# WASHINGTON STATE ERGONOMICS TOOL:

# PREDICTIVE VALIDITY IN THE WASTE INDUSTRY

A Thesis

by

SUSAN EPPES

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2004

Major Subject: Safety Engineering

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# ABSTRACT

Washington State Ergonomics Tool:
Predictive Validity in the Waste Industry. (May 2004)
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Chair of Advisory Committee: Dr. Jerome J. Congleton

This study applies the Washington State Ergonomics Tool to waste industry jobs in Texas. Exposure data were collected by on-site observation of fourteen different multi-task jobs in a major national solid waste management company employing more than 26,000 employees. This company has nationwide operations, and these jobs represent the majority of workers involved in the collection and processing of solid waste.

The WSET uses observational checklist methodology to evaluate generic risk factors in the following six major categories: awkward posture, highly repetitive motion, high hand force, repeated impact, lifting, and hand-arm vibration. The assessment tool incorporates these risk factors and combinations of risk factors into checklists for identifying three levels of potential exposure: safe, "caution zone" and "hazard zone" jobs. The tool was developed for employers to use in determining whether a job was likely to increase the risk of workplace musculoskeletal disorders (WMSDs) to their employees.

OSHA 200 logs were used as the main source of morbidity data. If there was one recorded WMSD, the job was classified as "positive." If there was no recorded WMSD, the job was classified as "negative." "Safe" jobs were those predicted not to expose workers to increased risk of WMSDs. Those that possessed one or more "caution zone" criteria but still fell below the "hazard zone" threshold required the employer to provide "awareness education" for employees and to further analyze the job for the presence of "hazard zone" risk factors. If hazard zone risk factors were not present, no further action was required. Jobs that upon further analysis possessed one or more of the "hazard zone" criteria were labeled "hazardous" jobs. If the further analysis shows the presence

of risk factors established in the hazard zone criteria (Appendix B), the employer would be required to take corrective action to reduce exposures to below the hazardous level.

Of the three jobs predicted to be "safe" by "caution zone" criteria, two did not have injuries and one did. Of the eleven jobs predicted by "caution zone" criteria to increase the risk of WMSDs, six resulted in injuries and five did not. Of the four jobs predicted by "hazard zone" criteria to be "problem" jobs, two jobs did result in injury and two did not.

This study found that the WSET "caution zone" criteria were more effective at predicting which jobs were likely to increase the risk of WMSDs than was the "hazard zone" checklist. The caution zone had high sensitivity and low specificity. The hazard zone criteria reflect a low sensitivity and a low specificity.

Further analysis revealed the WSET was helpful in predicting back injuries associated with lifting but not effective at predicting jobs with the potential for upper extremity injuries.

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# INTRODUCTION

In 2000 the Washington State Department of Labor and Industry published the Washington State Ergonomics Tool (WSET), designed to help employers determine which jobs present a potential risk for developing workplace musculoskeletal disorders.

The WSET employs observational methodology to assess specific risk factors in order to determine which jobs are more likely to expose employees to potential workplace musculoskeletal disorders (WMSDs). The tool uses a checklist approach to categorize a variety of tasks into "safe," "caution zone" and "hazard zone."

The objective of this paper is to assess the validity of the WSET as a predictor of whether a job has the potential for WMSDs. Following is the methodology used:

1. Identify jobs for analysis.
2. Assess worker exposure to musculoskeletal stressors for these jobs using WSET criteria.
3. Assess musculoskeletal morbidity for these jobs using OSHA logs.
4. Perform statistical analysis to determine whether WSET was a valid predictor of hazardous or safe jobs.

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This thesis follows the style and format of the *Journal of Occupational and Environmental Hygiene*.

## OVERVIEW

The Washington State Department of Labor and Industry defines workplace musculoskeletal disorders, or WMSDs, as serious ailments resulting in material impairment to the health and functional capacity of workers. In this definition they include injuries and illnesses that involve the bones, joints, muscles, tendons, nerves and supporting structures. WMSDs are work-related, non-traumatic, soft tissue musculoskeletal disorders, such as carpal tunnel syndrome, tendonitis, rotator cuff syndrome, and low back strain. They are associated with exposure to physical risk factors in the workplace, such as awkward postures, high hand force, highly repetitive motion, repeated impact, heavy, frequent, or awkward lifting, and moderate to high hand-arm vibration. [1]

The primary goal of business is to maximize shareholder wealth, but costs associated with workplace injury, especially workplace musculoskeletal disorders, have a significant negative financial impact. In 2001, the latest year for which WMSD figures are available, workplace musculoskeletal disorders cost U.S. businesses over $18 billion dollars. The WMSD trickle-down effect ultimately has a negative effect on the U.S. economy as a whole.

In 2001, 5.2 million people in the United States were hurt in private industry jobs, a rate of one new on-the-job injury or illness case every six seconds.[2] In 2001, the median number of days away from work was eight days for each WMSD injury.[3]

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[1] State of Washington Department of Labor and Industries: Concise explanatory statement (RCW 34.05.325.6a), WAC 296-62-051, Ergonomics:8 (2000).

[2] Dupont, Inc., Website: Safety is good business. *Safety that Works,* 2.5. [Online] Available http://www.dupont.com/safety/newsletter.

[3] Bureau of Labor Statistics: Table 11: Number of nonfatal occupational injuries and illnesses with days away from work involving musculoskeletal disorders by selected worker and case characteristics, 2001. [Online] Available http://www.bls.gov.

Nearly half of all WMSD injuries occurred in the manufacturing (119,458) and services (134,851) sectors.[4]

While the frequency of workplace accidents is decreasing, the expense of treating lost workday case workplace injuries continues to rise. According to the latest Liberty Mutual Workplace Safety Index, worker injuries now cost employers about one billion dollars each week.[5] The National Safety Council estimates each lost workday-case costs U.S. industry more than $33,000.[6] Indirect costs for each lost workday-case, including lower productivity, missed deliveries and overtime, are an estimated two to five times as much.[7]

In 2001, the Bureau of Labor Statistics (BLS) reported 1,537,567 total cases of lost workdays in American businesses, of which 522,528 (33 percent) involved WMSDs.[8] Extrapolating these figures indicates that costs associated with WMSDs exceed $18 billion per year. Tables 1 through 4 below highlight information available from the U.S. Department of Labor Bureau of Labor Statistics (BLS) on WMSD injuries. Table 1 quantifies the nature of WMSD injuries; Table 2 lists the part of body affected; Table 3 quantifies the event or exposure causing injury/illness; and Table 4 breaks WMSDs down by the source.

