Bloswick, Drinkaus, Mann, & Sesek, 2005). According to the ACGIH, HAL is the frequency of hand exertions and duty cycle, essentially it involves the allocation of work activity with recovery periods for that work activity (ACGIH, 2018). Latko, et al (1997), proposed a method to determine HAL, trained observers use a rating scale which is based on exertion frequency, speed of motion and rest pauses (ACGIH, 2018; Allee et al., 2010; Antonucci, 2019; T. J. Armstrong et al., 1999; T. J. Armstrong & Ebersole, 2006; T. J. Armstrong et al., 1997).

Calculation of HAL is performed by review of expert ratings, hand exertion frequency, duty cycle (duty cycle is the exertion time / exertion + rest time * 100%); HAL values are rounded to the nearest whole number, interpretation of that number is based on a scale ranging from 0 – 10. 0 denotes idle work or no significant exertions and 10 denotes rapid motions or prolonged exertions characterized by difficulty keeping up with the activity (ACGIH, 2018; Akkas et al., 2017; T. J. Armstrong et al., 1999; T. J. Armstrong et al., 2015; T. J. Armstrong & Ebersole, 2006; Bao et al., 2014; Burt et al., 2013).

NPF is the peak force divided by the strength of the population to which the standard is applicable, the $90^{th}$ percentile is utilized in order to limit random work elements (ACGIH, 2018; T. J. Armstrong & Ebersole, 2006; Bernard et al., 2005). NPF also uses a scale from 0 – 10, 0 would denote virtually no effort and 10 would mean maximum possible effort (ACGIH, 2018; T. J. Armstrong & Ebersole, 2006; Bernard et al., 2005). According to ACGIH, (2018) determining NPF for a given job activity requires;

- Measuring the hand forces and relative postures.
- Gathering strength data for the posture, the specific worker and work population (most strength data can be obtained from the literature).
- Calculating NPF by dividing the required force by strength.

Visual analogue scales or the Borg scale can be used to determine the effort and work activity performed by the worker. The Borg scale is comprised of non-linear verbal anchor points, the worker is asked to describe which point is the closest representation of the effort level used to complete their job activity (Borg, 1982). Trained observers use visual analogue scales to determine force exposures; ACGIH, (2018) suggests that having multiple observers' rate and discuss job force exposures may increase the precision of observer ratings. Values for normalized peak force (NPF) and HAL should be rounded to the nearest whole integer, values less than 1 were considered outside of the scope of the TLV because they were not repetitive work and values in excess of 10 were deemed to be rapid movements and difficult to maintain, thus the recommendation is that the HAL values never exceed a value of 9 (ACGIH, 2018).

Potential problems may arise when using NPF to assess the force of an individual in a job activity. The problem lies with finding reliable data if any, for the postures or the population in question. However, there is literature that substantiates posture as a vital indicator that increases the likelihood of MSD's of the upper extremity (Akinfeleye, Akodu, Atanda, & Giwa, 2015; Anderson et al., 1997; Antonucci, 2019; Antwi-Afari et al., 2017; T. J. Armstrong & Ebersole, 2006; Beek & Punnett, 2000; Brouwer, Keyserling, Silverstein, & Stetson, 1993; Checkoway, Kaufman, Morgan, Silverstein, & Spielholz, 2001). Posture and hand activity can be used to assess the probability of an MSD being developed.

# CHAPTER THREE: METHODS

The data used were obtained from a study involving jobs in the automotive industry. Four plants participated in the study and they were identified as BSP, CEP, DTP, and KTP. BSP represents a stamping plant, CEP represents powertrain, specifically engines, and DTP and KTP are assembly plants. A total of 50 jobs were targeted at each plant. For each job, the medical database was queried for MSDs associated with the job, and an operator was interviewed. Investigators focused on the job, rather than the worker, to understand which job caused injuries. The UAW-Ford Ergonomics Surveillance Tool was used to gather data on postures and repetitive actions for the job of interest. Specifically, values for posture and HAL were noted.

