

6-18-2008

Assessing the Predictive Validity of the UAW-Ford Ergonomic Surveillance Tool

Gregory S. Krivonyak
University of South Florida

Follow this and additional works at: <https://digitalcommons.usf.edu/etd>



Part of the [American Studies Commons](#)

Scholar Commons Citation

Krivonyak, Gregory S., "Assessing the Predictive Validity of the UAW-Ford Ergonomic Surveillance Tool" (2008). *USF Tampa Graduate Theses and Dissertations*.
<https://digitalcommons.usf.edu/etd/348>

This Thesis is brought to you for free and open access by the USF Graduate Theses and Dissertations at Digital Commons @ University of South Florida. It has been accepted for inclusion in USF Tampa Graduate Theses and Dissertations by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact digitalcommons@usf.edu.

Assessing the Predictive Validity of the UAW-Ford Ergonomic Surveillance Tool

by

Gregory S. Krivonyak

A thesis submitted in partial fulfillment
of the requirements for the degree of
Masters of Science in Public Health
Department of Environmental and Occupational Health
College of Public Health
University of South Florida

Major Professor: Stuart M. Brooks, M.D.
Thomas Truncale, D.O.
Thomas E. Bernard, Ph.D.

Date of Approval:
June 18, 2008

Keywords: first time occupational visit, distal upper extremity, Strain Index, case
job, sensitivity, specificity

© Copyright 2008, Gregory S. Krivonyak

Dedication

This paper is dedicated to my beloved wife, Aimee Dorine, the one person who has stood by me through all my struggles, trials and tribulations, who has been my greatest cheerleader, and without whom I would not have been able to complete this project. She is owed a debt of gratitude that is immeasurable.

Acknowledgments

First I must thank Dr. Thomas E. Bernard for making this project available to me. He supervised, guided, and assisted every step of the writing process.

I also must thank Drs. Stuart M. Brooks and Thomas Truncale, who have guided and instructed me through the last two years.

I must also acknowledge the organizations and persons that were instrumental in the project for which I am reporting: UAW-Ford National Joint Programs; NIOSH through the Sunshine ERC at USF; University of Utah's Phil Drinkaus and Sharon Davis; and USF's Kathleen Rockefeller and Barbara Kennedy.

Table of Contents

List of Tables	iii
List of Symbols and abbreviations	v
Abstract	vi
Introduction	1
Risk Factors for Musculoskeletal Disorders	1
Exposure Assessment Methods	3
Assessing Validity	5
Current Study	5
Literature Review	7
Distal Upper Extremity	8
Lower Back	10
Neck and Shoulders	13
Exposure Assessment	15
Predictive Validity Studies Linking Job Risk Factors to Musculoskeletal Disorders	18
Methods	20
Target Job Analysis for Ergonomic Surveillance Tool	20
Injury History for Target Jobs	21
Predictive Validity	23
Results	24
Distal Upper Extremity	24
Lower Back	26
Neck and shoulders	28
Discussion	31
Distal Upper Extremity	31
Lower Back	31
Neck and Shoulders	32

Table of Contents (continued)

General Discussion	32
References	34
About the Author	END PAGE

List of Tables

Table 1	Target job distribution among plants	24
Table 2	Case job (injury job) distribution by Ergonomic Surveillance Tool predictions for first time office visits and symptoms for distal upper extremity	25
Table 3	Observed injury/no-injury job distribution for distal upper extremity by EST decision level	25
Table 4	Sensitivity and specificity for distal upper extremity comparing Ergonomic Surveillance Tool decision levels as GY v. R and G v. YR	25
Table 5	Observed injury/no-injury job distribution for distal upper extremity by predicted first time office visit level	26
Table 6	Sensitivity and specificity for distal upper extremity comparing predicted first time office visit decision levels as GY v. R and G v. YR	26
Table 7	Case job (injury job) distribution by Ergonomic Surveillance Tool predictions for first time office visits and symptoms for lower back	26
Table 8	Observed injury/no-injury job distribution for lower back by EST decision level	27
Table 9	Sensitivity and specificity for lower back comparing Ergonomic Surveillance Tool decision levels as GY v. R and G v. YR	27
Table 10	Observed injury/no-injury job distribution for lower back by predicted first time office visit level	28
Table 11	Sensitivity and specificity for lower back comparing predicted first time office visit decision levels as GY v. R and G v. YR	28
Table 12	Case job (injury job) distribution by Ergonomic Surveillance Tool predictions for first time office visits and symptoms for neck and shoulders	28
Table 13	Observed injury/no-injury job distribution for neck and shoulders by EST decision level	29
Table 14	Sensitivity and specificity for neck and shoulders comparing Ergonomic Surveillance Tool decision levels as GY v. R and G v. YR	29

List of Tables (continued)

Table15	Observed injury/no-injury job distribution for neck and shoulders by predicted first time office visit level	29
Table 16	Sensitivity and specificity for Neck/Shoulder comparing predicted FTOV decision levels as GY vs. R and G vs. YR.	30

List of Symbols and Abbreviations

1.	UAW	United Automobile Workers
2.	EST	Ergonomics Surveillance Tool
3.	ESP	Ergonomics Surveillance Program
4.	LEC	Local Ergonomics Committees
5.	FTOV	First Time Office Visit
6.	DUE	Distal Upper Extremities
7.	LB	Lower Back
8.	NS	Neck and Shoulders
9.	BLS	Bureau of Labor and Statistics
10.	OHSIM	Occupational Health, Safety, and Injury Management Branch

Assessing the Validity of the UAW-Ford Ergonomic Surveillance Tool

Gregory S. Krivonyak, M.D.

ABSTRACT

Work-related musculoskeletal disorders (MSDs) account for more than 350,000 occupational illnesses and injuries in the United States. Many job risk factors for developing MSDs are found in the automotive industry and the United Automobile Workers (UAW)-Ford Ergonomics Surveillance Tool (EST) has been designed to screen these jobs into high, moderate or low risk for work-related musculoskeletal disorders affecting the distal upper extremity (DUE), lower back (LB) and/or neck and shoulders (NS). The purpose of this effort was to examine the predictive validity of the EST against a sample of target jobs at four Ford plants.