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[4] Bureau of Labor Statistics: Table 11.

[5] Croasmun, J.: One billion reasons to employ ergonomics. *Ergonomics Today,* 12/10/2003. [Online] Available http://www.ergoweb.com/news.

[6] Dupont, Inc., Website: Safety is good business.

[7] Ibid.

[8] Bureau of Labor Statistics: Table 11.

Table 1

2001 BLS WMSD Nature of Injury/Illness

| Nature of Injury/Illness | Number of cases | Percent of total |
|---|---|---|
| Sprains and Strains | 399,722 | 76% |
| Soreness and Pain | 50,240 | 9.6% |
| Carpal Tunnel Syndrome | 26,522 | 5.0% |
| Musculoskeletal system/ connective tissue disease/ disorder | 23,601 | 4.5% |
| Hernia | 22,443 | 4.3% |
| Total | 522,528 | 100% |

Table 2

2001 BLS WMSD Part of Body Affected

| Part of Body Affected | Number of cases | Percent of total |
|---|---|---|
| Trunk | 370,049 | 70.8% |
| Upper extremities | 81,398 | 15.5% |
| Lower extremities | 37,633 | 7.2% |
| Neck | 11,064 | 2% |
| Other | 22,384 | 4% |
| Total | 522,528 | 100% |

Table 3

2001 BLS Event or Exposure Causing WMSDs

| Event or exposure causing WMSD | Number of cases | Percent of total |
|---|---|---|
| Bending, climbing, crawling, reaching, twisting | 69,247 | 13.2% |
| Overexertion | 393,182 | 75.3% |
| Repetitive motion | 60,099 | 11.5% |
| Total | 522,528 | 100% |

Table 4

2001 BLS Source of Injury/Illness Causing WMSDs

| Source of injury/illness | Number of cases | Percentage of total |
|---|---|---|
| Containers | 149,616 | 28.6% |
| Worker motion or position | 127,960 | 24.5% |
| Parts and materials | 64,761 | 12.4% |
| Health care patient | 54,973 | 10.5% |
| Furniture, fixtures | 23,132 | 4.4% |
| Machinery | 21,879 | 4.2% |
| Vehicles | 19,683 | 3.7% |
| Hand tools | 15,216 | 2.9% |
| Other | 45,308 | 8.7% |
| Total | 522,528 | 100% |

The term "ergonomics**,"** from the Greek "ergo," meaning work, and "nomics," meaning law, roughly translates into "the laws of work." In a business context, the term refers to the body of knowledge, principles, or "laws" that orient the employee to his mechanized work environment in a way that maximizes his safety, comfort and ultimately his long term productivity.

According to the Liberty Mutual Workplace Safety Index, lost workday cases cost American business a billion dollars every week, with WMSDs accounting for over a third of these cases. Businesses can reduce the negative financial impact of WMSDs and maximize shareholder wealth by applying the principles of ergonomics to their workplaces.

The WSET

The Washington State Ergonomics Tool (WSET), developed by the Washington State Department of Labor and Industry (L&I), was designed as a tool for employers to:

1) Assess jobs and identify those with high potential for causing WMSDs, and
2) Identify specific risk factors that increase the potential risk of the job to be a WMSD hazard.

This screening tool takes a straightforward, checklist approach that assesses the presence of a variety of generic risk factors, as well as intensity, duration, posture and frequency of exposure.

The WSET breaks jobs down into three categories: 1) "safe" jobs, those with no "caution zone" or "hazard zone" risk factors present; 2) "caution zone" jobs which meet any of fourteen specific caution zone job criteria and have a sufficient degree of risk to require cautionary steps, such as awareness education and further job analysis, but do not necessarily have risks great enough to require corrective action; and 3) "hazard zone" jobs, a subset of "caution zone" jobs that, after more thorough investigation, are found to possess risk factors above the caution zone level criteria. If the further analysis shows the presence of risk factors established in the hazard zone criteria (Appendix B), the employer would be required to take corrective action to reduce exposures to below the hazardous level.

The WSET was created to help employers identify and reduce employee exposure to hazards that can cause or aggravate WMSDs. The approach is hazard-based rather than injury-based and focuses on identifying potential dangers in advance rather than after an injury has occurred. The Washington State Dept. of Labor and Industry, creators of the tool, believe this is a more effective way to protect employees. L&I estimated that, had all elements of the WSET been fully implemented, it would have prevented annually 40 percent of the WMSD injuries and 50 percent of WMSD-associated costs statewide.[9]

Washington L&I selected risk factors to be included in the Washington State Ergonomics Tool (WSET) that have been associated with contributing to WMSDs. It states: "…we believe strong scientific evidence supports our selection of these particular risk factors that are measured by WSET…."[10]

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[9] State of Washington Department of Labor and Industries: Concise explanatory statement:102.

[10] Ibid:10.

