Safety Research

Physical Work Exposures

Comparing self-reported, observer-rated and O*NET ratings

By Bethany T. Gardner, David A. Lombardi, Ann Marie Dale, Alfred Franzblau and Bradley Evanoff

THE NATURE OF WORK IN AMERICA is changing. The number of jobs requiring monotonous repetition of the same physical task is declining due to increased automation of manufacturing processes, corporate downsizing and outsourcing of many labor-intensive jobs to other countries. In turn, the complexity of American jobs has been rapidly increasing, leading to an expansion of individual workers' job duties and more highly variable job tasks.

Despite these changes, musculoskeletal disorders (MSDs) continue to be a leading work-related health concern in the U.S. (Bernard, 1997; NRC & IOM, 2001), accounting for approximately one-third of all injuries and illnesses requiring time away from work (BLS, 2005). In addition to personal characteristics that increase the likelihood of developing an MSD, the etiology of MSDs has been linked to work-related physical exposures, such as forceful and repetitive job tasks and awkward working postures (Bernard, 1997; NRC & IOM, 2001).

SH&E professionals face the increasingly difficult task of estimating the magnitude of physical exposures incurred by workers in order to quantify their risks for developing work-related MSDs associated with these exposures. However, no universally applicable standardized measure comparable to methods for measuring other environmental risk factors such as chemical or radiation exposures is available for assessing physical exposures related to MSDs (Bernard, 1997; NRC & IOM, 2001).

Popular approaches to analyzing job demands include direct measurement of risk factors using sophisticated instruments to capture forces, postures and vibration; observation or videotaped ergonomic job analysis of workers performing typical work tasks at the jobsite; and worker self-reports of exposure through interviews or questionnaires (David, 2005). With these measures, there is often a trade-off between the precision and level of detail provided by a given method and the time and cost effectiveness of each method. In addition, the purpose or goal of the analysis (e.g., writing job descriptions, ergonomic assessment, causal relations analysis) will likely influence which data collection method is selected based on the level of detail and accuracy of job information that is required or desired.

SH&E professionals and researchers suggest that direct measurement of workplace exposures is the most precise method of data collection, followed by observational methods, since the data can be detailed and are based on objective measurement and analysis (David, 2005). However, debate continues in the scientific literature about the number of measurement or video samples required to capture the range of variability in job tasks and exposures over time, or to capture variability between workers performing the same job. In addition, no universally accepted standardized methodologies exist for utilizing these techniques (David, 2005; Guangyan & Buckle, 1999). Furthermore, direct measure or observation methods are usually costly and labor intensive, and may require specific expertise.

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Abstract: *SH&E professionals need to understand the physical exposures that workers encounter in order to provide appropriate treatment options for injuries and make return-to-work decisions. Such exposure estimates are made more difficult by the increasing diversity of jobs and the variability of work tasks within a single job. No universally applicable measure is available for assessing work-related physical exposures specifically for musculoskeletal disorders. A new and potentially useful source of occupational information is the Occupational Information Network (O*NET), which contains occupational information on more than 900 occupations.*

Questionnaires have been used successfully in many large-scale epidemiological studies to estimate exposures associated with large numbers of jobs in order to differentiate jobs into relative categories such as high, medium or low risk. Questionnaires and self-reports are often employed to collect high-level exposure data on a large number of workers or jobs relatively quickly and inexpensively as compared to direct measurements or videotaping.

However, one challenge is minimizing the error (or bias) in these measures, thus reducing the likelihood of misclassifying an exposure so that in the analysis it would be accurately identified as (or not as) a risk factor or hazard (Loomis & Kromhout, 2004). Random misclassification often leads to a failure to reject the null hypothesis, whereas systematic error can go either way, depending on the direction of the bias.

A new source of occupational information, the Occupational Information Network (O*NET), is increasingly being utilized by researchers, SH&E professionals, employers and vocational rehabilitation counselors. It provides summary data of typical physical and mental demands using the standard occupational classification (SOC) code and the job title. Such information could be useful in differentiating high-risk jobs from low-risk jobs, and between different jobs in the same industry or across industries.

