Validity of Generic Risk Factors and the Strain Index for Predicting Nontraumatic Distal Upper Extremity Morbidity

Nine individual generic risk factors, eight combinations of generic risk factors, the presence of any generic risk factor, and the Strain Index were evaluated for 56 jobs by 2 evaluators blinded to morbidity measures. Jobs then were assigned to dichotomous hazard classifications (problem versus safe) according to recommendations from the literature. OSHA 200 logs were used to ascertain historical evidence of distal upper extremity (DUE) morbidity, and jobs were assigned to a dichotomous morbidity classification (positive versus negative) using none versus one or more recorded cases as the criterion. Evidence of association and measures of predictive validity were evaluated by comparing hazard and morbidity classifications using 2 × 2 contingency tables. Five individual generic risk factors, three generic risk factor combinations, and the presence of any generic risk factor were not associated with morbidity classification. The odds ratio estimates among the four individual generic risk factors and the five combinations of generic risk factors associated with DUE morbidity varied from 3.3–36.0. The Strain Index had the largest estimated odds ratio of any exposure factor at 108.3. The exposure methods were grouped according to patterns of predictive validity. With one exception, the individual generic risk factors and their combinations had high sensitivity with low specificity (many false-positives), low sensitivity with high specificity (many false-negatives), or low sensitivity with low specificity. The only generic risk factor that demonstrated reasonable predictive validity was the use of gloves—its sensitivity, specificity, positive predictive value, and negative predictive value were equal to 0.75. The Strain Index performed better than any of the individual or combinations of generic risk factors. Its sensitivity, specificity, positive predictive value, and negative predictive value were all approximately 0.90.

Keywords: generic risk factors, musculoskeletal exposure assessment, musculoskeletal risk assessment, predictive validity, strain index

In most aspects of occupational and environmental health, practitioners rely on exposure assessment to estimate or determine the likelihood that a particular exposure scenario increases the risk of adverse health effects in an exposed population (risk assessment). With regard to neuromusculoskeletal disorders of the distal upper extremity (defined as the elbow, forearm, wrist, and hand), the identification of generic risk factors has been advocated as a method of risk assessment since the 1980s. The most commonly mentioned generic risk factors for distal upper extremity (DUE) disorders include repetitiveness, forcefulness, pinch grasp, awkward posture, localized mechanical compression, vibration, gloves, and cold temperature.

By and large, the construct validity of the generic risk factor method is based on clinical and epidemiological data. Reviews summarizing and evaluating evidence that the generic risk factors are associated with DUE disorders have
been published. For example, the National Institute for Occupational Safety and Health (NIOSH) evaluated the epidemiological literature to describe the relationship of carpal tunnel syndrome to repetition, force, posture, vibration, and selected combinations. It concluded that there was "insufficient evidence" of a causal relationship for posture; "evidence" of a causal relationship for repetition, force, and vibration; and "strong evidence" for some combinations of these risk factors (e.g., force and repetition, force and posture). For hand/wrist tendinitis, they reported "evidence" of a causal association with repetition, force, and posture, and "strong evidence" for some combinations of these risk factors (e.g., repetition and force). Reviews of this nature may contribute to determining whether an exposure attribute is a risk factor for a particular health outcome but, as noted by NIOSH, may not define when increased risk is present or absent. In addition, external validity may be an issue (e.g., whether the reported associations extend to other populations, jobs, facilities, or industries other than those of the original studies).

In general, practitioners who rely on the generic risk factor method approach DUE risk assessment from the perspective of noting the presence or absence of one or more of the generic risk factors mentioned in the previous paragraphs. If one or a combination of risk factors is present, the job is assumed to expose workers to increased risk of DUE conditions and, if all risk factors are absent, the job does not.

One alternative method for analyzing jobs for risk of DUE morbidity is the Strain Index (SI). The SI is a semiquantitative method of analyzing jobs based on the theory that the exertional demands on the hands determine whether the job exposes workers to increased risk of DUE conditions. The SI describes hand exertions according to six task variables: intensity of exertion, duration of exertion, exertions per minute, hand/wrist posture during exertions, speed of work, and duration of task per day. The output of the SI method is an SI score. Based on preliminary data from a pork processing plant, all but one job with SI scores greater than five had workers with reported DUE conditions, whereas jobs with SI scores less than five did not. The data in this article were taken from subsequent research to assess the predictive validity of the SI in other industries.