The Washington State Department of Labor and Industry used the following methodology and reasoning to determine the six specific risk factor exposure levels that would define "safe," "caution zone" and "hazard zone" jobs:

> First, L&I searched the epidemiological literature for methodologically sound studies that estimated the quantitative relationship between observable workplace risk factor exposures and the occurrence of WMSDs. L&I gave the most serious consideration to studies meeting the NIOSH epidemiological review criteria for acceptable quality and sound study design.
>
> Second, L&I identified a subset of these studies that quantified risk factor exposure in terms of frequency, duration and/or intensity (or magnitude).
>
> Third, L&I looked for risk factor exposure levels at which WMSDs began to occur and higher levels of risk factor exposure at which WMSDs became more widespread or severe. In particular, L&I identified exposure levels (or ranges of exposure) to risk factors at which there was a statistically strong relative risk of at least 1.5 for one or more types of WMSDs.
>
> Fourth, L&I considered the evidence as a whole in the manner similar to NIOSH. Thus these studies were not only viewed individually (taking into account good epidemiological principles) but together as a body of evidence for making broader interpretations about epidemiological causality.
>
> Fifth, L&I converted these scientifically estimated risk levels into regulatory exposure levels that adequately protect workers, but also take into account the need for consistency, understandability, simplicity, and practical application. Caution zone criteria were set at levels where the risk begins to rise and caution is needed. The hazard zone criteria were set at levels where the evidence for high risk of WMSD is most secure. The methodology described resulted in the adoption of exposure levels to risk factors that fall within a reasonable zone and are understandable to employers, protective of employees and administratively workable.[11]

Under WSET guidelines, jobs would be reviewed annually. L&I intended to evaluate the effectiveness of the WSET using two tools: a periodic review of workers' compensation claims for WMSDs; and a periodic survey of employers' perceptions about WMSDs, workplace risk factors and steps taken to prevent WMSDs.

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[11] State of Washington Department of Labor and Industries: Concise explanatory statement:68.

# METHODOLOGY

This study applies the Washington State Ergonomics Tool to jobs at five waste processing plants and along several waste collection routes in Texas. The study had four stages conducted in the following order: (1) job selection, (2) hazard classification based on exposure assessment, (3) injury/illness analysis and morbidity classification, and (4) description and analysis of the corresponding 2x2 contingency tables.

## Job Selection

Exposure data were collected from the observation of fourteen multi-task jobs in the Houston, Texas metropolitan area operations of a major national solid waste management company. These jobs represent the majority of workers involved in the collection and processing of solid waste. The data were collected by on-site observation and videotaped for further evaluation.

During data collection, job analysis, and hazard classification, job analysts were blinded to morbidity data. Supervisors provided information on shift duration and typical daily collection and production rate for each job. Employees were aware they were being observed.

Following are the jobs analyzed:

- 3 residential collection
    - manual residential rear load driver
    - manual residential rear load helper
    - manual residential recycle curbside driver
- 2 landfill operations
    - landfill heavy equipment operator
    - landfill spotter
- 3 material recovery facilities
    - commercial paper pre-sort sorter
    - paper line sorter

    - rigid container sorter
- 5 maintenance facilities
    - mechanic
    - painter
    - container repair
    - tire repair
    - truck washer
- 1 medical waste processing plant
    - medical waste processor

All jobs were multi-task, involving employees who perform a number of different tasks during a shift instead of repeating the same task throughout the day.

Hazard Classification Based on Exposure Assessment

The WSET breaks down generic risk factors into six major categories: awkward posture, highly repetitive motion, repeated impact, lifting, and hand-arm vibration. The assessment tool incorporates these risk factors and combinations of risk factors, i.e. posture, frequency and duration, into the following checklist for identifying "safe," "caution zone" and "hazard zone" jobs (see Table 5):

Table 5

Washington State Ergonomics Tool
Job Evaluation Checklist

| **CAUTION ZONE** | **HAZARD ZONE** |
|---|---|
| **AWKWARD POSTURE** | **AWKWARD POSTURE** |
| 1. Working with the hand(s) above the head, or the elbow(s) above the shoulders more than 2 hours total per day. | 1. Working with the hand(s) above the head or the elbows above the shoulders more than 4 hours total per day. |
| 2. Working with the neck or back bent more than 30 degrees (without support and without the ability to vary posture) more than 2 hours total per day. | 2. Repeatedly raising the hand(s) above the head, or the elbow(s) above the shoulder(s) more than once per minute more than 4 hours total per day. |

Table 5 Continued

| CAUTION ZONE | HAZARD ZONE |
|---|---|
| 3. Squatting more than 2 hours total per day. | 3. Working with the neck bent more than 45° (without support or the ability to vary posture) more than 4 hours total per day. |
| 4. Kneeling more than 2 hours total per day. | 4. Working with the back bent forward more than 30° (without support or the ability to vary posture) more than 4 hours total per day. |
| | 5. Working with the back bent forward more than 45° (without support or the ability to vary posture) more than 2 hours total per day. |
| **HIGH HAND FORCE** | 6. Squatting more than 4 hours total per day. |
| 5. Pinching an unsupported object(s) weighing 2 or more pounds per hand, or pinching with a force of 4 or more pounds per hand, more than 2 hours per day (comparable to pinching half a ream of paper). | 7. Kneeling more than 4 hours total per day. |
| 6. Gripping an unsupported object(s) weighing 10 or more pounds per hand, or gripping with a force of 10 or more pounds per hand, more than 2 hours total per day (comparable to clamping light duty automotive jumper cables onto a battery). | |
| **HIGHLY REPETITIVE MOTION** | **HIGH HAND FORCE** |
| 7. Repeating the same motion with the neck, shoulders, elbows, wrists, or hands (excluding keying activities) with little or no variation every few seconds, more than 2 hours total per day. | 8. Pinch grip with highly repetitive motion more than 3 hours total per day. |
| 8. Performing intensive keying more than 4 hours total per day. | 9. Pinch grip with deviated wrist posture more than 3 hours total per day. |
| **REPEATED IMPACT** | 10. Pinch grip more than 4 hours total per day. |
| 9. Using the hand (heel/base of palm) or knee as a hammer more than 10 times per hour, more than 2 hours total per day. | 11. Gripping an unsupported object with highly repetitive motion for more than 3 hours total per day. |