What Is O*NET?

The O*NET database (found at www.onetcenter.org) is a publicly available database containing occupational information on more than 900 occupations. It was developed by the U.S. Department of Labor's Employment and Training Administration as a replacement for the *Dictionary of Occupational Titles.* The database was developed using initial surveys of occupation analysts and is continuously updated based on surveys of workers and occupation experts.

The database includes quantitative information on dozens of work component variables organized into six major domains: worker characteristics, worker requirements, experience requirements, occupational requirements, workforce characteristics and occupation-specific information (O*NET Consortium, 2007c, 2007d).

The *Dictionary of Occupational Titles* was first published in 1939 and it was last revised in 1991. The manual was intended "to assist job seekers, employers, educational and training institutions, researchers and other interested parties with the most current and accurate occupational information possible" (DOL, 1991). It was used to help set minimum requirements for hiring decisions, develop job descriptions and establish parameters for post-offer preplacement job screens. Due to rapid changes in the American labor force and economy, DOL decided to replace the manual with O*NET to allow for easier and more rapid updates and increased public access to occupational information (O*NET Consortium, 2007b).

Researchers have recently started using occupational information from O*NET as surrogate measures of job attributes such as psychosocial measures, physical work and organizational exposures (d'Errico, Punnett, Cifuentes, et al., 2007; Zimmerman, Christakis & Stoep, 2004; Wolfe, Michaud, Choi, et al., 2005; Verma, Sorock, Pransky, et al., 2007; D'Souza, Keyserling, Werner, et al., 2007; D'Souza, Werner, Keyserling, et al., 2008).

To evaluate the reliability of several O*NET measures, studies have directly compared independently collected exposure measures and exposure estimates in O*NET for physical work exposures and psychosocial work exposures at the job or industry level (D'Souza, et al., 2007; D'Souza, et al., 2008; Cifuentes, Boyer & Gore, et al., 2007; Cifuentes, Boyer, Gore, et al., 2008).

Table 1

Descriptions of Self-Reported, Observed & O*NET Exposure Estimates

Self-Reported & Observed Exposures

Each question worded as: On average, how much time do you spend each day . . .

Variable name	Description
Lifting > 2 lb	Lifting, carrying, pushing or pulling objects weighing more than 2 lb?
Forceful grip	Using your hand in a forceful grip?
Wrist bending	Bending or twisting your hands or wrists?

O*NET Variables

Variable name	Description
Abilities database: Each question worded as: What level of the ability is needed to perform your current job?	
Static strength	The ability to exert maximum muscle force to lift, push, pull or carry objects.
Wrist-finger speed	The ability to make fast, simple, repeated movements of the fingers, hands and wrists.
Work activities database: Each question worded as: What level of the activity is needed to perform your current job?	
Handling/moving objects	Using hands and arms in handling, installing, positioning and moving materials, and manipulating objects.

Detailed descriptions of each exposure estimate from the exposure assessment methods that were mapped as part of the comparison process.

The database also may be useful to SH&E professionals seeking to estimate physical and mental demands of work across a wide array of jobs. In the absence of individual-level exposure data or to complement other sources, O*NET data may be useful for risk prediction, targeted interventions or work ability decisions at the group level based on job titles. The data could be used to identify high-risk jobs by job title in order to prioritize jobs for further study, to guide job placement or return to work, and to estimate past exposures from previous jobs or activities.

However, little information is currently available on the validity of O*NET physical work exposure estimates compared to those obtained from other sources. This study was designed to compare exposure estimates obtained from O*NET to those obtained from videotaped job observations and worker self-reports.