Individual jobs for this study were selected by a stratified random assignment. Health records from Ford were reviewed in order to identify first time office visits (FTOVs), which were symptomatic complaints made by individual workers. Jobs that were associated with FTOVs were defined as case jobs for the three body regions. These case jobs were compared with predictions for injury by EST. Sensitivity and specificity were used to test predictive validity.

While the sensitivity was poor for all body regions tested, the specificities were fairly strong for DUE and NS when looking at low risk compared to

moderate/high risk. The low risk DUE specificity was 0.67 and increased to 0.78 when looking at low/moderate risk compared to high. Low back specificity for low risk was 0.51 but increased to 0.85 when looking at low/moderate risk compared to high. The NS specificity score was 0.81, increasing to 0.85 when looking at low/moderate risk. While the EST does not predict which jobs are high risk for injury, it does screen out safe jobs. Therefore, jobs identified by the EST as low/moderate risk are likely to be safe.

Chapter 1: Introduction

The 2006 annual Survey of Occupational Injuries and Illnesses published by the Bureau of Labor and Statistics (BLS) reported that there were 1.2 million cases of occupational injuries and illnesses, occurring at a rate of 128 per 10,000 workers, with a median of 7 days lost per case. Approximately one third (357,160) of these cases developed musculoskeletal disorders (MSDs) with a median of 9 lost days per case.

About one-third of all MSDs affect the trunk (which includes the shoulder and back). This breaks down to 250,870 (21.2 %) cases related to the back and 75,810 (6.4 %) cases due to shoulder injuries. Shoulder injuries led to the longest period of days missed from work (median=9). Upper extremities accounted for the next largest group of cases (274,180, 23.2 %). (Statistics, 2007)

Risk factors for Musculoskeletal Disorders

Musculoskeletal disorders are associated with three major categories of risk factors: that of the individual worker, the psychosocial context, and the physical demands. Individual factors, also known as personal risk factors, usually include physical characteristics (gender, height, weight, pre-morbid health status, education, and lifestyle). (NIOSH, 1997) Pre-morbid health can be affected by specific systemic diseases such as collagen vascular disorders (rheumatoid

arthritis and lupus), gout, and diabetes. (Punnett & Wegman, 2004) Psychosocial risk factors are an ambiguously defined collection of characteristics which NIOSH separates into three domains: “(1) factors associated with the job and work environment, (2) factors associated with the extra-work environment, and (3) characteristics of the individual worker.” The qualities that make up job and work environment are also known as work organization factors. These include attributes associated with job content which can be “workload, repetitiveness, job control, mental demands, and job clarity; organizational characteristics (tall vs. flat organizational structures and communication issues); interpersonal relationships at work (supervisor-employee relationships and social support) temporal aspects of the work and task (cycle time and shift work); financial and economic aspects (pay, benefit, and equity issues); and community aspects (occupational prestige and status). Extra-work environmental factors are usually defined as non-work responsibilities which can include those associated with parent, spouse, or children.” Psychosocial appear to be linked to musculoskeletal disorders.(NIOSH, 1997)

The physical demands of work have been associated with development of work-related musculoskeletal disorders. These risk factors may globally increase the risk for injury or only affect certain body regions like the distal upper extremity, lower back and/or the neck and shoulders. Most of the studies done previously have looked at disorders affecting the lower back, but some have looked at the distal upper extremity and neck and shoulder.

Exposure Assessment Methods

First, physical stressors may cause muscle strain, which may aggravate or worsen work-related biomechanical stress. Second, the psychosocial burden could alter perception and testimony of musculoskeletal symptoms, and/or understanding of their etiology. Where psychosocial risk factors are difficult to define and measure, physical risk factors for a single job can be clearly defined and have measurable characteristics that can be used to differentiate degree of risk from other jobs. Physical risk factors are due to the stress placed on the human body by performing the duties of a particular job. These risk factors include force of exertion, posture used, repetition of motion, static force, and vibration. They have been studied in relation to work-related musculoskeletal disorders focusing on whole-body, specific body regions or both. Physical risk factors can be modified by engineering and administrative controls (NIOSH, 1997), and they are of particular interest to the current research effort.

Job risk factor evaluations can be performed using specific methodologies that vary according to method of analysis. These approaches can be classified into three groups: qualitative, semiquantitative, and quantitative methods. A qualitative analysis is a subjective evaluation. It can be completed by performing walk-through surveys supplemented by information gathered through a review of employer's records of on-site injuries and personal interviews between the investigator and individuals who perform the jobs in the survey area. The walk-through survey is hampered by its complete dependence on the experience and knowledge base of the investigator. Yet, if the walk-through survey is not the best

means of inspecting the job site, then, a second approach can be done through job hazard or job safety analysis. (Chengalur, 2004)

A more structured approach “describes known job risk factors, may suggest the degree of presence necessary to be a threshold concern, and provides a method to indicate whether the threshold presence is associated with the job.” “A recent checklist designed for work-related musculoskeletal disorders was developed and distributed by the State of Washington Department of Labor and Industries for its 2000 Ergonomics Rule (Washington, 2000).”

A drawback of qualitative assessment is that it relies strongly on the judgment and practice of the ergonomist. If the ergonomist identifies job risk factors, then further analysis should be performed using the more objective semiquantitative or quantitative analysis methodologies. Semiquantitative techniques may require a little more effort to collect data, usually involve some processing of the data to reach a decision, may focus on a body region, and consider two or more contributing factors.