Table 5 Continued

| CAUTION ZONE | HAZARD ZONE |
|---|---|
| **HEAVY, FREQUENT OR AWKWARD LIFTING** | 12. Gripping and unsupported object with deviated wrist posture more than 3 hours total per day. |
| 10. Lifting object weighing more than 75 pounds once per day or more than 55 pounds more than 10 times per day. | 13. Gripping an unsupported objective with a force of more than 10 lbs more than 4 hours total per day. |
| 11. Lifting objects weighing more than 10 pounds if done more than twice per minute, more than 2 hours total per day. | **HIGHLY REPETITIVE MOTION** |
| 12. Lifting objects weighing more than 25 pounds above the shoulders, below the knees or at arms length more than 25 times per day. | 14. Using the same motion with little or no variation every few seconds (excluding keying activities), pinching grip, high, forceful exertions with the hands, more than 2 hours total per day. |
| **MODERATE TO HIGH HAND-ARM VIBRATION** | 15. Using the same motion with little or no variation every few seconds with pinching grip more than 6 hours total per day. |
| 13. Using impact wrenches, carpet strippers, chain saws, percussive tools (jack hammers, scalers, riveting or chipping hammers) or other tools that typically have high vibration levels, more than 30 minutes total per day. | 16. Intensive keying with deviated wrist posture more than 4 hours per day. |
| 14. Using grinders, sanders, jig saws or other hand tools that typically have moderate vibration levels more than 2 hours total per day. | 17. Intensive keying more than 7 hours per day. |
| | **REPEATED IMPACT** |
| | 18. Using the hand (heel/base of palm) as a hammer more than once per minute more than 2 hours per day. |
| | 19. Using the knee as a hammer more than once per minute more than 2 hours total per day. |
| | **APPENDIX A – LIFTING** |
| | **APPENDIX A – LIFTING** |
| | **APPENDIX B – HAND-ARM VIBRATION** |

Each of the fourteen jobs was reviewed and analyzed to determine if any of the caution zone or hazard zone WSET checklist risk factor criteria were met. If none of the caution zone factors was present, the job was considered "safe." If one or more of the caution zone risk factors were present, the job was classified as a "caution zone" job and further evaluated for hazard zone criteria. If one or more of the hazard zone criteria were met, the job was classified as a "hazardous" job.

Injury/Illness Analysis and Morbidity Classification

After completing the initial exposure assessments and assigning hazard classifications, a retrospective review of OSHA 200 logs was conducted for January 1997 through December 1999 to identify reported cases of WMSDs in the fourteen waste industry jobs. A job was classified as "positive" if one or more injury or illness occurred in the three-year time period under study. A job was considered "negative" if no WMSD injuries or illnesses occurred.

The OSHA log provided the date of injury, job title, injury type, body part affected, cause of injury, and classification of injury (lost work day cases, restricted duty or medical treatment).

Description and Analysis

Measures of predictive validity and evidence of association were calculated using 2x2 tables (see Table 6). Rows reflect hazard classifications (whether a job is predicted to be "problem" or "safe"), and the columns reflect morbidity classifications (whether an injury actually occurred), "positive" or "negative." Jobs are represented as cell counts: cell *a* reflects jobs predicted to be problem where injuries do occur; *b* reflects jobs predicted to be a problem where injuries did not occur; *c* reflects jobs predicted to safe but resulted in injury; and *d* reflects jobs predicted to be safe that actually were. Table 7 provides formulas for measures of predictive validity.[12]

[12] Rucker, N. and J.S. Moore: Predictive validity of the strain index in manufacturing facilities. *Applied Occupational and Environmental Hygiene 17*:66.

Table 6

2x2 Table

| | | *Morbidity Classification* | |
|---|---|---|---|
| | | Positive | Negative |
| *Hazard Classification* | Problem | a | b |
| | Safe | c | d |

Table 7

Statistical Formulas

| | |
|---|---|
| Sensitivity | a/(a + c) |
| Specificity | d/(b + d) |
| Positive predictive value | a/(a + b) |
| Negative predictive value | d/(c + d) |
| Odds ratio | ad/bc |

The ability of the WSET to predict the injury potential of a job is explained in the following statistical terms:

- Sensitivity reflects the ability of an exposure assessment method to correctly identify positive jobs (those predicted by the checklist to be hazardous) as problem jobs (jobs resulting in illness or injury).
- Specificity refers to the ability of the exposure assessment method to correctly identify negative jobs (those predicted by the checklist to be safe) as safe jobs (jobs not resulting in illness or injury).
- Positive predictive value (PPV) reflects the percentage of problem jobs that are positive jobs (jobs predicted to be hazardous that do result in injuries) and
- Negative predictive value (NPV) refers to the percentage of safe jobs that are negative jobs (jobs predicted to be safe that in fact are safe).

Chi-squared statistics (likelihood ratio, or LR) were used to evaluate the relationship between morbidity classification ("positive" or "negative") and hazard classification ("problem" or "safe"). The strength of association was reported as the odds ratio. If at least one cell had a count less than 5, Fisher's exact test was utilized to determine statistical significance. Data were analyzed using SPSS software version 10.0 on a personal computer.

# RESULTS

## Hazard Classification Based on Exposure Assessment

All jobs were analyzed for the presence of WSET "caution zone" generic risk factors. Those with "caution zone" factors present were further analyzed for "hazard zone risk" factors. Finally, the jobs were broken down into the three categories: safe, caution zone and hazard zone. Table 8 below summarizes these findings.

Table 8

WSET Hazard and Caution Zone Classification
for Waste Industry Jobs Analyzed

| JOB | CAUTION ZONE RISK FACTORS (CAUSE/ AFFECTED BODY PART)* | HAZARD ZONE RISK FACTORS (CAUSE/AFFECTED BODY PART)* |
|---|---|---|
| Manual residential rear load driver | 12 (lifting/back) | |
| Manual residential rear load helper | 12 (lifting/back) | |
| Manual residential recycle curbside driver | | |
| Landfill heavy equipment operator | | |
| Landfill spotter | | |
| Medical waste processor | 1 (awkward posture/upper extremities), 6, (high hand force/upper extremities), 7 (highly repetitive motion/upper extremities), 11 (lifting/back) | 14 (highly repetitive motion/upper extremities) |
| Material recovery facility-commercial paper presort sorters | 7 (highly repetitive motion/upper extremities) | 15 (highly repetitive motion/upper extremities) |
| Material recovery facility - paper line sorter | 7 (highly repetitive motion/upper extremities) | 15 (highly repetitive motion/upper extremities) |
| Material recovery facility - rigid container sorter | 7 (highly repetitive motion/upper extremities) | 15 (highly repetitive motion/upper extremities) |
| Mechanic | 6 (high hand force/upper extremities) | |

Table 8 Continued

| JOB | CAUTION ZONE RISK FACTORS (CAUSE/ AFFECTED BODY PART)* | HAZARD ZONE RISK FACTORS (CAUSE/AFFECTED BODY PART)* |
|---|---|---|
| Painter | 7 (highly repetitive motion/upper extremities) | |
| Container repair | 2 (awkward posture/upper extremities), | |
| Tire repair | 3 (awkward posture/lower extremities), 6 (high hand force/upper extremities), 10 (lifting/back) | |
| Truck washer | 7 (highly repetitive motion/upper extremities) | |

*These numbers correlate with the WSET checklist discussed in Table 6 above.