Table 2

Demographic Data for All Subjects

Characteristic	Subjects with self-reported exposure data[a]	Subjects with observed exposure data[b]
Age	*M* 30.5 (*SD* 10.3)	*M* 32.7 (*SD* 11.1)
Male	631 (65%)	224 (57%)
Female	341 (35%)	172 (43%)
Level of education		
Did not complete high school	64 (7%)	24 (6%)
Graduated high school or GED	417 (43%)	165 (42%)
Completed some college	274 (28%)	129 (32%)
Graduated 4-year college	141 (14%)	46 (12%)
Attended graduate or professional school	75 (8%)	31 (8%)
SOC occupational category		
Construction and extraction	383 (39.4%)	148 (37.4%)
Building and grounds cleaning and maintenance	153 (15.8%)	85 (21.5%)
Healthcare practitioners and technical	118 (12.1%)	70 (17.7%)
Office and administrative support	80 (8.2%)	36 (9.1%)
Other	238 (24.5%)	57 (14.4%)

Note. *[a]N = 972. [b]N = 396.*

Table 3

Physical Work Exposure Estimates

Industry		Handling/lifting objects[a] *M* (*SD*)	Strength demands[b] *M* (*SD*)	Repetition[c] *M* (*SD*)
All workers	O*NET	4.23 (2.1)	2.87 (1.0)	1.91 (0.6)
	Self-reported	5.15 (2.1)	5.05 (2.0)	5.51 (1.8)
	Observed	5.17 (1.5)	4.48 (1.8)	5.42 (1.6)
Construction	O*NET	5.75 (0.4)	3.65 (0.8)	1.94 (0.8)
	Self-reported	6.38 (1.1)	5.87 (0.4)	5.82 (0.4)
	Observed	6.87 (0.5)	6.06 (1.3)	6.29 (1.5)
Building maintenance	O*NET	3.26 (0.6)	2.14 (0.4)	0.79 (0.3)
	Self-reported	5.99 (1.7)	5.20 (2.1)	5.37 (2.0)
	Observed	5.51 (1.4)	3.98 (1.2)	5.63 (0.9)
Healthcare	O*NET	4.12 (0.9)	2.02 (0.8)	2.20 (0.5)
	Self-reported	4.00 (2.0)	3.46 (2.1)	5.25 (1.8)
	Observed	3.60 (1.5)	2.58 (1.2)	4.30 (1.6)
Office/administrative	O*NET	2.38 (0.9)	1.41 (0.7)	1.78 (0.7)
	Self-reported	2.99 (1.8)	2.96 (2.3)	4.71 (2.5)
	Observed	2.60 (1.7)	2.18 (1.1)	3.11 (1.6)

Note. *Average physical work exposure estimates for all subjects, grouped by industry and exposure. [a]O*NET estimate: handling/moving objects; self-reported and observed ratings: Lifting objects > 2 lb. [b]O*NET estimate: static strength; self-reported and observed ratings: forceful gripping. [c]O*NET estimate: wrist/finger speed; self-reported and observed ratings: wrist bending.*

Study Methods

Data Collection

The exposure data used in the present study were collected within a larger, 3-year prospective study of the personal and work-related risk factors associated with carpal tunnel syndrome (CTS), the Predictors of Carpal Tunnel Syndrome Study (PrediCTS study). The study participants were 1,108 newly hired workers from industries including construction, healthcare, manufacturing and biotechnology. Participants completed questionnaires about their work and medical histories at the baseline phase of the study and at several points over the 3-year study period.

A subset of 396 workers was videotaped and physical work exposures were rated job observations performed by a trained ergonomist based on job observations. For this study, the research team compared the physical work exposure estimates from the O*NET database with both workers' self-reported job exposure data and the observed physical work exposure data collected at the 6-month follow-up. Self-reported 6-month follow-up survey data were available for 972 workers.

Self-Reported Physical Work Exposures

Self-reported physical work exposure data were collected using a validated questionnaire (Nordstrom, Vierkant, Layde, et al., 1998; Franzblau, Werner, Valle, et al., 1993; Franzblau, Werner, Alberts, et al., 1994; Franzblau, Salerno, Armstrong, et al., 1997; Salerno, Franzblau, Armstrong, et al., 2001; Katz, Punnett, Simmons, et al., 1996), including ratings of duration of eight physical exposures associated with CTS and other upper extremity MSDs. The questions included: bending of the hand and wrist, forearm rotation, use of pinch grip, use of handheld vibrating power tools, finger or thumb pushing or pressing, forceful gripping, lifting objects weighing more than 2 lb and assembly line tasks.