While quantitative analytic methods will give more objective results, they are more labor intensive and require special skills. The data must not only be carefully collected, but must be processed before any decision can be made. These techniques focus on a single body region and look at several contributing factors. The drawback with the quantitative methodology is that it requires a disciplined ergonomist, because it is painstakingly tedious, slow, and often does not yield clear results until a much later point in time. (Chengalur, 2004)

Assessing Validity

Validity of a measurement is an expression of the degree to which a measurement measures what it purports to measure. There are three types of measurement validity: construct, content, and criterion. Construct validity is the measurement's ability "to correspond to theoretical concepts (constructs) [regarding] the event in question. Content validity is "the extent to which the measurement incorporates the domain of the phenomenon under study. Criterion validity "is the [degree] to which the measurement correlates with an external criterion of the phenomenon under study." Two aspects of criterion validity are concurrent validity and predictive validity. Criterion validity is when the criterion and the measurement occur at the same time vs. predictive validity is the ability of the measurement to predict the criterion. ." (Last, 1988)

Oleckno describes two types of [study] validity: internal and external. Internal validity is the "degree to which the results of a study are true for the target population." This type of validity is deleteriously affected by systematic error. However, external validity is the level of applicability of the study's results for the given population to other populations. This second type of validity can also be called generalizability. Internal validity carries greater weight than external validity because a study must first be internally valid before it can be externally valid. (Oleckno, 2002)

Current Study

The United Automobile Workers (UAW)-Ford Ergonomics Surveillance

Tool (EST) was developed to identify jobs with significant risk factors for work-related musculoskeletal disorders (MSDs). The EST is used to gather data on job risk factors for individual jobs. These data are then provided to the ESP for categorization into Low, Moderate and High risk. The assigned category depends on the predicted probabilities of a first time office visit (FTOV) and symptoms. The analysis and outcomes are based on three body regions independently: Distal Upper Extremities (DUE), Lower Back (LB), and Neck/Shoulders (NS).

The purpose of this effort was to examine the predictive validity of the EST against a sample of target jobs at four Ford plants.

Chapter 2: Literature Review

Much of the literature concerning job risk factors for musculoskeletal disorders has focused on lower back disorders, and the majority of these studies have been cross-sectional. A lack of a clear classification of musculoskeletal disorder by region has made comparisons of the literature cumbersome. Therefore, the data must often be extrapolated in order to statistically compare the various findings.

A relationship exists between musculoskeletal disorders and work exposure to stress of a physical nature even after adjusting for age, sex, body mass index, and other factors. Punnett and Wegman's report concludes that exposure to poor ergonomic conditions are associated with musculoskeletal disorders in at least one body region. These ergonomic factors include "repetitive upper extremity motion patterns, forceful exertions; whether manual only or whole-body (heavy lifting); non-neutral body postures, and vibration." The authors found that the greatest risk has been consistently seen when a combination of these ergonomic factors are present. (Punnett & Wegman, 2004) Numerous U.S. and foreign governmental agencies (Musculoskeletal Committee of the International Commission for Occupational Health, the US National Institute for Occupational Safety and Health, the European Agency for Safety and Health at Work, and the SALTSA Joint Programme for Working Life Research in

Europe) have examined the relationship between exposures to biomechanical and psychosocial issues in the workplace and onset of musculoskeletal disorders. Even though there are methodological issues with the epidemiological studies done so far that makes them difficult to interpret and compare with other such studies, the majority of researchers concede that the evidence while having its limitations is consistent and its strength supersedes these limitations. The specific risk factors that are in agreement include repetitive and stereotyped motions, forceful exertions, non-neutral postures, vibration, and combinations of these exposures. (Punnett & Wegman, 2004)

The relationship between MSDs to ergonomic factors has been reviewed extensively for the body regions: lower back, distal upper extremity, and neck/ and shoulder by NIOSH. They have reviewed the literature critically and compiled evidence using four of the Braxton-Hill criteria: temporal relationship, consistency in association, coherence of evidence, and exposure/response relationship.

Distal Upper Extremity

The NIOSH publication reported that intensified, monotonous work and low social support were positively associated with upper extremity MSDs including those related to the hand and wrist. (1997)

Personal risk factors (worker age, anthropometric measures, and health state) have been most causally linked to lower back disorders, however several studies have looked at how these characteristics relate to MSDs of the distal

upper extremity. Attributes pertaining to the individual include gender, intelligence, level of education, social class, culture, personality traits, attitudes towards life in general and job satisfaction in particular. NIOSH reported that poor job satisfaction, anxiety and depression, problems away from work, shift work have all been examined for their association to MSDs affecting the upper extremity. Dissatisfaction with job was reviewed closely. Three studies for and one against were discovered for job satisfaction. among workers seems to be associated with upper extremity MSDs. Decreased level of control and low social support have been found to be positively associated with problems pertaining to the upper extremity. (1997)

Bongers, Kremer, and Laak's review of the literature pertaining to psychosocial risk factors for upper extremity problems (shoulder, elbow, or hand/wrist) found that worker reaction to perceived high stress both work and non-work related was associated with these problems in most studies. (2002).

Fewer studies have examined the distal upper extremity as a whole. Musculoskeletal disorders of the distal upper extremity are usually further specified as to pertaining to the elbow, forearm, wrist, and/or hand. Studies examining job risk factors for these four parts of the distal upper extremity were critically reviewed in the 1997 NIOSH paper. The most prevalent risk factors were related to repetition, force, posture, vibration, and combinations. The strongest evidence was for a combination of the above risk factors. Individually, the elbow was causally linked with force, but there was insufficient evidence to link posture or repetition to elbow MSDs. Hand and wrist MSDs were most

strongly linked to combinations of repetition, force, posture and/or vibration. Repetition and force provided evidence for causation.(NIOSH, 1997) Punnett, Gold, Katz, Gore, and Wegman study of automotive workers reported that MSD of the upper extremity were positively associated with combined ergonomic stressors, such as repetitive work, non-neutral postures, and forceful exertions (2003).

Lower Back

Lower back problems are associated with 3 types of job risk factors: personal, psychosocial, and physical characteristics. A review by Dempsey and colleagues has recommended that personal risk factors (worker age, sex, injury history, relative strength and smoking) should be further studied and included in research into the etiology of lower back disorders. They also noted a trend for seniority of worker was inversely related to development of lower back disorders. (1997) In a 15-year retrospective cohort study, Muller et al, further suggest that workers aged 50 years and older are less likely to report lower back injuries. They report that workers who performed manual, unskilled labor were more likely to be absent from work. The skilled workers may have conditioned their muscles to fatigue less and are less prone to injury. (1999)

Other risk factors like personality traits and emotional problems were supported as risk factors by both longitudinal and cross-sectional studies. Muller et al report that the strongest predictor for future sick listing for low back trouble is the worker's previous reaction to pain and discomfort. (1999) Yet, studies

looking at psychological variables are cumbersome to compare among each other because researchers have classified risk factors as psychological in some studies and psychosocial in others. Without a universal nomenclature for these terms and the associated risk factors, the data is difficult to compare and the assumptions made may be meaningless.