The purpose of this project was to evaluate and compare evidence of association, strength of association (if present), and indices of predictive validity of the generic risk factor method and the SI method among 56 jobs. For each job, predictions of hazard potential using these two methods were compared with evidence that workers performing each job experienced the predicted morbidity.

METHODS

The sequence of events in this study were: (1) exposure assessment; (2) hazard classification (based on exposure assessment); (3) retrospective morbidity assessment; (4) morbidity classification (based on morbidity assessment); and (5) description and analysis of the corresponding 2 × 2 contingency tables. Exposure assessment and hazard classification were completed in a blinded fashion prior to morbidity assessment and morbidity classification.

Study Jobs

To be included in the study, jobs had to be observable, unchanged during the observation periods for morbidity, and amenable to the two job analysis methodologies. Of 59 jobs initially targeted for inclusion, 3 (5%) were excluded because they involved multiple tasks—a situation currently not addressed by the SI. Of these 56 jobs, 33 jobs (51.6%) were performed by 1 employee, 8 (12.5%) by 2 employees, 9 (14.1%) by 3 employees, 5 (8.9%) by 4 employees, and 1 (1.6%) by 6 employees.

Manufacturing

Twenty-eight (50%) of the 56 jobs were from two manufacturing plants. Sixteen jobs were from a facility that fabricated and assembled chairs. Jobs varied from upholstering seats and backs to the assembly of components and chairs. The other 12 jobs were from a facility that fabricated and assembled hose connectors and hoses. Jobs included machine loading and unloading, parts stamping, hose connector assembly, and attachment of connectors to hoses. The manufacturing work forces were relatively stable.

Poultry Processing

The other 28 jobs were from 1 turkey processing plant. These jobs represented almost all aspects of turkey disassembly and processing, including live hanging, evisceration, parts dissection, trimming, processing, and packaging. In contrast to the manufacturing facilities, turnover in the poultry processing plant was approximately 100% per year.

Assessment of Exposure

As described below, the right and left sides of each worker were evaluated for the presence or absence of generic risk factors by independent raters. Based on direct observations and videotapes, one graduate student evaluated the manufacturing jobs and another graduate student evaluated the poultry processing jobs. Both students were trained in the job analysis methods. The supervising professor also analyzed all jobs via videotape. Differences were resolved by consensus. If a risk factor was present on either or both sides, it was considered present for the job. In general, methods for assessing exposure were taken from the literature (as indicated by citations).

Repetitiveness

If the job cycle was less than or equal to 30 sec or more than 50% of the cycle time involved performance of a fundamental cycle, the job was classified as highly repetitive.

Forcefulness

Pinch grasp and use of gloves have been mentioned as factors that contribute to high forcefulness. Pinch grasp was considered present if an object was held between the thumb and one or more of the fingers. Glove use was considered present if workers were observed to wear gloves. A third perspective on forcefulness, called forcefulness-SI, relied on the intensity of exertion rating scale from the SI model. A rating of 1 ("light") was considered low forcefulness-SI. A rating greater than 1 (greater than or equal to "somewhat hard") was considered high forcefulness-SI. A fourth construct of high forcefulness, called forcefulness All, combined all indicators of high forcefulness. Jobs with the presence of pinch grasp, use of gloves, or an SI intensity of exertion rating greater than 1 were classified as high forcefulness All, and jobs without pinch grasp, without use of gloves, and an SI intensity of exertion rating equal to 1 were classified as low forcefulness All.