Three of the fourteen jobs (21%) were predicted to be safe, possessing none of the caution zone or hazard zone risk factors. For the caution zone risk factors, eleven of the fourteen jobs (78%) were predicted to increase the risk of injuries. Under WSET criteria that link risk factors to body region, of those eleven, four (28%) were predicted to increase the risk of WMSD injuries to the back and eight (57%) to the upper extremities. For those jobs further evaluated for hazard zone risk factors, four were predicted to cause injury. All were associated with risk factors linked to upper extremities.

Injury/Illness Analysis and Morbidity Classification

Table 9 below shows OSHA 200 data for the fourteen waste industry jobs being analyzed. It also segregates the back and upper extremity injuries to analyze WSET ability to predict WMSD injuries with regard to these specific body regions.

Table 9

OSHA 200 Injuries/Illnesses by Job

| JOB | TOTAL NO. OSHA INJURIES | TOTAL NO. OSHA WMSD INJURIES/ ILLNESSES | BACK/ LIFTING | UPPER EXT. | FTE/ YEAR |
|---|---|---|---|---|---|
| Manual residential rear load driver | 74 | 19 | 9 | 4 | 60 |
| Manual residential rear load helper | 63 | 18 | 8 | 5 | 120 |
| Manual residential recycle curbside driver | 13 | 1 | 0 | 1 | 30 |
| Landfill heavy equipment operator | 8 | 0 | 0 | 0 | 60 |
| Landfill spotter | 2 | 0 | 0 | 0 | 15 |
| Medical waste processor | 6 | 2 | 1 | 0 | 12 |
| Material recovery facility-commercial paper presort sorters | 5 | 0 | 0 | 0 | 25 |
| Material recovery facility paper line sorter | 4 | 0 | 0 | 0 | 20 |
| Material recovery facility rigid container sorter | 4 | 1 | 0 | 1 | 15 |
| Mechanic | 21 | 5 | 1 | 0 | 50 |
| Painter | 1 | 0 | 0 | 0 | 3 |
| Container repair | 12 | 3 | 3 | 0 | 15 |
| Tire repair | 1 | 0 | 0 | 0 | 5 |
| Truck washer | 0 | 0 | 0 | 0 | 6 |
| Total | 214 | 49 | 21 | 11 | 436 |

Review of three years of OSHA logs (1997-1999) yielded 214 total injuries for the fourteen jobs being analyzed, 49 of which were WMSDs (23%). The OSHA annual incidence rate for recordable injuries, calculated as an average of the three-year data, is 15.78. The average annual incidence rate for 4953 SIC code for the years 1997 through 1999 is 10.7.

Of the 49 WMSD injuries analyzed, 48, or 94 percent, occurred in caution zone jobs. Two job titles, residential rear load driver and residential rear load helper, accounted for 77 percent of the injuries.

Caution Zone Risk Factors and Morbidity Classification

Table 10 below shows jobs with caution zone risk factors present that were further analyzed to determine whether they were positive or negative for back or upper extremity injuries. In Table 10, "1" indicates that an injury did occur and "0" indicates there were no injuries.

Table 10

Jobs with Caution Zone Risk Factors
and Morbidity Classification

| JOB | CAUTION ZONE RISK FACTORS | POSITIVE/ NEGATIVE JOBS | POSITIVE/ NEGATIVE BACK (LIFTING) | POSITIVE/ NEGATIVE UE |
|---|---|---|---|---|
| Manual residential rear load driver | 12 (lifting/back) | 1 | 1 | 1 |
| Manual residential rear load helper | 12 (lifting/back) | 1 | 1 | 1 |
| Manual residential recycle curbside driver | | 1 | 0 | 1 |
| Landfill heavy equipment operator | | 0 | 0 | 0 |
| Landfill spotter | | 0 | 0 | 0 |
| Medical waste processor | 1 (awkward posture/ upper extremities), 6, (high hand force/ upper extremities), 7 (highly repetitive motion/ upper extremities), 11 (lifting/ back) | 1 | 1 | 0 |
| Material recovery facility-commercial paper presort sorters | 7 (highly repetitive motion/upper extremities) | 0 | 0 | 0 |

Table 10 Continued

| JOB | CAUTION ZONE RISK FACTORS | POSITIVE/ NEGATIVE JOBS | POSITIVE/ NEGATIVE BACK (LIFTING) | POSITIVE/ NEGATIVE UE |
|---|---|---|---|---|
| Material recovery facility - paper line sorter | 7 (highly repetitive motion/ upper extremities) | 0 | 0 | 0 |
| Material recovery facility - rigid container sorter | 7 (highly repetitive motion/upper extremities) | 1 | 0 | 1 |
| Mechanic | 6 (high hand force/upper extremities) | 1 | 1 | 0 |
| Painter | 7 (highly repetitive motion/upper extremities) | 0 | 0 | 0 |
| Container repair | 2 (awkward posture/upper extremities), | 1 | 1 | 0 |
| Tire repair | 3 (awkward posture/lower extremities), 6 (high hand force/upper extremities), 10 (lifting/back) | 0 | 0 | 0 |
| Truck washer | 7 (highly repetitive motion/ upper extremities) | 0 | 0 | 0 |

Results of the analysis for caution zone risk factors and lifting (back) indicated that four of the fourteen (28%) were predicted to increase the risk of injury for lifting: manual residential rear load driver, manual residential rear load helper, medical waste processor and tire repair. Three of those four (75%) were reported to have lifting injuries, all of which were predicted by WSET criteria: manual residential rear load driver, manual residential rear load helper and medical waste processor.