Psychosocial risk factors are an ambiguously defined collection of characteristics which NIOSH separates into three domains: “(1) factors associated with the job and work environment, (2) factors associated with the extra-work environment, and (3) characteristics of the individual worker.”(1997)

Examining the relationship between MSDs and psychosocial characteristics, namely: job satisfaction, work freedom, supervisor support, work time, work fast, work hours, must work, safety climate, work stress and work schedule, found that all but work fast and work schedule were significant for ‘back pain’. The only attribute of the individual that seemed to significantly change how workers reported their back pain was whether or not they had an on-the-job low back injury within the last year. The authors discovered that physical loads were associated with musculoskeletal disorders. Workers who lift heavy loads had a greater tendency to develop low back pain. The authors also concluded that physical loading, stress and musculoskeletal disorders were related in a significant way, but because this study is cross-sectional in nature, causality cannot be determined. (Waters, Dick, Davis-Barkley, & Krieg, 2007) Job satisfaction has been examined as a possible risk factor for development of lower back disorders in the workplace and the research done has provides mixed

results. (Ferguson & Marras, 1997) Hughes et al reported that workers with higher job satisfaction were more likely to develop low back pain, which may be attributable to the worker culture of their aluminum smelter study.(1997)

The relationship between MSDs to ergonomic factors has been reviewed extensively for the body regions: lower back, distal upper extremity, and neck/ and shoulder by NIOSH. They have reviewed the literature critically and compiled evidence using four of the Braxton-Hill criteria:: temporal relationship, consistency in association, coherence of evidence, and exposure/response relationship. Four ergonomic factors are associated with lower back MSDs. The strongest evidence was for lifting/forceful movement and whole body vibration. For force thirteen of eighteen studies showed positive relationships, and one fulfilled all four criteria. For whole body vibration, 19 studies were discovered, 15 of which demonstrated positive associations, but none fulfilled all four criteria. There was also positive evidence for heavy physical work causing lower back MSDs. Eighteen studies were discovered that examined heavy physical work as a risk factor, however, none met all criteria and most used subjective exposure assessments. There was insufficient evidence, however, to link lower back disorders to static posture. (1997)

In a cross-sectional study of Swedish nurses, job strain alone and in combination with physical exertion was shown to increase the chance for development of musculoskeletal symptoms. (Josephson, Lagerstrom, Hagberg, & Wigaeus Hjelm, 1997) In the Waters et al report, the physical factors: “heavy lifting” and “hand movements” were highly significant for back pain. Heavy lifting

was defined as activity that involved pushing, pulling or lifting repeatedly. Hand movements included “repetitive or stressful hand movements or awkward postures.”

A British study of policemen using body armor (mass = 8.5 kg) as a variable representative of physical occupational stress for first-time reporting of lower back problems, reported that those wearing body armor were more likely to develop lower back problems. (Burton, Tillotson, Symonds, Burke, & Mathewson, 1996)

One population-based study from a municipality outside of Copenhagen, Denmark, examined risk factors for low back pain, but was not able to delineate specific predictors for work-related lower back pain. (Biering-Sorensen & Thomsen, 1986)

Neck and Shoulder

For the neck and shoulder job risk factors are divided into the same groupings as in DUE and LB. Hartman, Vrieling, Huirne, and Metz’s study of sick leave in Dutch farmers found that individuals who were over 40, overweight and smoke seem to develop MSDs of the neck and shoulder. (2006)

Pertaining to affects of the worker psyche, the NIOSH 1997 report stated that intensified workload, monotonous work, and low social support were positively associated with upper extremity MSDs, especially those related to the neck and shoulder. Andersen and colleagues demonstrated a relationship between high job demands and shoulder disorders. (2003) The Hartman et al

study also suggested that excessive worry increased the risk of NS MSDs.

Leroux, Brisson and Montreuil's paper found that there was a high prevalence of neck-shoulder symptoms in workers exposed to high job strain. They also found that high job strain caused more problems in workers with low social support. (1997) Bongers et al (2002) found a strong association for worker stress perception and reaction to upper extremity problems, which included the shoulder.

Job risk factors for the neck and shoulder musculoskeletal disorders were critically reviewed in the 1997 NIOSH paper and found positive associations between neck and shoulder MSDs and repetition, force, and posture. (The evidence for vibration was sufficient for shoulder but not neck MSDs.). For repetition twenty of twenty six studies reported statistically significant positive association between neck and neck/shoulder MSDs. Eleven of these studies had odds ratios greater than 3.0. For force or forceful work (also measured as "heavy physical workload) 11 of 17 studies reported statistically significant associations between neck and neck/shoulder MSDs. Two of these studies had ORs greater than 3.0. For posture 31 studies were reviewed and 27 of these discovered statistically significant positive association between neck or neck/shoulder MSDs. Thirteen of these studies had odds ratios or Prevalence Rate Ratios greater than 3 and 9 had risk estimates between 1 and 3.(NIOSH, 1997)

Hughes, Silverstein, and Evanoff's looking at MSDs in aluminum smelter workers found using a univariate analysis a strong relationship between shoulder

disorders and elevated arm work. They also demonstrated via a model using multiple logistic regression that torque applied to the forearm is associated with shoulder disorders. (1997) Andersen and colleagues (2003) showed that repetition of movement was associated with shoulder symptoms, particularly pressure tenderness

One study examining almost 500 workers, mostly consisting of computer users, reported that many distal upper extremity occupational-related disorders appear to have a proximal origin. The data also suggests that these workers have a problem with their posture, which seems to be a predictor of development of future occupational injuries often arising in the shoulder and neck. (Pascarelli & Hsu, 2001)

In a prospective cohort study, Andersson and colleagues report that awkward neck flexion ($> 20^\circ$) for ~ 66% of the work day (OR 2.6, 95% CI 1.3 to 5.1) and “repetitive movements of the shoulder (adjusted OR 3.0, 95% CI 1.5 to 5.8) were the strongest physical indicator for future pain and development of tenderness to the neck and/or shoulder”. (2003)

Exposure Assessment Methods

The job risk factors for musculoskeletal disorders regardless of body region or type of risk factor can be evaluated via qualitative, semi-quantitative, or quantitative analyses. Qualitative analysis occurs when data is measured based on a non-numerically additive scale. Qualitative data measured subjectively based on criteria in a nominal or ordinal scale. Semi-quantitative analysis is a

technique that is a combination of a non-numerical and a numerical scale. Quantitative analysis occurs when data is grouped based on numerical quantities. While quantitative data provides the greatest support to a study because it is objectively measured without a component of subjectivity, qualitative data is often the easiest to obtain, so can be a worthy place to begin a study.