Posture, Vibration, Localized Compression, and Cold

Nonneutral wrist posture was considered present if wrist deviation was observed. Hand-arm vibration was considered present if workers used a vibrating tool. Localized mechanical
Combinations of Generic Risk Factors

Pairs of generic risk factors selected for evaluation included high repetitiveness and pinch grasp; high repetitiveness and nonneutral wrist posture; high repetitiveness and high forcefulness (SI and All); and high forcefulness (SI and All) and nonneutral wrist posture. The two trios of high repetitiveness, high forcefulness (SI and All), and nonneutral wrist posture also were evaluated. For these eight combinations, if both (or all three) of the generic risk factors were present, the combination was considered present. If any one of the risk factors was absent, the combination was considered absent. Finally, the presence of any generic risk factor also was evaluated.

SI

SI task variables and scores were ascertained and calculated for the right and left sides of each job. The job was assigned the higher score of the two sides. The details of the SI evaluations for these jobs are subjects of other manuscripts.

Hazard Classification

Hazard classification refers to the dichotomous prediction, based on exposure assessment, of whether a job probably does or does not expose workers to increased risk of DUE morbidity. Jobs predicted to expose workers to increased risk of DUE morbidity were called “problem” jobs. Jobs predicted to not expose workers to increased risk of DUE morbidity were called “safe” jobs. Exposure assessment and hazard classification were completed in a blinded fashion prior to morbidity assessment and morbidity classification.

For the generic risk factor method, the presence of a particular risk factor on one or both sides was the criterion for predicting that a job was a problem job for that risk factor. The absence of that particular risk factor on both sides was the criterion for predicting that the job was a safe job for that risk factor. Combinations of generic risk factors were evaluated using the indicated Boolean logic (AND versus OR). For the SI method, an SI score greater than 5 on either or both sides was the criterion for predicting that a job was a problem job. An SI score less than or equal to 5 on both sides was the criterion for predicting that the job was a safe job.

The term problem to describe jobs in this article should not be confused with “problem jobs” used by the Occupational Safety and Health Administration (OSHA) in its Ergonomics Program Proposed Rule. In this article, problem describes a hazard prediction based on exposure. In the proposed rule, a “problem job” is one in which a “covered musculoskeletal disorder” has been reported (i.e., it describes an attribute based on morbidity).

Morbidity Assessment

Consistent with recommendations from OSHA and NIOSH, evidence of DUE morbidity was ascertained for these 56 jobs retrospectively from OSHA 200 logs. OSHA 200 logs for three consecutive 1-year intervals were available for 46 of the jobs. Records for 1.75 consecutive years were available for six jobs, beginning with the date they were established. Two jobs changed at the same time during the 3-year observation period. Since the precise dates of the changes were known and it was possible to assess exposures pre- and postchange, the pre- and postchange jobs were treated as distinct jobs with shorter periods of observation time (approximately 2 years prechange and 1 year postchange, respectively).

In this article the morbidity data were counts of recorded incidents (individual entries on the OSHA 200 log) by job. Several reported incidents on a particular job were considered to be separate incidents if they involved different body parts, different sides of the body, or the time interval between incidents was greater than 3 months. Three months was selected because the authors believe that most DUE disorders resolve within that time period, so the return of symptoms within that time frame is more likely to represent recurrence of the original condition rather than a new condition. The number of full-time equivalent employees, number of lost-time incidents, and number of days lost or restricted also were noted.

Morbidity Classification

Morbidity classification refers to the dichotomous classification of jobs according to whether they have a history of workers with DUE morbidity. If there was at least one recorded incident related to the DUE and attributed to “repeated trauma” (Column 7 on the OSHA 200 log) during the observation period, the job was classified as “positive.” If there was no reported DUE morbidity during the observation period, the job was classified as “negative.” This criterion is similar to OSHA’s definition of a “problem job” in that it is based on a single recorded incident. Although this study used a one incident “trigger” for a “positive” job, it will be possible to evaluate the performance of these exposure assessment methods using other trigger criteria later.

Statistical Analysis

Evidence of association and measures of predictive validity were derived from 2 x 2 contingency tables (see Figure 1). Odds ratios were used to describe strengths of association. Statistical significance was determined using Pearson's chi-square if all cell counts in the table were greater than 5 or Fisher’s exact test if any cell count was less than 5. The criterion for statistical significance was α < 0.05. There were no adjustments for multiple comparisons. Calculations were performed on a personal computer using SPSS 8.0 for Windows.