Results of the analysis for caution zone risk factors and upper extremities (UE) indicated that nine jobs (64%) were predicted to increase the risk of injury for UE. Eight of those nine (89%) did not result in UE injury. One job, rigid container sorter, was reported to have a UE injury.

Three jobs (21%) not predicted to result in UE injury actually had UE injuries, one of which was a manual residential recycling driver that was predicted by the WSET to be a "safe" job. Both manual residential rearload driver and manual residential rearload helper reported injury to upper extremities.

Of the three jobs positive for high hand force (21%), medical waste processor, mechanic and tire repair, none had UE injuries.

Six jobs were positive for highly repetitive motion (43%): medical waste processor, commercial paper presort sorters, paper line sorter, rigid container sorter, painter and truck washer. One (17%), rigid container sorter, resulted in a UE injury; the other five (83%) did not.

For the risk factor of awkward posture, three jobs (21%) were predicted to result in injury: medical waste processor, container repair and tire repair. The medical waste processor and container repair were both reported to have back injuries. The tire repair had no injuries.

For the risk factor of lifting, four jobs (29%) were predicted to result in injury: manual residential driver, manual residential helper, medical waste processor and tire repair. Three of the four (75%) were reported to have back injuries; only the tire repair reported no injuries.

Analysis of Caution Zone Risk Factors and Injury/Illness

The WSET breaks down caution zone activities into six major categories: awkward posture, high hand force, highly repetitive motion, repeated impact, lifting and hand-arm vibration. Tables 9 and 10 above show a breakdown of jobs with caution zone risk factors present and morbidity classification. Following is a summary of the results of those analyses.

*Single and Multiple Caution Zone Risk Factor Jobs*

Of the eleven jobs predicted to be positive jobs under the WSET caution zone criteria, nine (82%) were single risk factor:

- 5 highly repetitive motion

- 2 lifting
- 1 high hand force
- 1 awkward posture.

The remaining two jobs (18%), container repair and medical waste processor, had multiple risk factors. Container repair had risk factors associated with awkward posture, high hand force and lifting; medical waste processor had risk factors associated with awkward posture, high hand force, highly repetitive motion and lifting.

*Caution Zone Jobs, Risk Factors and Injury Results*

The residential driver was predicted to be a caution zone job based on the single risk factor of lifting. Of the nineteen injuries listed for residential driver, fourteen (74 percent) were reported to be caused by lifting, to the following body parts:

- 9 back
- 3 pelvis/groin
- 2 shoulder.

These injuries were concordant with the risk factor of lifting. Two other shoulder injuries were not associated with lifting.

The residential helper was predicted to be a caution zone job based on the single risk factor of lifting. Of the eighteen injuries listed for residential helper, thirteen (72 percent) were reported to be caused by lifting, to the following body parts:

- 8 back
- 2 shoulder
- 1 pelvis/groin
- 1 wrist
- 1 upper extremity.

These injuries were also concordant with the risk factor of lifting. The only non-lifting UE injury was reported by the manual residential recycle driver, caused by throwing, which is not a WSET risk factor. There were five other upper extremity injuries, four reported to be caused by lifting.

There was one caution zone risk factor for mechanic, high hand force, which would seem to be predictive of upper extremity injuries. There were in fact no UE injuries. Of the five injuries reported for mechanic, three were reported to be caused by pushing/pulling (not a WSET risk factor) and two reported to be caused by lifting, one back and one pelvis/groin. High hand force is therefore a discordant risk factor for upper extremities.

The four risk factors present for medical waste operator were awkward posture, highly repetitive motion, high hand force and lifting. Two injuries were recorded for medical waste operators, both reported to be caused by lifting, one back and one pelvis. There were no UE injuries. Lifting was therefore a concordant risk factor; awkward posture, highly repetitive motion and high hand force were discordant.

The only risk factor for container repair was awkward posture. All three of the injuries were reported to cause by lifting, and all were back injuries. There were no UE injuries. Awkward posture was therefore a discordant risk factor.

The single risk factor for sorter was highly repetitive motion. One injury was recorded, reported to be caused by reaching, to the wrist. Highly repetitive motion is therefore a concordant risk factor.

Analysis of Hazard Zone Risk Factors and Jobs

Four of the eleven caution zone jobs (36%) were predicted to be problem jobs under WSET hazard zone criteria, all four based on the single risk factor of highly repetitive motion. This contrasts with caution zone jobs, where there were both single and multiple risk factors present.

Table 11 below shows a breakdown of caution zone jobs further analyzed for the presence of hazard zone, lifting and upper extremity risk factors, along with morbidity classification.

Table 11

Jobs by Hazard Zone Risk Factors
with Morbidity Classification

| JOB | HAZARD ZONE RISK FACTORS | POSITIVE/ NEGATIVE JOBS | POSITIVE/ NEGATIVE LIFTING | POSITIVE/ NEGATIVE UE |
|---|---|---|---|---|
| Manual residential rear load driver | | 1 | 1 | 1 |
| Manual residential rear load helper | | 1 | 1 | 1 |
| Medical waste processor | 14 (highly repetitive motion/upper extremity) | 1 | 1 | 0 |
| Material recovery facility-commercial paper presort sorters | 15 (highly repetitive motion/upper extremity) | 0 | 0 | 0 |
| Material recovery facility - paper line sorter | 15 (highly repetitive motion/upper extremity) | 0 | 0 | 0 |
| Material recovery facility - rigid container sorter | 15 (highly repetitive motion/upper extremity) | 1 | 0 | 1 |
| Mechanic | | 1 | 1 | 0 |
| Painter | | 0 | 0 | 0 |
| Container repair | | 1 | 1 | 0 |
| Tire repair | | 0 | 0 | 0 |
| Truck washer | | 0 | 0 | 0 |

Eleven jobs determined to be caution zone were further analyzed for hazard zone criteria. Of those, four jobs were predicted to be hazard zone jobs, all based on the single risk factor of highly repetitive motion: medical waste processor, rigid container sorter, commercial paper presort and paper line sorter. Three injuries occurred in two job titles, medical waste processor and rigid container sorter.