Several qualitative analytic instruments are used in ergonomic evaluations. These include the OSHA Screening Tool, VDT Checklist, Modified WMSD Checklist, hand activity level (HAL) threshold limit value (TLV), and ACGIH TLV for Back. David critiques the methodologies used to perform exposure analysis for certain risk factors associated with occupational musculoskeletal derangements. The author classifies them as “self reports, observational methods, and direct measurements.” Self-reports include questionnaires, diaries from individual workers, and interviews. These techniques are advantageous to the investigator because they are “straightforward to use, applicable to a wide range of working situations and appropriate for surveying large numbers of subjects at comparatively low cost. However, these studies are not without their faults. The major drawback of these studies is that the investigator must rely on the “worker perceptions of exposure” which “have been found to be imprecise and unreliable. Additionally, the source of the information may be limited by communication difficulties that can arise due to language barrier, “literacy, [education,] comprehension, or question interpretation.” Yet, these studies do provide information that identifies worker groups at high risk that

can be used for more quantifiable methods. (David, 2005)

One of the more straightforward techniques is to observe. Observational methodology allows for subjectively grading exposures associated with the workplace in a systematic fashion. The greatest advantage is that these are cheap to perform and they can be used for a wide range of applications. However, since the data is being evaluated by an individual, it is prone to the bias of that individual in the form of “intra- and inter-observer variability when choosing between different categories of exposure level, and are more suited to the assessment of static (posture held) or repetitive (simple pattern) jobs. (David, 2005)

There are also more “advanced observational techniques” available to evaluate “postural variation for highly dynamic activities” to those that can finance their costs. These techniques involve a format using video surveillance. These instruments use video- or computer-recorded data which is graded objectively with particular software suited to the data. Models to assess force and torque may be used to analyze the data. However, the most elegant method for analysis is by direct measurements. (David, 2005)

These instruments may use sensors placed on the person to be tested. These instruments may use “simple, hand-held devices for measurement of the range of joint motion to electronic goniometers that provide continuous recordings of the movement across joints during the performance of the task. Lightweight devices have been developed for application directly across articulating joints for measurement of finger and wrist angles and forearm

rotation.” Techniques that employ direct measurement are good to use because they can generate a large body of data that is highly accurate and can be for a number of variables associated with exposures. However, they do require more from the investigators than other methodologies and may not be practical. The investigators must be financed well in order to afford to perform the techniques. The investigator must take into account the following: the cost of the machines used to perform and analyze the data, the cost of hiring skilled persons who can use the machines to gather data, possibly more individuals to analyze the data, and the time required to complete all parts of the investigation. Also, the sensors used to gather data may be uncomfortable to the worker and result in changes in how they perform their work. (David, 2005)

Predictive Validity Studies Linking Job Risk Factors to MSDs

There are several forms of validity, but predictive validity is most appropriate for this study. It is an indication of how well the EST can predict injuries on the job. The measures of predictive validity are sensitivity and specificity. Sensitivity has a score of 0 to 1, and indicates how well EST can predict a job associated with an injury. Specificity also has a score of 0 to 1 and indicates how well EST can predict a job that is not associated with an injury. When both the sensitivity and the specificity are high the tool is said to be able to discriminate well; that is, it can predict both injury and non-injury jobs well.

Predictive validity has only been assessed in a few ergonomic instruments. Most notably, predictive validity has been tested in the Strain Index

by Moore and Garg. This tool screens jobs at risk for distal upper extremity MSDs. Originally, it was used to assess risk in a pork processing plant (Moore and Garg, 1995) It was shown to have strong predictive validity (sensitivity = 0.92, specificity = 1.0), so it was retested by Knox and Moore in a turkey processing plant (sensitivity = 0.86, specificity = 0.83 (2001); and again in two manufacturing plants in 2002 (sensitivity =1.0, specificity = 0.84 (Moore, Rucker, and Knox). Additionally, the Strain Index has been comparatively evaluated with the TLV-ACGIH (HAL). The two instruments were found to be in good agreement regarding exposure classification most of the time (56 % accuracy). (Spielholz, Bao, Howard, Silverstein, Smith, Salazar, 2008). The predictive validity has been reported for the 1993 revised NIOSH Lifting Equation. It was shown to be fairly good at identifying tasking that put stress on the lower back and increase the risk of lower back injury. (Waters et al, 1999)

Chapter 3: Methods

These ergonomic studies were carried out at target plants that have implemented the EST/ESP and have adequate compliance with the current medical tracking system (OHSIM). The plants that were included in this study were two vehicle assembly plants (Michigan Truck and Wayne Assembly), one transmission plant (Van Dyke) and one stamping plant (Woodhaven Stamping). These represented a large range of jobs included in the initial development effort and with the exception of the stamping plant; the job content is relatively constant over the day and week. Further, the plants had reasonable job content stability for the preceding 12 months and 6 months after the job assessments.

Target Job Analysis for EST

The first step was to select 45 jobs within a plant. The job selection was a stratified random sample of jobs in departments associated with production. A brief screening tool based on the WISHA Checklist was used to assign a low, moderate (WISHA Caution) or high (WISHA Hazard) level of risk for Low Back, Distal Upper Extremity, and Neck/Shoulder. To make the selection, a sequence of numbers was assigned to work stations on a recent plant map. A random number generator was then used to order the assigned workstation numbers. Five jobs assigned to six categories (Moderate and High Level by Body Region) and at least five jobs were assigned to Low when they were low for all body

regions.