Observed Physical Work Exposures

One-hour worksite visits were performed by one of three trained ergonomists, and included brief interviews with workers and supervisors and approximately 20 minutes of videotaping of key work tasks. Ratings of each worker's physical work exposures were completed by three researchers, based on observation of the videotape and informa-

No statistically significant differences existed in demographics between the subset of workers who received a worksite observation and the study population as a whole. Overall, O*NET estimates tend to provide lower estimates of physical work exposures.

Across all three methods, the construction industry jobs had the highest exposure estimates, followed by building maintenance jobs, healthcare workers, and office and administrative jobs.

tion obtained from the worksite interviews. Each worker's physical work exposures were rated by consensus using the same questions included in the self-reported questionnaires described previously.

Linking the Three Exposure Estimates

An O*NET job title and code was assigned to each worker based on the 2,000 SOC from BLS, according to employer and job title information provided in the self-reported 6-month follow-up questionnaire. Using the SOC codes as a key field, selected O*NET 12.0 physical work exposure estimates were assigned to each worker with self-reported and observed ratings for the measures that were to be compared across the three data sets.

O*NET version 12.0 contained 12 databases with occupational information describing both job and worker characteristics for all occupations in the system. The research team identified two databases that contained data "elements" related to upper extremity physical work exposures that include abilities and work activities. All of the two databases' physical work exposure elements that related to upper extremity exposures were identified. Decisions were made *a priori* regarding which data elements most closely resembled the exposure variables collected from the PrediCTS study, and the hypothesized relationships among the different variables.

The self-reported and observed exposure ratings were mapped to selected O*NET exposure estimates that best represented each exposure in the available data set. For example, the O*NET estimate for "handling/moving objects" was compared to the estimate from the self-reported and observed exposures to "lifting objects weighing greater than 2 lb." Detailed descriptions of each exposure estimate from the exposure assessment methods are included in Table 1 (p. 32).

The primary exposure categories selected for comparison between the three estimates included variables related to handling and lifting objects tasks, strength demands and repetition. Each comparison is described in further detail.

Handling & Lifting Objects Variable

Handling and lifting objects was a common task among the occupations represented by the subjects in the PrediCTS study, described in the self-reported questionnaires as "lifting objects weighing greater than 2 lb." The O*NET exposure variable selected to represent object handling tasks was "handling/moving objects" (Table 1).

Strength Demands Variables

Strength demands were also chosen for comparison among the three exposure methods. The O*NET estimate for "static strength" was best represented by the self-reported and observed ratings for "forceful gripping." The O*NET static strength variable implies use of the whole body to push, pull, lift or carry objects. The forceful gripping variable is a proxy for upper body strength. Given that pushing/pulling, and lifting and carrying require upper body strength, this mapping seemed appropriate, yet not direct.