In this study, sensitivity reflects the ability of an exposure assessment method to correctly identify positive jobs as problem jobs. Specificity reflects the ability of the exposure assessment method to correctly identify negative jobs as safe jobs. Positive predictive value (PPV) refers to the fraction (or percentage) of problem jobs that are positive jobs, and negative predictive value (NPV) refers to the fraction (or percentage) of safe jobs that are negative jobs. The formulas for calculating these parameters are listed in Figure 1. An ideal exposure method would have all counts in cells a and d. Counts in cell b represent false positive predictions and tend to reduce specificity and PPV. Counts in cell c represent false negative predictions and tend to reduce sensitivity and NPV.

RESULTS

Of the 56 jobs, 28 (50%) were positive and 28 (50%) were negative using the single-incident trigger. Seven jobs had 1 recorded incident, none of the jobs had 2 incidents, 1 job had 3 recorded incidents, and the remaining 20 jobs had 4 or more recorded incidents. Among positive jobs, incidence rates per 100
workers per year varied from 5.6 to 383.3. Two jobs had incidence rates less than 10. Twenty-two (79%) of the 28 positive jobs had lost time incidents.

Cell counts, odds ratio, 95% confidence interval, ρ value, sensitivity, specificity, positive predictive value, and negative predictive value for each exposure factor are listed in Table 1.

### Evidence of Association between Hazard and Morbidity Classifications

Among individual generic risk factors, there was no evidence of association for pinch grasp, nonneutral wrist posture, vibration, localized mechanical compression, or cold temperature with the morbidity classifications of these jobs. The combinations of high repetitiveness and pinch grasp; high repetitiveness and high forcefulness-SI and nonneutral posture; and high repetitiveness and high forcefulness-All and nonneutral posture; and the presence of any generic risk factor also were not associated with the morbidity classifications of these jobs. No negative associations were observed.

Among individual generic risk factors, there was evidence of positive association for high repetitiveness, gloves, and high forcefulness-SI with odds ratio estimates of 12.8, 9.0, and 36.0, respectively. There was also evidence of association for high forcefulness-All, but the odds ratio could not be calculated. The combinations of high repetitiveness and high forcefulness-SI; high repetitiveness and high forcefulness-All; high forcefulness-SI and nonneutral wrist posture; and high forcefulness-All and nonneutral wrist posture also had significantly elevated odds ratio estimates of 31.2, 27.0, 27.0, and 6.3, respectively.

The SI hazard classification was positively associated with the morbidity classifications of these jobs with an estimated odds ratio of 108.3.

### Predictive Validity

The data in Table 1 can be further summarized by dividing the exposure attributes into groups based on their predictive tendencies. Review of the literature failed to identify established or recommended criteria for rating predictive validity; therefore, a cut point of 0.75 for sensitivity, specificity, PPV, and NPV was chosen to facilitate description of the results. If a parameter was greater than or equal to 0.75, it was described as “high.” If a parameter was less than 0.75, it was described as “low.”

#### Low Sensitivity and Low Specificity

Exposure factors with sensitivity and specificity less than 0.75 included pinch grasp; the combination of high repetitiveness and pinch grasp; and the combination of high repetitiveness and nonneutral wrist posture. These exposure factors also had PPV and NPV less than 0.75.

#### High Sensitivity and Low Specificity

Exposure factors with sensitivity greater than or equal to 0.75 included pinch grasp; the combination of high repetitiveness and pinch grasp; and the combination of high repetitiveness and nonneutral wrist posture. These exposure factors also had PPV and NPV less than 0.75.