The EST was based on an independent analysis by two experienced job analysis teams of two, one team from the University of Utah and one team from the University of South Florida. Immediately after the EST data were collected by the individual observers, a forced consensus data sheet was completed. This consensus was the Standard for the EST decision.

Injury History on Target Jobs

To obtain the injury history on the job, the OHSIM database for each plant was queried for all musculoskeletal injuries from May 1, 2006 to September 30, 2007. A pre-scan of the database was performed by USF to select out jobs that were clearly not part of the study. These included departments that did not have target jobs in them and injuries to the hips and lower extremities.

The next step was to examine the information for each injury in the database to determine if there was sufficient information describing the job to determine if the job was a target job or not. For those jobs for which there was sufficient information, the injury was assigned to the target job or removed from consideration because it was not a target job.

The remaining injury entries in the database were then linked to names and reviewed by members of the LEC. Many of the employees on the list were no longer employed by Ford or had moved to a different plant. For those employees, the LEC reviewed the names and often could link the injury to a job. In those cases, that was the attributed job, and as before the injury was assigned to a target job or removed from the list as appropriate. If the person was still

employed at the plant, the study team and LEC member sought that person to ask them what job they attributed the injury report to. Again, the injury was assigned to a target job if that job was identified or the record was discarded.

An occupational medicine resident at USF reviewed the employee's injury description. A musculoskeletal disorder is defined by the Department of Labor as a "[malady or derangement involving] muscles, nerves, tendons, joints, cartilage, or spinal discs." This definition excludes disorders resulting from accidental injuries due to "slips, trips, falls, motor vehicle accidents, or similar accidents." The 2006 BLS survey further explained that MSD cases result when the injury in question is described as an injury affecting the ligaments or tendons such as a sprain, strain, or tear. This can involve the upper or lower back, neck and shoulders, distal upper extremities, or lower extremities. The 2006 BLS study did not include the following maladies: herniated nucleus pulposus, tarsal tunnel syndrome or Reynaud's phenomenon. This specific group of conditions can be considered a MSD, however, this survey classifies these injuries and illnesses in categories that also include non-MSD cases." (Statistics, 2007) The BLS descriptions were followed for a case definition.

The occupational medicine resident also reviewed the assigned body location from OHSIM and the employee narrative, and compared it with the medical department's classifications of the injury to a body region. If an injury was described as affecting the lower back it needed to have the word low or lower or lumbar or lumbosacral in the narrative before the injury was given its final placement. Worker reports of injuries must state neck, cervical, or shoulders

to be labeled as neck and shoulders. If it was shoulders and/ or neck it was placed into NS. DUE was assigned to injuries that the worker described as affecting the hand, wrist, forearm, and/or elbow. In a few cases, the OHSIM database indicated Thorax and the injury was not clearly Low Back or Neck/Shoulder, and the entry was not assigned to the target job.

Predictive Validity

There are several forms of validity, but predictive validity is most appropriate for this study. It is an indication of how well the EST can predict injuries on the job. The measures of predictive validity are sensitivity and specificity. Sensitivity has a score of 0 to 1, and indicates how well EST can predict a job associated with an injury. Specificity also has a score of 0 to 1 and indicates how well EST can predict a job that is not associated with an injury. When both the sensitivity and the specificity are high the tool is said to be able to discriminate well; that is, it can predict both injury and non-injury jobs well.

In the development of EST, the unit of observation was the job and the case definition for injury was one or more FTOVs associated with the job. This case definition is retained in this report as well.

Chapter 4: Results

The study team used a random selection/stratification protocol based on modified WISHA Caution/Hazard Checklists to identify target jobs in four automotive plants. Table 1 lists the number of target jobs considered in this predictive validity study by plant. The results for each body region are presented in the following sections.

Table 1. Target job distribution among plants.

Plant	Michigan	Wayne	Woodhaven	Van Dyke	Total
	Truck	Assembly	Stamping	Transmission	
Number	38	32	36	39	145

The goal of the job stratification was to obtain a distribution of jobs across the range of EST risk from Green to Red in each body region with nominally 5 high and moderate risk jobs per body region per plant. That is, the goal was to have about 20 high and moderate risk jobs in each body region.

Distal Upper Extremity (DUE)

Table 2 shows the allotment of case jobs by predicted risk for an FTOV and Symptoms. From the injury history of the jobs, there were 51 DUE case jobs. Most (40) were low risk for FTOV and moderate risk for Symptoms. Few cases were associated with high predicted risk for either FTOV or Symptoms.

Table 2. Case job (injury job) distribution by EST predictions for FTOVs and symptoms for DUE.

DUE FTOVs	Symptoms			Total
	Red	Yellow	Green	
Red	0	5	0	5
Yellow	1	5	0	6
Green	1	30	9	40
Total	2	40	9	51

Table 3 describes the number of DUE case jobs and no-case jobs against the overall EST score. The Red level had 28 jobs, which exceeded the goal of 20 but the moderate risk fell a little short of 20 at 15. About two-thirds of the target jobs were not associated with injuries. About 80% of the jobs with injuries occurred with low predicted risk.

Table 3. Observed injury/no-injury job distribution for DUE by EST decision level.

DUE/EST	Injury	No injury	Total
Red	7	21	28
Yellow	5	10	15
Green	39	63	102
Total	51	94	145

Table 4 provides the DUE sensitivity and specificity with respect to grouping (GY v. R and G v. YR). It is clear that specificity is much higher than sensitivity.

Table 4. Sensitivity and specificity for DUE comparing EST decision levels as GY vs. R and G vs. YR.

DUE/EST	GY vs. R	G vs. YR
Sensitivity	0.14	0.24
Specificity	0.78	0.67

Table 5 gives the distribution of case jobs compared to the predicted FTOV to compare to EST. There were some small changes compared to Table 3. The Red level lost 6 jobs, two of which moved to the Yellow level and the other four to

Green.

Table 5. Observed injury/no-injury job distribution for DUE by predicted FTOV level.

DUE/Predicted FTOV	Injury	No injury	Total
Red	5	12	17
Yellow	6	11	17
Green	40	71	111
Total	51	94	145

As a result, the specificities in Table 4 are improved slightly (see Table 6) with some further loss of sensitivity.