Figure 1

Comparison of Physical Exposure Ratings for Object Handling/Lifting

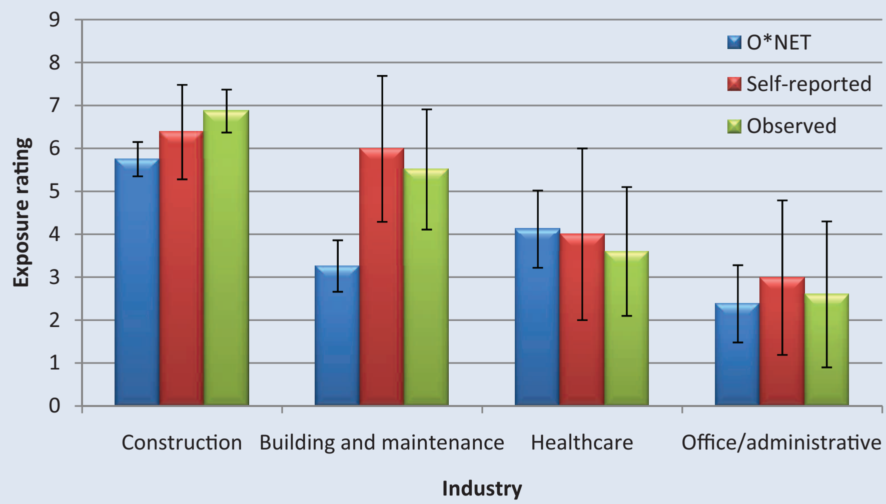
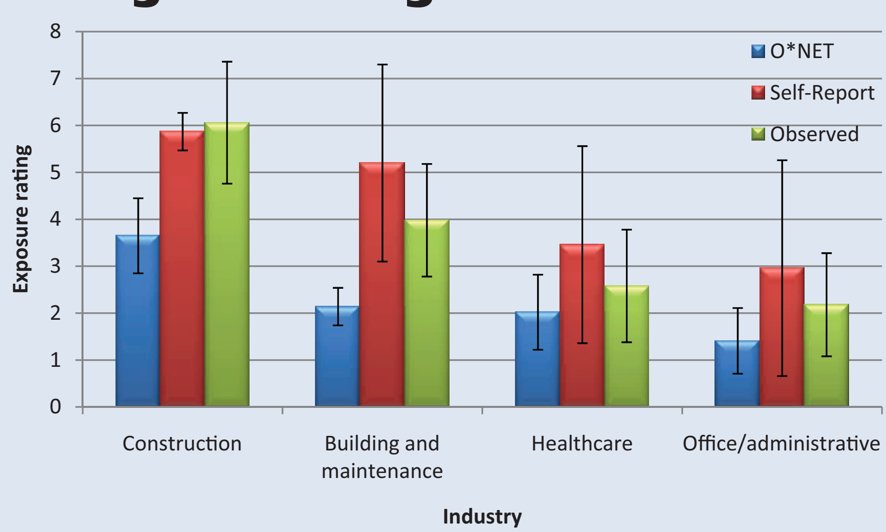


Figure 2

Comparison of Physical Exposure Ratings for Strength Demands

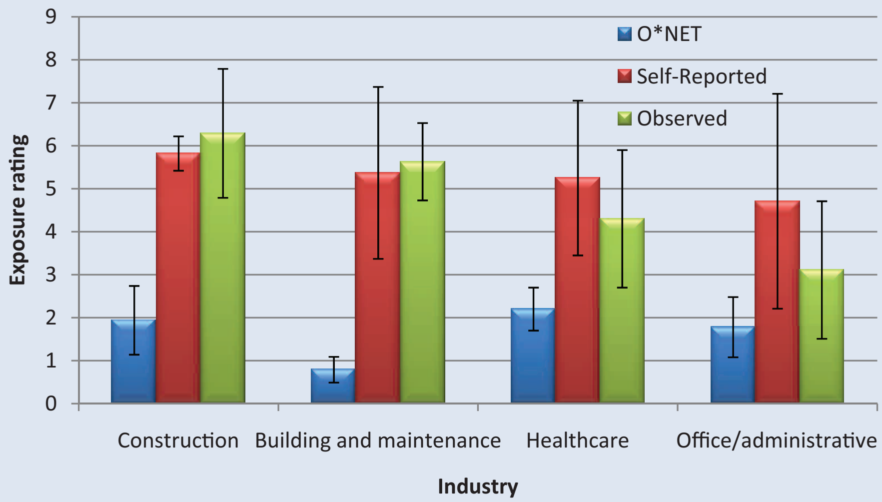


Repetition Variables

The O*NET estimate that best represented repetition is the measure of "wrist/finger speed." This variable was compared to the self-reported and observed ratings for "wrist bending." The O*NET variable specifically describes the repeated movements of the hands and wrists, whereas the wrist bending tasks imply repeated wrist movements as a component of task performance.

Figure 3

Comparison of Physical Exposure Ratings for Repetition



The average exposure estimates for all three physical exposure variables (handling and lifting objects, strength demands and repetition) were highest for self-reports, followed by observer ratings, with O*NET estimates lower than either rating method.