Two of the injuries were for medical waste processor, both reported to be caused by lifting, one back and one pelvis, neither of which are concordant with the highly repetitive motion/upper extremity risk factor identified in the hazard zone checklist. One

was for rigid container sorter, reported to be caused by reaching, to the wrist. This is a UE injury and is therefore concordant with the risk factor of highly repetitive motion.

Of the four jobs predicted to increase the risk of UE injuries due to the risk factor of highly repetitive motion, one (25%) was concordant with the HRM risk factor.

Of the eleven caution zone jobs further analyzed, six (55%) actually had injuries. Five of those were reported to be caused by lifting. None were predicted based on hazard zone criteria, making the risk factor of lifting discordant.

Four jobs were determined to be hazard zone jobs for the risk factor of highly repetitive motion/upper extremity. One of the jobs (25%) reported an upper extremity injury.

Description and Analysis

Using the following 2x2 tables, sensitivity, specificity, positive predictive validity, negative predictive validity and odds ratios were calculated.

Of the fourteen jobs analyzed, eleven fell into the "caution zone" category and three were predicted to be "safe." Following are the results of caution zone vs. safe zone calculations:

Table 12

Safe Zone 2x2 Table

| | | *Morbidity Classification* | |
|---|---|---|---|
| | | Positive | Negative |
| *Hazard Classification* | Caution | 6 | 5 |
| | Safe | 1 | 2 |

Table 12 above correctly predicted six jobs (43%) to have injury that did and correctly rejected two jobs (14%) to not have injury that did not. Five jobs (36%) predicted to result in injury did not, and one was predicted to be "safe" that actually resulted in injury.

Table 13

Safe Zone Calculations

| | | |
|---|---|---|
| Sensitivity | a/(a + c) | 0.86 |
| Specificity | d/(b + d) | 0.29 |
| Positive predictive value | a/(a + b) | 0.55 |
| Negative predictive value | d/(c + d) | 0.67 |
| Odds ratio | ad/bc | 2.4 |

Table 13 above shows that, using caution zone criteria, the sensitivity value was .86, and the tool was therefore determined to be sensitive. An effective screening tool should reflect high sensitivity, and the WSET "caution zone" fulfilled its stated goal by detecting jobs with the potential to increase risk of WMSDs. However, it was not specific, with a value of .29. One job predicted to be safe in fact resulted in injury. (This injury could be misclassified because of the low numbers of injuries occurring in this job category.) The PPV and NPV fell below the .75 parameter. The odds ratio was determined to be 2.4. Fisher's exact test results p = 1.00, range 0.16 – 36.94.

The fourteen jobs were further analyzed to determine the effectiveness of the tool in evaluating the risk factor of lifting (back).

Table 14

Back/Lifting 2x2 Table

| | | *Morbidity Classification* | |
|---|---|---|---|
| | | Positive | Negative |
| *Hazard Classification* | Back injury | 3 | 1 |
| | No back injury | 2 | 8 |

Table 14 above correctly predicted three jobs (21%) to have injury that did and correctly rejected eight jobs (57%) that did not result in injury. It missed two jobs (14%)

not predicted to cause injury that did and one predicted to result in injury that did not. Eleven of the fourteen (78%) were predicted correctly; three (12%) were not. This analysis proved to be effective for predicting the increased risk of WMSDs for the risk factor of lifting. If the WSET tool were used for lifting-related jobs, it would be a good tool because it correctly rejected jobs not predicted to result in back injury. Table 15 below shows sensitivity, specificity and predictive value calculations.

Table 15

Back/Lifting Calculations

| | | |
|---|---|---|
| Sensitivity | a/(a + c) | 0.6 |
| Specificity | d/(b + d) | 0.89 |
| Positive predictive value | a/(a + b) | 0.75 |
| Negative predictive value | d/(c + d) | 0.8 |
| Odds ratio | ad/bc | 12 |

Analyzing jobs for the presence of back/lifting risk factors and associated injuries, the sensitivity value was .60, and the tool was therefore determined not to be sensitive. It was specific, with a value of .89. The PPV of .75 and NPV of .8 indicate the tool is effective for this application. The odds ratio was determined to be 12. Fisher's exact test results $p < 0.10$, range 0.9 – 162.4.

In Table 16 below the fourteen jobs are further analyzed for risk factors associated with upper extremity injuries.

Table 16

Upper Extremity 2x2 Table

| | | *Morbidity Classification* | |
|---|---|---|---|
| | | Positive | Negative |
| *Hazard Classification* | UE injury | 1 | 8 |
| | No UE injury | 3 | 2 |

Applying WSET criteria for upper extremity injuries, the tool predicted one job (7%) to cause injury that did and two (14%) to not result in injury that did not. Eight (57%) were predicted to result in injury that did not, and three (21%) were predicted not to result in injury that in fact did. Table 17 below shows that the WSET, applied only for this specific body region, was not a good predictor of upper extremity injuries, seventy eight percent resulted in false positive predictions.

Table 17

Upper Extremity Calculations

| | | |
|---|---|---|
| Sensitivity | a/(a + c) | 0.25 |
| Specificity | d/(b + d) | 0.20 |
| Positive predictive value | a/(a + b) | 0.11 |
| Negative predictive value | d/(c + d) | 0.40 |
| Odds ratio | ad/bc | 0.08 |

Assessing the jobs for risk factors associated with upper extremity injuries, sensitivity was .25 and specificity was .20. The PPV and NPV both fell below the .75 parameter. The tool was ineffective in this application. The odds ratio was determined to be .08. Fisher's exact test results p = 1.00, range .09 – 20.70.

Of the eleven caution zone jobs further analyzed for hazard zone criteria, four met the characteristics of hazard zone jobs. Of the six jobs correctly predicted by the caution zone criteria to increase the risk of injury, two were positive for hazard zone criteria, medical waste processor and rigid container sorter. Of the five false positives, two were positive for hazard zone criteria that had no reported injuries.