#### Low Sensitivity and High Specificity

High forcefulness-SI; vibration; localized mechanical compression; cold temperature; the combination of high repetitiveness and high
The definitions and methods for assessing high repetitiveness, pinch grasp, gloves, nonneutral wrist posture, vibration, localized mechanical compression, cold temperature, and the SI were based on publications that used these methods, described their use, or advocated their use. It was not feasible to replicate the definition of high forcefulness used in the reports of Silverstein et al. (1987) or Armstrong et al. in this study; therefore, these results may not be comparable to theirs. They categorized jobs as high or low forcefulness based on whether a variable called the “adjusted force” was greater or less than 6 kg. The adjusted force was derived from normalized rms surface electromyography measurements collected over the flexor muscle mass of the forearm. For each job the adjusted force was calculated by adding the mean rms value for the job to the quotient of the variance of the measurements divided by their mean. The two additional definitions for high forcefulness (SI and All) used in the present study have not been used previously in the context of generic risk factors. The first definition, high forcefulness SI, was selected because it represented an ordinal estimate of the magnitude of exertions applied by the hands based on the concept of percentage maximal strength. The second definition, high forcefulness-All, relied on the presence of any factor that might indicate the presence of high forcefulness (pinch grasp, gloves, or high forcefulness SI). In general, combinations were selected and constructed according to published reports in the literature. Overall, the methods used to assess exposure in this study are representative of what the practitioners and advocates of the generic risk factor and SI methods recommend.

### Exposure Assessment

#### Methodological Issues

In a study such as this, the results and their interpretations may be affected by the selected methods. The following sections discuss reasons for choosing the methods selected in this study and potential limitations.

### DISCUSSION

#### Potential Limitations

The following sections discuss reasons for choosing the methods selected in this study and potential limitations.

#### High Sensitivity and High Specificity

The use of gloves and the SI both had sensitivity and specificity greater than or equal to 0.75. The PPV for each was 0.75 and 0.90, respectively. The NPV for each was 0.75 and 0.93, respectively.

---

**TABLE 1. Odds Ratios, 95% Confidence Intervals (CIs), P-Values, and Measures of Predictive Validity for the Generic Risk Factors and the Strain Index for 56 Jobs**