Comparing the Three Exposure Estimates

The three exposure estimates all use seven-point ordinal scales, although the scales quantify different aspects of the exposure, such as duration versus intensity. Since all the scales had similar ranges and were ordinal, it was reasonable to compare the mean values of the scales. For worker exposure ratings from the three estimates, mean exposure values and 95% confidence intervals were calculated and graphically presented.

The first two digits of the SOC provide an industry-level identifier and were used to group workers with similar job demands into industry-level groupings. The four largest industries represented by workers in the study included 1) construction (SOC 47); 2) housekeeping and groundskeeping (SOC 37); 3) healthcare and technical professions (SOC 29); and 4) office/administrative professions (SOC 43). These four job categories represent jobs ranging from generally high physical exposures to low physical exposures. Comparisons of the three physical work exposure estimates were conducted across these four industries.

Study Results

Subjects

The demographic characteristics of the workers in the study population are presented in Table 2 (p. 33). Nine hundred seventy-two workers (87.7%) completed a self-reported questionnaire with ratings of their physical work exposures at 6-month follow-up. Most of workers were males (n = 631, 65%) with an average age of 30.5 years; 63% were Caucasian. The largest occupational group (based on SOC industry-level groupings) represented was construction trades (39.4%), followed by building and grounds cleaning/maintenance (15.7%), healthcare practitioners (12.1%), and office and administrative professionals (24.5%). On site expert observations were completed on 396 (35.7%) of the original 1,108 workers enrolled in the study. No statistically significant differences existed in demographics between the subset of workers who received a worksite observation and the study population as a whole.

Physical Work Exposure Estimates

The average physical work exposure estimates for all subjects, grouped by industry and exposure assessment method are presented in Table 3 (p. 33). Overall, O*NET estimates tend to provide lower estimates of physical work exposures, followed by observed exposures, with self-reports tending to provide the highest estimates of exposures.

Comparison of Exposure Methods

Comparison graphs for each exposure by industry are shown in Figures 1-3. Across all three rating methods, the construction industry jobs had the highest exposure estimates, as expected, followed by building maintenance jobs, healthcare workers, and office and administrative jobs. Given the nature of the work, the construction industry jobs were expected to have the highest exposure estimates regardless of the exposure rating method employed. Similarly, the office and administrative jobs were generally expected to have the lowest exposure estimate across all methods.

The average exposure estimates for all three physical exposure variables (handling and lifting objects, strength demands and repetition) were highest for self-reports, followed by observer ratings, with O*NET estimates lower than either rating method. While the average quantitative estimates differed across the three exposure rating methods, the *relative* rankings between the four industry groups were remarkably consistent between the three methods.

*In the absence of other more precise exposure data, O*NET data may provide reasonable exposure estimates relatively quickly with fewer resources and effort.*

Given the different rating procedures employed in the three methods, differences in the quantitative estimates were expected. However, the consistency in the relative rankings of the exposure estimates between the three methods supports the use of O*NET exposure estimates for group-level applications in the absence of individual-level data such as self-reports or observed exposure ratings.

Discussion

The primary objective of this study was to compare physical work exposure estimates obtained from O*NET to those obtained from videotaped job observations and self-reports by workers. In general, self-reported ratings tended to be higher than O*NET exposure estimates, and observed ratings of exposure were lower. However, all three exposure estimation approaches similarly ranked jobs by exposure levels (i.e., high-, medium-, low-exposure levels).

Study Limitations & Strengths

One potential limitation of these findings is that there is not precise mapping of the self-reported and observed exposure ratings to specific O*NET estimates of physical work exposures. For example, no a single item in either O*NET or the Nordstrom questionnaire used for self-reported and observed ratings captures repetition. The O*NET exposure estimate that best captured hand repetition was "wrist-finger speed," and in the self-reported and observed ratings it was "wrist bending."

However, since this is the first study to examine many of the selected O*NET exposure estimates selected, hypotheses about the mapping of data variables onto specific O*NET physical work exposure variables were made *a priori* based on the researchers knowledge of exposure methods and understanding of the jobs performed by the workers enrolled in the PrediCTS study.