Table 18 below shows the results of hazard zone vs. caution zone calculations:

Table 18

Hazard Zone 2x2 Table

| | | *Morbidity Classification* | |
|---|---|---|---|
| | | Positive | Negative |
| *Hazard Classification* | Hazard | 2 | 2 |
| | Caution | 4 | 3 |

For WSET hazard zone criteria, the tool accurately predicted two jobs (18%) to result in injury and correctly rejected three (27%) that did not result in injury. It predicted two jobs (18%) to result in injury that did not and four (36%) to not result in injury that did.

Table 19

Hazard Zone Calculations

| | | |
|---|---|---|
| Sensitivity | a/(a + c) | 0.33 |
| Specificity | d/(b + d) | 0.60 |
| Positive predictive value | a/(a + b) | 0.50 |
| Negative predictive value | d/(c + d) | 0.43 |
| Odds ratio | ad/bc | 0.75 |

Table 19 above shows that the hazard zone criteria reflect a low sensitivity and low specificity. The PPV and NPV are also low, with a value below 0.75. The odds ratio was calculated to be .75. Fisher's exact test p = 1.00, with a range of 0.06 – 9.94.

The tool's sensitivity unfortunately dropped dramatically from caution zone (6 of 7) to hazard zone (2 of 6) criteria analysis. Applying hazard zone criteria, the tool's specificity is .60, which is lower than an employer would find useful in determining which jobs would most likely result in injury.

# DISCUSSION

Observational methods are often used in ergonomic job analysis because they are less costly and less time consuming than other methods. The WSET is an observational method tool that is largely posture-based. It is a structured assessment tool that provides the employer with specific values to analyze jobs for the presence of risk factors. The WSET is easy to use and applicable to both single-task and multi-task jobs.

The WSET addresses multi-task jobs and their impact on the entire body, with a focus on specific body regions. The tool assesses multi-task jobs by evaluating each task performed during the workday and adding the total time of exposure to that specific risk factor. For example, a residential garbage collector may spend three hours on a truck collecting garbage but may spend only two hours actually gripping bags or garbage cans. The WSET should accurately reflect the time spent performing each generic risk factor task.

The WSET "caution zone" criteria were more effective at predicting which job categories were likely to increase the risk of WMSDs than were the "hazard zone" criteria. By using the criteria incorporated into the "caution zone" checklist, an employer would be alerted to more jobs that had the potential to increase the risk of WMSDs. The screening tool was sensitive, but, using "hazard zone" criteria, lacked the desired high specificity.

For the six jobs predicted under "caution zone" criteria to result in injury/illness, all risk factors correlated closely to the type of injury. For example, of the 37 injuries recorded for residential driver and residential helper, 27 were reported to be caused by the single risk factor of lifting, which was in fact the only risk factor detected by the caution zone criteria for these jobs.

The four hazard jobs were all predicted under the risk factor of highly repetitive motion. The three injuries were reported to be caused by lifting and reaching. Using the WSET hazard zone criteria, these injuries could be related to reaching and lifting in a highly repetitive manner. Analysis revealed the WSET was helpful in predicting back injuries associated with lifting but not effective at predicting jobs with the potential for

upper extremity injuries. It appears that exposure and injury are related; however, it is difficult to assign a specific threshold at which an injury will occur.

One of the intended assets of the WSET was that it could be used on its own, without requiring the employer to purchase any special tools for analyzing jobs, such as a dynamometer. This presents a challenge when assessing the generic risk factor of high hand force. Without a dynamometer, it is difficult to accurately determine what constitutes a pinch grip of four or more pounds of hand force and/or gripping with a force of ten pounds per hand. Additionally, push/pull risk factors were not included in the final version of the WSET because of the special tools required to determine push/pull forces.

An assessment tool, while potentially valuable, should not be viewed as a single solution for evaluating the potential for a job to increase the risk of WMSD injury. A tool is more effective when incorporated into a broader ergonomics program including the following elements:

- Workplace analysis. Including retrospective and prospective intervention, injury/illness and workers compensation data, job analyses, input from employees and supervisors, and body part discomfort surveys.
- Hazard prevention, correction and control. Changing the job by implementing some type of control method, such as engineering, work practice, or administrative controls.
- Medical management. Early detection and treatment to minimize the effects of cumulative trauma disorders.
- Training and education. Early efforts to insure that employees are sufficiently informed about ergonomic principles and injury prevention.
- Implementation and validation. Critical for measuring the effectiveness of the changes.

It is critical to remember that the Washington State Ergonomics Tool was developed to evaluate jobs, not individuals. The fourteen jobs analyzed represent the majority of job titles involved in manual material handling of waste and recyclables, and

these industry job titles are unlikely to change in the near future. Future analysis might include more subjects, but the jobs will remain essentially the same. Evaluating more subjects would create a bigger data pool, but the results would probably not change significantly and would still reflect a need for more sensitive criteria.

# CONCLUSIONS

The Washington State Department of Labor and Industries was on the right track with the WSET concept, but they did not establish the relationship between the tool and the health outcomes (incidence of injury/illness).

Designers of the tool set "caution zone" levels of exposure where the risk of WMSDs begins to rise and caution is required. "Hazard zone" levels were set where the risk of WMSDs was predicted to be highest. Of the fourteen jobs analyzed in this study, three were projected to safe, with no risk of injury, and four were predicted to be hazardous, with a high risk of injury. In the three jobs predicted to safe, one resulted in injury. In the eleven "caution zone" jobs that fell below "hazard zone" levels, four injuries occurred. Of the four hazardous jobs, two had injury and two did not.

U.S. businesses need a tool that will assess multi-task jobs in a straightforward, easy-to understand fashion, such as an observational checklist. Had Washington field-tested the tool with several employers to assess its predictive validity, they may have more accurately assessed the levels at which certain risk factors contribute to a job having increased risk for WMSD injuries and been able to develop a more useful tool for businesses to incorporate into their ergonomic programs.

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