Table 6. Sensitivity and specificity for DUE comparing predicted FTOV decision levels as GY vs. R and G vs. YR.

DUE/Predicted FTOV	GY vs. R	G vs. YR
Sensitivity	0.10	0.22
Specificity	0.87	0.76

Lower Back

Table 7 shows the allotment of cases by predicted risk for FTOVs and Symptoms. From the injury history of the jobs, there were 23 Low Back case jobs. Half (11) were low risk for FTOV and moderate risk for Symptoms. Six and 1 case jobs were associated with high predicted risk for FTOV and Symptoms respectively.

Table 7. Case job (injury job) distribution by EST predictions for FTOVs and symptoms for Low Back.

Low Back FTOVs	Symptoms			Total
	Red	Yellow	Green	
Red	1	5	0	6
Yellow	0	5	0	5
Green	0	11	1	12
Total	1	21	1	23

The distribution of case jobs (Injury) and non-case jobs by EST decision level is shown in Table 8. The distribution of jobs across the risk levels favored Green (about half), but there were more than the goal of 20 for Red (24) and Yellow (47). About 15% of the jobs were associated with an injury history. Among case jobs, about half of these were at the low EST level with Yellow and Red sharing the others. About half the non-case jobs were also at the Green level and about 15% at the Red level.

Table 8. Observed injury/no-injury job distribution for Low Back by EST decision level.

LB/EST	Injury	No injury	Total
Red	6	18	24
Yellow	5	42	47
Green	12	62	74
Total	23	122	145

Table 9 is the sensitivity and specificity with respect to grouping (GY v. R and G v. YR). Grouping GY yields high specificity and low sensitivity scores.

Grouping YR, however, leaves sensitivity and specificity near 0.5.

Table 9. Sensitivity and specificity for Low Back comparing EST decision levels as GY vs. R and G vs. YR.

LB/EST	GY vs. R	G vs. YR
Sensitivity	0.26	0.48
Specificity	0.85	0.51

Table 10 is used to compare to predicted injury only. Interestingly, there were no changes in the case job and no case job distributions compared to Table 8.

Table 10. Observed injury/no-injury job distribution for Low Back by predicted FTOV level.

LB/Predicted FTOV	Injury	No injury	Total
Red	6	18	24
Yellow	5	42	47
Green	12	62	74
Total	23	122	145

As a result, the sensitivities and specificities were identical (see Table 11).

Table 11. Sensitivity and specificity for Low Back comparing predicted FTOV decision levels as GY vs. R and G vs. YR.

LB/Predicted FTOV	GY vs. R	G vs. YR
Sensitivity	0.26	0.48
Specificity	0.85	0.51

Neck and Shoulder

Table 12 shows the distribution of case jobs by predicted risk for FTOV and Symptoms. From the injury history of the jobs, there were 31 NS case jobs. Half (15) were low risk for FTOV and moderate risk for Symptoms. Few cases were associated with high predicted risk for either FTOV or Symptoms.

Table 12. Case job (injury job) distribution by EST predictions for FTOVs and symptoms for Neck/Shoulder.

NS/EST	Symptoms			Total
	FTOVs	Red	Yellow	
Red	0	6	0	6
Yellow	0	10	0	10
Green	0	15	0	15
Total	0	31	0	31

Table 13 describes the number of Neck/Shoulder case and no-case jobs against the overall EST score. The 20 job goal for Red and Yellow were exceeded with 28 for Red and 64 for Yellow. Almost 80% of the jobs were not associated

with injuries and 50% of the injuries occurred with low predicted risk.

Table 13. Observed injury/no-injury job distribution for Neck/Shoulder by EST decision level.

NS/EST	Injury	No injury	Total
Red	6	22	28
Yellow	10	54	64
Green	15	38	53
Total	31	114	145

Table 14 is the sensitivity and specificity with respect to grouping (GY v. R and G v. YR). Interestingly, the specificity is high when looking at GY vs. R, but drops off greatly when looking at G vs. YR.

Table 14. Sensitivity and specificity for Neck/Shoulder comparing EST decision levels as GY vs. R and G vs. YR.

NS/EST	GY vs. R	G vs. YR
Sensitivity	0.19	0.52
Specificity	0.81	0.33

In Table 15, the distribution of case jobs predicted by FTOV only is shown.

There were some small changes compared to Table 13.

Table 15. Observed injury/no-injury job distribution for Neck/Shoulder by predicted FTOV level.

NS/FTOV	Injury	No injury	Total
Red	6	17	23
Yellow	10	54	64
Green	15	43	58
Total	31	114	145

As a result, the sensitivities and specificities in Table 16 are only slightly different from those in Table 14.

Table 16. Sensitivity and specificity for Neck/Shoulder comparing predicted FTOV decision levels as GY vs. R and G vs. YR.

NS/Predicted FTOV	GY vs. R	G vs. YR
Sensitivity	0.19	0.52
Specificity	0.85	0.38

Chapter 5: Discussion

The purpose of this project effort was to assess the predictive validity of the EST. The sampling goal was to have at about 20 high and moderate risk jobs in each body region. The sampling goal was met. Because the job analyses were pooled, there was a tendency to have more jobs in the low and moderate risk levels than the high risk.

Distal Upper Extremity

The sensitivity was weak for the EST. The specificity was fairly good for EST at 0.67 for the Green level alone and 0.78 for the Green/Yellow grouping (see Table 4). When just the predicted FTOV was used to set risk level, the specificity increased to 0.76 for Green alone and 0.87 for the Green/Yellow combination (see Table 6). Because most of the case jobs for DUE were clustered under a moderate level for predicted Symptoms (Table 2), this result was not surprising. The other reason that this would occur is because the current case definition is based on injury history and not symptoms.

Low Back

For Low Back, the Green level alone for EST (Table 9) and for predicted FTOV (Table 11) were weak with sensitivity at 0.48 and specificity at 0.51. But the specificity for the Green/Yellow combination was 0.85 along with a weak sensitivity of 0.26. There were fewer case jobs for low back and again the case jobs clustered under moderate predicted risk for symptoms. Also the case

definition may affect the lack of spread for symptoms.