Potential limitations also exist in using a job-title-based database as a surrogate source of exposure information. The O*NET exposure estimates were average values for each exposure item and, in some cases, were based on relatively small survey sample sizes. These smaller sample sizes can introduce potentially large standard errors.

This is an acknowledged limitation of the O*NET data, and the database developers caution users against utilizing ratings with small sample sizes and large standard errors.

Exposure misclassification is a recognized limitation across all exposure methods (Loomis & Kromhout, 2004; Spielholz, Silverstein, Morgan, et al., 2001) for jobs with a high number of heterogeneous job tasks. Better understanding of exposure method and increasing precision in measurement techniques will continue to improve exposure estimates, but to date, no universally accepted exposure method is available.

As each subsequent release of the O*NET database is updated to incorporate additional surveys of existing occupations, and as ratings for additional occupations are included, expert ratings of physical work exposures should continuously improve. Thus, the O*NET ratings could be successfully utilized in very large epidemiological studies when exposure information is lacking (D'Souza, et al., 2007).

An important strength of this study is the simultaneous comparison of three measurement methods. This study is also the first to examine O*NET physical exposure variables for upper extremity physical work exposures. Previous studies have examined the reliability of O*NET variables for lower extremity exposures and psychosocial factors (D'Souza, et al., 2007; D'Souza, et al., 2008; Cifuentes, et al., 2007; Cifuentes, et al., 2008), and reported the O*NET data provide reasonable estimates of relative exposure levels for several variables.

The O*NET databases include ratings of physical work exposures from several sources, including expert ratings by O*NET "analysts" and "occupational experts," and self-reported ratings by "job incumbents," so these ratings may provide more valid estimates of physical work exposures than self-reports alone. O*NET data elements that the research team extracted for this analysis included ratings from all of these potential sources, analysts, experts and incumbents.

Another important strength of using the O*NET physical work exposure data is that in the absence of other more precise exposure data, they may provide reasonable exposure estimates relatively quickly with fewer resources and effort. Studies examining ergonomic, socioeconomic and injury risk factors have begun to use O*NET as a supplemental source of exposure information (Verma, et al., 2007; Boyer, Galizzi, Cifuentes, et al., 2009).

The O*NET work exposure data can easily be merged with large population data sets that contain safety and health outcomes data, such as historical cohort studies, but limited or no work exposure data apart from job titles. O*NET exposure data can be used where other methods are not possible or feasible, as a convenient way to rank work exposures of different jobs.

Few methods are currently available for obtaining exposures related to upper extremity disorders despite the high rates of injuries and associated costs. O*NET provides additional information about upper extremity exposures and may enhance evaluations that depend on physical exposure estimates. However, further validation of these data is necessary to determine the utility of O*NET estimates in large-scale epidemiological studies.

Conclusion

In the study population, O*NET estimates provided a reasonable overall estimation of physical job demands to the upper extremity. While some exposures were underestimated when compared to observed exposure measures, O*NET data correctly ranked job industries by relative exposure levels. These results suggest that O*NET may be a useful tool for SH&E professionals because it can rapidly provide estimates of physical exposures across multiple industry categories.

In the absence of direct observation or other exposure measures, such estimates may be useful for prioritizing industries for further study, targeting interventions or estimating risks.

However, the limitations of database must be recognized. While it may provide valid rankings of exposures relative to other industries, the scales used may not be directly comparable to other measures. Many jobs have interindividual variability of exposures that may not be captured when estimating the exposure of an individual worker using O*NET data. Furthermore, only a limited number of domains are described in the database.

The results of the current study suggest that three separate methods of assessing exposure can be used successfully to rank job industries by relative exposure levels, however, additional studies are necessary to determine the validity of the self-reported and observer-rated exposures collected in the PrediCTS study.

Despite these limitations, O*NET data provide a convenient, estimate of some workplace physical exposures. For some applications, these exposure estimates may provide useful supplemental information to data collected by other methods. ■

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