The data on clinic visits and the USF Symptom Interview created the framework from which a case definition could be established. A case is determined by one of two conditions, the first was medical records indicating a visit from the employee in response to pain experienced on the job, or second by answering yes to certain interview questions that dealt with pain experienced and treatment-seeking.

Descriptive statistics were obtained for Posture and HAL individually as main effects. The mean and standard deviation were also obtained for each plant, the product of HAL and Posture, and for cases and non-cases.

Logistic regression was used to test the relationship between hand repetition and posture. The main effects were ran as ordinal data with values ranging 1-5, and the interactions were ran as continuous data. The term “cDUE” stands for case Distal Upper Extremity. The equations tested are as follows:

Equation #1: $p\ [cDUE] = \alpha + \beta_1 Posture + \beta_2 HAL + \beta_3 Posture * HAL$

Equation #2: $p\ [cDUE] = \alpha + \beta_1 Posture * HAL$

Equation #1 includes the main effects and the interaction of Posture and HAL. In order to use Equation #1, both main effects have to be significant to consider the interaction. Equation #2 looked at the product of HAL * Posture.

CHAPTER FOUR: RESULTS

There were 201 jobs considered, of which, 132 were non-cases and 69 were cases. Analysis of the data was accomplished using the JMP software from the Statistical Analysis Software (SAS) Institute Inc. Table I shows the distribution of cases and non-cases for all plants.

Table 1. Number of Cases and Non-Cases Reported in all Ford Plants

| Plant | Interviews | Cases | Non-Cases | Total |
|---|---|---|---|---|
| BSP (stamping) | 50 | 5 | 43 | 48 |
| CEP (engine) | 57 | 12 | 41 | 53 |
| DTP (assembly) | 43 | 24 | 18 | 42 |
| KTP (assembly) | 59 | 28 | 30 | 58 |
| **Total** | 209 | 69 | 132 | 201 |

Table 2 shows the descriptive statistics for HAL by cases and non-cases across plants.

Table 2. Descriptive Statistics for HAL by Cases and Non-Cases by Plant

| Plant | Case Mean (± Std) | Non-Case Mean (± Std) |
|---|---|---|
| BSP (stamping) | 3.0 (± 0.7) | 3.0 (± 0.5) |
| CEP (engine) | 2.9 (± 0.6) | 2.7 (± 0.6) |
| DTP (assembly) | 3.3 (± 0.6) | 2.9 (± 0.5) |
| KTP (assembly) | 3.0 (± 0.7) | 3.1 (± 0.3) |

Table 3 shows the descriptive statistics for Posture by cases and non-cases in all plants.

Table 3. Descriptive Statistics for Posture by Cases and Non-Cases by Plant

| Plant | Case Mean (± Std) | Non-Case Mean (± Std) |
|---|---|---|
| BSP (stamping) | 1.8 (± 1.3) | 1.0 (± 0.3) |
| CEP (engine) | 2.8 (± 0.5) | 2.4 (± 0.6) |
| DTP (assembly) | 2.9 (± 0.3) | 2.9 (± 0.2) |
| KTP (assembly) | 3.0 (± 0.4) | 2.9 (± 0.4) |

Table 4 shows the descriptive statistics for the Product of HAL and Posture by cases and non-cases across plants.

Table 4. Descriptive Statistics for HAL * Posture by Cases and Non-Cases by Plant

| Plant | Case Mean (± Std) | Non-Case Mean (± Std) |
|---|---|---|
| BSP (stamping) | 5.6 (± 4.2) | 3.3 (± 0.8) |
| CEP (engine) | 8.2 (± 2.5) | 6.5 (± 2.4) |
| DTP (assembly) | 9.8 (± 2.0) | 8.5 (± 1.4) |
| KTP (assembly) | 9.1 (± 2.5) | 9.0 (± 2.0) |
| **Total** | 8.9 (± 2.7) | 6.3 (±2 .9) |

Plants DTP and KTP had the highest documented cases, the mean for plant DTP was 9.8 with a standard deviation of 2.0 and plant KTP had a mean of 9.1 with a standard deviation of 2.5.

Equation #1 showed no statistical significance for the main effects but had a significant interaction at $p = 0.025$.

Equation #2 was statistically significant showing a p value of $<0.001$.