<table>
<thead>
<tr>
<th>Exposure Method</th>
<th>Cell a</th>
<th>Cell b</th>
<th>Cell c</th>
<th>Cell d</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P-Value</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>High repetitiveness</td>
<td>27</td>
<td>19</td>
<td>1</td>
<td>9</td>
<td>12.8</td>
<td>1.5-109.6</td>
<td>0.01</td>
<td>0.96</td>
<td>0.32</td>
<td>0.59</td>
<td>0.90</td>
</tr>
<tr>
<td>Pinch grasp</td>
<td>12</td>
<td>18</td>
<td>16</td>
<td>10</td>
<td>0.4</td>
<td>0.1-1.2</td>
<td>0.11</td>
<td>0.43</td>
<td>0.36</td>
<td>0.40</td>
<td>0.39</td>
</tr>
<tr>
<td>Gloves</td>
<td>21</td>
<td>7</td>
<td>7</td>
<td>21</td>
<td>9.0</td>
<td>2.7-30.2</td>
<td>&lt;0.001</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>High forcefulness-SI</td>
<td>16</td>
<td>1</td>
<td>12</td>
<td>27</td>
<td>36.0</td>
<td>4.3-303.4</td>
<td>&lt;0.001</td>
<td>0.57</td>
<td>0.96</td>
<td>0.94</td>
<td>0.69</td>
</tr>
<tr>
<td>High forcefulness-All</td>
<td>28</td>
<td>20</td>
<td>0</td>
<td>8</td>
<td>NA</td>
<td>NA</td>
<td>0.012</td>
<td>1.00</td>
<td>0.29</td>
<td>0.58</td>
<td>1.00</td>
</tr>
<tr>
<td>Nonneutral posture</td>
<td>21</td>
<td>14</td>
<td>7</td>
<td>14</td>
<td>3.0</td>
<td>1.0-9.3</td>
<td>0.053</td>
<td>0.75</td>
<td>0.50</td>
<td>0.60</td>
<td>0.67</td>
</tr>
<tr>
<td>Vibration</td>
<td>3</td>
<td>7</td>
<td>25</td>
<td>21</td>
<td>0.4</td>
<td>0.1-1.6</td>
<td>0.30</td>
<td>0.11</td>
<td>0.75</td>
<td>0.30</td>
<td>0.46</td>
</tr>
<tr>
<td>Localized compression</td>
<td>4</td>
<td>1</td>
<td>24</td>
<td>27</td>
<td>4.5</td>
<td>0.5-43.1</td>
<td>0.35</td>
<td>0.14</td>
<td>0.96</td>
<td>0.80</td>
<td>0.53</td>
</tr>
<tr>
<td>Cold</td>
<td>3</td>
<td>4</td>
<td>25</td>
<td>24</td>
<td>0.7</td>
<td>0.2-3.3</td>
<td>1.00</td>
<td>0.11</td>
<td>0.96</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>High repetitiveness and pinch grasp</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>16</td>
<td>1.0</td>
<td>0.4-2.9</td>
<td>1.00</td>
<td>0.43</td>
<td>0.57</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>High repetitiveness and high forcefulness-SI</td>
<td>15</td>
<td>1</td>
<td>13</td>
<td>27</td>
<td>31.2</td>
<td>3.7-262.1</td>
<td>&lt;0.001</td>
<td>0.54</td>
<td>0.96</td>
<td>0.94</td>
<td>0.68</td>
</tr>
<tr>
<td>High repetitiveness and high forcefulness-All</td>
<td>27</td>
<td>14</td>
<td>1</td>
<td>14</td>
<td>27.0</td>
<td>3.2-227.0</td>
<td>&lt;0.001</td>
<td>0.96</td>
<td>0.50</td>
<td>0.66</td>
<td>0.93</td>
</tr>
<tr>
<td>High repetitiveness and nonneutral posture</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td>16</td>
<td>3.3</td>
<td>1.1-10.1</td>
<td>0.031</td>
<td>0.71</td>
<td>0.57</td>
<td>0.63</td>
<td>0.67</td>
</tr>
<tr>
<td>High forcefulness-SI and nonneutral posture</td>
<td>14</td>
<td>1</td>
<td>14</td>
<td>27</td>
<td>27.0</td>
<td>3.2-227.0</td>
<td>&lt;0.001</td>
<td>0.50</td>
<td>0.96</td>
<td>0.93</td>
<td>0.66</td>
</tr>
<tr>
<td>High forcefulness-All and nonneutral posture</td>
<td>21</td>
<td>9</td>
<td>7</td>
<td>19</td>
<td>6.3</td>
<td>2.0-26.3</td>
<td>0.001</td>
<td>0.75</td>
<td>0.68</td>
<td>0.70</td>
<td>0.73</td>
</tr>
<tr>
<td>High repetitiveness, high forcefulness-SI, and nonneutral posture</td>
<td>5</td>
<td>1</td>
<td>23</td>
<td>27</td>
<td>5.9</td>
<td>0.6-53.9</td>
<td>0.19</td>
<td>0.18</td>
<td>0.96</td>
<td>0.93</td>
<td>0.54</td>
</tr>
<tr>
<td>High repetitiveness, high forcefulness-All, and nonneutral posture</td>
<td>14</td>
<td>7</td>
<td>14</td>
<td>21</td>
<td>3.0</td>
<td>1.0-9.3</td>
<td>0.053</td>
<td>0.50</td>
<td>0.75</td>
<td>0.67</td>
<td>0.60</td>
</tr>
<tr>
<td>Any generic risk factor</td>
<td>28</td>
<td>27</td>
<td>0</td>
<td>1</td>
<td>NA</td>
<td>NA</td>
<td>0.61</td>
<td>1.00</td>
<td>0.04</td>
<td>0.51</td>
<td>1.00</td>
</tr>
<tr>
<td>Strain Index</td>
<td>26</td>
<td>3</td>
<td>2</td>
<td>25</td>
<td>108.3</td>
<td>16.7-705.0</td>
<td>&lt;0.001</td>
<td>0.93</td>
<td>0.69</td>
<td>0.90</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Note: NA = not applicable.

* Determined by Fisher's exact test.
Hazard Classification
The criteria for assigning hazard classifications also were derived from published literature related to the generic risk factor and SI methods. It should be noted that authors discussing either method have cautioned against rigid interpretation of the exposure assessments; however, definitive dichotomous-like decisions regarding hazard classification must ultimately be made.