Neck/Shoulder

The Neck/Shoulder had a fairly strong specificity for the combination of Green/Yellow for EST (Table 14) and for predicted FTOV risk level (Table 16) at 0.81 and 0.85, respectively. Otherwise, the values for sensitivity and specificity were weak. The small number of injuries and the case definition may have affected both outcomes.

General Discussion

The strength of the original concept for the EST was to safely take jobs off the table for further consideration. The Green level does this well for DUE, but has weaker results for Low Back and Neck/Shoulder. In practice, the plants appear to be concentrating on Red jobs, which is appropriate. It turns out that combining the Green and Yellow levels together as a decision to delay action is reasonable. That is, based on a simple case definition of one injury defining a job as a case leads to specificities generally over 0.80.

There was also a lack of discrimination based on symptoms. This was seen in the very little difference in the data when using EST or the predicted FTOV alone. This may be confounded by the case definition. But an examination of all the jobs distributed over the three levels of predicted risk by FTOV and symptoms also shows that most of the jobs analyzed had moderate risk for symptoms. For these two reasons, the contribution of the predicted symptoms was not a strong contributor in this validity study.

The original development of the EST included both symptoms and FTOVs for two reasons. The first was that there was a considerable disconnect between case jobs based on injuries and case jobs based on symptoms. The second was that symptoms were also important. Ultimately, it is FTOVs that must be controlled and there was anecdotal information that some of the FTOVs were due to being new on the job and reporting the symptoms associated with the new work. Unfortunately, we cannot go examine that as a hypothesis.

The EST model does not consider psychosocial, work organization, or personal risk factors. These attributes are many and varying. While they are not considered for very the very reason that the interest is in the job demands, these factors can add considerable noise.

In conclusion, the EST does succeed at taking jobs off the table for further consideration. The validity study supports the value for a revised version that can take the predicted symptoms components out of the model without a significant loss of predictive value. In addition, it is a good time to reconsider the threshold point and perhaps maximize the specificity and chose just one cut point.

The EST is an ergonomic assessment instrument that has been validated. It is useful for identifying jobs that pose low risk for injury.

References

- Andersen, J. H., Kaergaard, A., Mikkelsen, S., Jensen, U. F., Frost, P., Bonde, J. P., et al. (2003). Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies. *Occup Environ Med*, 60(9), 649-654.
- Biering-Sorensen, F., & Thomsen, C. (1986). Medical, social and occupational history as risk indicators for low-back trouble in a general population. *Spine*, 11(7), 720-725.
- Burton, A. K., Tillotson, K. M., Symonds, T. L., Burke, C., & Mathewson, T. (1996). Occupational risk factors for the first-onset and subsequent course of low back trouble. A study of serving police officers. *Spine*, 21(22), 2612-2620.
- Chengalur, S. N., Rodgers, Suzanne H., Bernard, Thomas E. (2004). *Kodak's Ergonomic Design for People at Work* (2nd ed.). Hoboken: John Wiley & Sons, Inc.
- David, G. C. (2005). Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occup Med (Lond)*, 55(3), 190-199.
- Dempsey, P. G., Burdorf, A., & Webster, B. S. (1997). The influence of personal variables on work-related low-back disorders and implications for future research. *J Occup Environ Med*, 39(8), 748-759.
- Ferguson, S. A., & Marras, W. S. (1997). A literature review of low back disorder surveillance measures and risk factors. *Clin Biomech (Bristol, Avon)*, 12(4), 211-226.
- Hughes, R. E., Silverstein, B. A., & Evanoff, B. A. (1997). Risk factors for work-related musculoskeletal disorders in an aluminum smelter. *Am J Ind Med*, 32(1), 66-75.
- Josephson, M., Lagerstrom, M., Hagberg, M., & Wigaeus Hjelm, E. (1997). Musculoskeletal symptoms and job strain among nursing personnel: a study over a three year period. *Occup Environ Med*, 54(9), 681-685.
- Last, J. (Ed.) (1988) (2nd ed.). New York: Oxford University Press.
- Muller, C. F., Monrad, T., Biering-Sorensen, F., Darre, E., Deis, A., & Kryger, P. (1999). The influence of previous low back trouble, general health, and working conditions on future sick-listing because of low back trouble. A 15-year follow-up study of risk indicators for self-reported sick-listing caused by low back trouble. *Spine*, 24(15), 1562-1570.
- NIOSH. (1997). *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back*. Retrieved from.
- Oleckno, W. (2002). *Essential epidemiology principles and applications*. Long Grove, Illinois: Waveland Press, Inc.
- Pascarelli, E. F., & Hsu, Y. P. (2001). Understanding work-related upper extremity disorders: clinical findings in 485 computer users, musicians,

- and others. *J Occup Rehabil*, 11(1), 1-21.
- Punnett, L., & Wegman, D. H. (2004). Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol*, 14(1), 13-23.
- Statistics, B. o. L. a. (2007). *Nonfatal occupational injuries and illnesses requiring days away from work, 2006* Retrieved. from <http://www.bls.gov/news.release/pdf/osh2.pdf>.
- State of Washington Department of Labor and Industries Proposed Ergonomic Rule Hearing*, Department of Labor and Industries (2000).
- Waters, T. R., Dick, R. B., Davis-Barkley, J., & Krieg, E. F. (2007). A cross-sectional study of risk factors for musculoskeletal symptoms in the workplace using data from the General Social Survey (GSS). *J Occup Environ Med*, 49(2), 172-184.

About the Author

Gregory S. Krivonyak received a Bachelor's Degree in Biology from Fairmont State College in 1997 and a doctorate of medicine from Joan C. Edwards School of Medicine, Marshall University in 2003. He completed his internship in pediatrics at the University of South Florida in 2004, enrolled in the Occupational Medicine Residency Program at University of South Florida in the fall of 2006 and is scheduled to graduate Summer, 2008.

Prior to starting medical school, after completing a semester of the biomedical sciences masters program at Marshall University Graduate School, he began work as a researcher for a private cardiologist in Charleston, WV, and was credited as lead author in three publications. He currently holds membership in the American College of Occupational and Environmental Medicine.