The Receiver Operating Characteristic curve (ROC) is used to determine how well a classification model will perform. This metric can be used to tell how accurate a model will be in distinguishing sensitivity from specificity. FIGURE 1 shows the ROC curve obtained from the product of HAL and Posture.

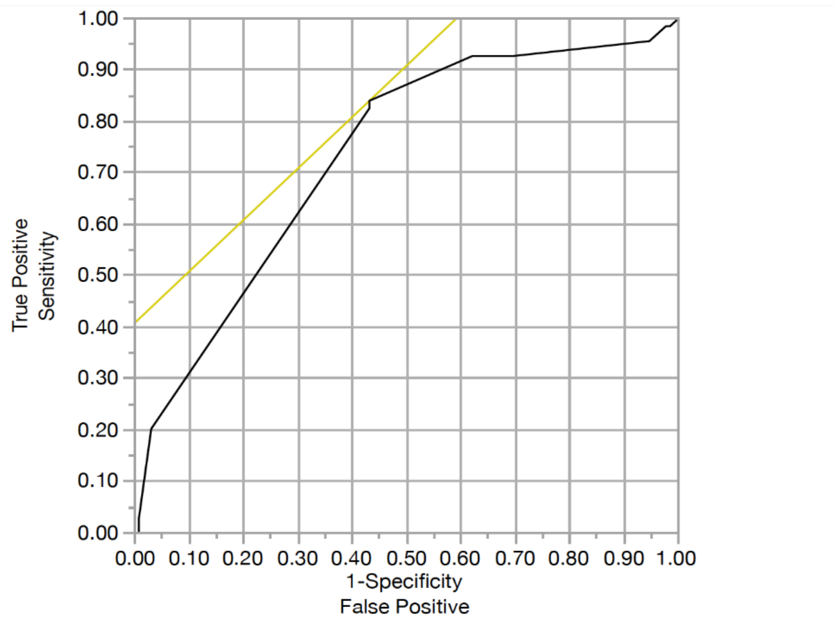


Figure 1. Receiver Operating Characteristic curve for the product of Posture and HAL

The ROC area under the curve (AUC) obtained for this result was 0.73. The p-value obtained from Equation #2 substantiates this result that HAL and Posture can be used to predict the likelihood of an MSD occurring.

# CHAPTER FIVE: DISCUSSION

Musculoskeletal disorders are caused by the prevalence of force, posture and frequency in the workplace. The ACGIH TLV for hand activity includes these three risk factors. To determine if Posture and HAL are reliable indicators in assessing exposure of workers in a manufacturing setting, the proposed method must accurately predict the likelihood of an MSD developing in an individual. This study's goal is to show that Posture and HAL can be used to assess an MSD. One great benefit of using Posture and HAL to assess MSDs, is that it is not reliant on data of the postures and populations being studied.

A case in this study occurred in one of two ways, a visit to the plant clinic with the diagnosis of an MSD or through a positive interview in which the worker reported interference with work or personal life and pursued treatment. Equation #2 was significant at $p < 0.0001$ for the product of Posture * HAL.

The ROC curve had an AUC of 0.73, which is a good indictor of the model's ability to discriminate a case from a non-case. The closer the ROC curve approaches a value of 1, the better the model is at distinguishing a case from non-case. An AUC of 0.73 is not particularly good, therefore, decisions have to be made about favoring sensitivity or specificity at the cost of the other.

The current TLV uses HAL and NPF to assess over exposure in individuals. While NPF may potentially increase the ROC value, it may also have no effect. Using Posture simplifies the process of assessing occupational injuries because it does not require specific literature in order to assess the risks of developing an MSD. The ease of use allows for an easier assessment of potential MSDs developing in exposed workers in occupational settings.

# CHAPTER SIX: CONCLUSION

This study examined the use of HAL and Posture to assess distal upper extremity MSDs. The current TLV for hand activity uses HAL and NPF. NPF can be difficult to analyze due to the fact that sometimes the data required to predict exposure in a particular position may not be readily available if available at all. The analysis shows the proposed model of HAL and Posture, may be used in predicting the development of MSDs.

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