Morbidity Assessment
There is no gold standard for validating the prediction of the presence or absence of a neuromusculoskeletal hazard. Prediction that a hazard exists implies increased risk of occurrence of morbidity, and neuromusculoskeletal morbidity has clinical and epidemiological characteristics that render it suitable to surveillance; therefore, one or more indicators of neuromusculoskeletal morbidity are rational choices. Potential sources of data that could be used as indicators of increased morbidity include passive surveillance sources (worker's compensation claims history or injury/illness records) or active surveillance sources (symptom surveys or clinical examinations). Each of these has strengths, weaknesses, and limitations.

Each company's OSHA 200 logs were selected as data sources for the outcome measure in this study because they were readily accessible and have been recommended for such purposes by others, including NIOSH and OSHA. However, their use may have limitations for several reasons. First, OSHA 200 logs are susceptible to over- or underreporting as well as over- or underrecording. Based on interviews with record-keeping personnel at all sites and review of supplemental information at two sites, the reliability of these logs for case ascertainment was considered good. Second, OSHA 200 logs are susceptible to misclassification of exposure, disease, and work relatedness. In this study, exposure misclassification would occur if the job related to the onset of the reported condition was not recorded properly. Based on the interviews and review of supplemental information mentioned above, exposure misclassification was not considered to be significantly present.

Diagnostic information was not used in this study, so disease misclassification was not considered an issue. Misclassification of work-relatedness would occur if either a condition unrelated to work was recorded as work related or a condition related to work was not recorded. In this study, misclassification of work relatedness is a possibility that raises two potential issues. First, if non-differential misclassification of work relatedness were present, the results would tend to underestimate the true magnitudes of association. The estimated odds ratios for many of the exposure factors were quite large, so it is suggested that if this form of misclassification were present, it did not significantly impact the results of this study. Second, even if this form of misclassification were present, it would have been present for all comparisons between exposures and outcomes; therefore, comparisons of the relationships between exposure factors and the morbidity classification would be allowed.

Morbidity Classification
A dichotomous strategy for morbidity classification was chosen because it made analysis of the data and interpretation of the results relatively simple and understandable. It also represents the way jobs often are targeted for analysis or intervention when surveillance data is considered. At this time, there is no gold standard or consensus method for determining when the occurrence of morbidity represents evidence of a hazard. Some argue that a single reported case, as used in this study, is sufficient. Others might argue that there needs to be consideration of the number of workers, the observation time, or the severity of the condition (e.g., incidence, lost-time incidence, or severity rates). At this time, there are no data to indicate the optimal method.

Evidence of Association with Morbidity Classification
Several generic risk factors that were associated with indicators of DUJ morbidity in prior studies and reviews were not associated with morbidity classification in this study, including pinch grasp, nonneutral wrist posture, vibration, localized compression, and cold temperature. The combinations of high repetitiveness and pinch grasp as well as high repetitiveness and high forcefulness (both SI and All) and nonneutral wrist posture also were not associated with morbidity classification. These observations are consistent with several potential inferences. First, the constructs for measuring these factors may be deficient. For example, several of these exposure factors could be described according to their magnitudes, durations, and frequencies, rather than their mere presence. At this time, however, such constructs have not been developed and validated for these particular generic risk factors and corresponding disorders. Second, some factors may be valid in some settings, but not others (e.g., they lack external validity). Third, some factors might be important only if present (e.g., localized mechanical compression) or only if absent (e.g., all generic risk factors), but these occurrences are relatively rare. Fourth, the findings for some factors may have been limited by inadequate study power. Of course, one or more of these inferences could be appropriate.

Based on comparing the magnitudes of the odds ratio estimates for the exposure factors and combinations that were positively associated with morbidity classification, the SI estimate varied from 3.16 times larger than the odds ratio estimates for the other factors. Whereas the outcome variable was the same for all exposure factors, the best explanation for this observation is that the construct of the SI is closer to the "true" measure of risk than the others. For example, five of the exposure factors that were positively associated with morbidity classification involved high repetitiveness. One part of the definition of high repetitiveness (job cycle time less than or equal to 30 sec) is based on production, not hand activity. For a job with a 30-sec job cycle, the hand could be used one time or hundreds of times; the hand could be used for 1 sec or 29 sec; or the hand could be used for very forceful exertions or very light exertions. In all three circumstances, however, the exposure would be classified as high repetitiveness and fail to capture these differences. The other generic risk factors and combinations that did not include high repetitiveness were forcefulness (SI or All), nonneutral wrist posture, or their combinations. Again, identifying potentially hazardous jobs based solely on estimating magnitudes of exertions or wrist deviations without consideration of their temporal patterns of occurrence would not be expected to provide as reliable estimates of "true" exposure as a method that considered such a temporal pattern. The SI may incorporate the most relevant factors into a more comprehensive model than the other approaches analyzed in this study.

Use of gloves was positively associated with morbidity classification. It also was associated positively with the SI hazard classification (OR = 5.3; 95% confidence interval: 1.7-16.5; p = 0.003); therefore, the impact of use of gloves was examined while stratified by the SI hazard classification. Of the 56 jobs, 29 jobs were classified as problem and 27 as safe according to the SI. Twenty (69%) of the 29 problem jobs involved the use of gloves. Of these 20 jobs, 19 (95%) were positive for DUJ morbidity and 1 (5%) was negative. In contrast, 9 (31%) of the 29 problem jobs did not involve the use of gloves. Of these, 7 (78%) were positive.
for DUE morbidity and 2 (22%) were negative. Eight safe jobs involved the use of gloves. Of these, 2 (25%) were positive for DUE morbidity and 6 (75%) were negative. Nineteen safe jobs did not involve the use of gloves. All 19 (100%) were negative for DUE morbidity. Stratification of use of gloves by SI hazard classification revealed no evidence of effect modification (Fisher exact test for use of gloves according to problem versus safe were 0.22 and 0.08, respectively).

Assessment of Predictive Validity

In this study, individual and combinations of generic risk factors with low sensitivity and low specificity failed to be reliable indicators of either the presence or absence of historical DUE morbidity. Individual and combinations of generic risk factors with high sensitivity and low specificity might be useful for screening purposes; however, because a significant number of the jobs targeted by these factors in this study had no historical evidence of DUE morbidity, they are unreliable predictors of increased risk and would lead to inefficient utilization of resources. Individual and combinations of generic risk factors with low sensitivity and high specificity tended to be relatively rare exposures and, in this study, failed to target many of the jobs with a history of DUE morbidity. The exposure factors with the most favorable values for sensitivity, specificity, PPV, and NPV were use of gloves and the SI. For use of gloves, the value for each was 0.75. For the SI, the value for each was approximately 0.90.

One interpretation for these observations is that the “true” construct for exposure for DUE disorders is represented by a multivariate function that considers the magnitudes and temporal patterns of one or several variables. The SI is based on exertional theory (exposure is best characterized by the exertional demands of the job), and its construct incorporates this multivariate perspective; therefore, it had the highest strength of association and best predictive validity. In contrast, the generic risk factor method represents, at best, a univariate perspective on this multivariate relationship; therefore, evidence of association was either lacking, inconsistent, or weaker relative to a “true” construct.

CONCLUSIONS

In this study most individual and combinations of generic risk factors demonstrated marginal to no predictive validity for the identification of jobs with and jobs without a history of DUE morbidity. Generic risk factors with relatively high sensitivity had many false-positive predictions. Generic risk factors with relatively high specificity had many false-negative predictions. Use of gloves was the generic risk factor with the most favorable predictive validity; however, it was absent for 25% of the jobs with DUE morbidity and present for 25% of the jobs without DUE morbidity. The SI was the exposure assessment method with the most favorable predictive validity. It misclassified approximately 10% of the jobs with and 10% of the jobs without DUE morbidity. The use of gloves is a relatively “empty” exposure construct, and stratification of glove use across SI hazard classifications revealed no evidence of association with morbidity classification; therefore, the SI is recommended over the use of gloves. These results provide evidence, in addition to that previously reported, of the SI’s external validity (generalizability) and predictive validity.

REFERENCES

11. Bernard, B.P. (ed.): Musculoskeletal Disor-