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Original article

Reliability of job-title based physical work exposures for the upper extremity: comparison to self-reported and observed exposure estimates

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ABSTRACT

Objectives To evaluate the agreement between job-title based estimates for upper extremity physical work exposures and exposure estimates from work observation and worker self-report.

Methods Self-reported exposure questionnaires were completed by 972 workers, and exposure estimates based on worksite observation were completed for a subset of 396 workers. Job-title based estimates were obtained from O*NET, an American database of job demands. Agreement between self-reported, observed and job-title based physical work exposures was assessed using Spearman correlations and intraclass correlation coefficients.

Results Job-title based exposure estimates from O*NET, self-reported and observer-rated exposures showed moderate to good levels of agreement for some upper extremity exposures, including lifting, forceful grip, use of vibrating tools and wrist bending.

Conclusions Job-title based physical work exposure variables may provide useful surrogate measures of upper extremity exposure data in the absence of other individual level data such as observed or self-reported exposure. Further validation of these data is necessary to determine the utility of the O*NET databases in future epidemiological studies.

What this paper adds

- The accuracy of exposure assessment for physical work demands varies widely depending on the method of measurement.
- Job-title based physical work exposure information from an existing database, such as O*NET, is a potential alternative to using other methods of exposure assessment, particularly when exposure data are lacking.
- In the current study, job-title based physical work exposures from the O*NET database, self-reported and observer-rated exposures showed moderate to good levels of agreement for some items.
- These findings are promising for using job-title based physical work exposures in future epidemiological studies and in practice, but additional reliability and validity studies are needed.

INTRODUCTION

The accuracy of exposure assessment for physical work demands varies widely depending on the method of measurement. In the absence of direct measures or observation of occupational exposure, self-reported measures collected using questionnaires are often used as estimates in epidemiological studies. Previously conducted studies have found various levels of agreement between exposure assessments derived from self-report and from work observations.[1–3] Often, self-reported work exposures are collected because they are less costly and time consuming than conducting observations; however, self-reported data are often considered to be less accurate.[2]

Challenges with estimating physical work exposures include individual variation, in addition to variation within job type or category.[4] For example, some studies have reported that symptomatic workers or workers with psychosocial concerns such as job dissatisfaction, may report more frequent or greater physical work exposures than their coworkers.[5 6] Furthermore, there is often variability in the duration and frequency of exposures within a single job or task, which limits the accuracy of self-reported exposures.[7 8] These issues are not unique to self-reports, as expert-observation exposure estimates are also affected by variation across people, task and time.[9–11] Standardised measures for quantifying the risks of musculoskeletal disorders have not advanced as much as those for measuring other environmental agents.[12 13] Quantification of physical exposures is complicated by variability in exposure, and by the multiple dimensions of exposures, including intensity, frequency and duration.[14 15]

Using job-title based physical work exposure information from an existing database is a potential alternative to using other methods of exposure assessment, particularly where job title is known and other exposure data are lacking. A promising publicly available source of data on work exposures is the Occupational Information Network (O*NET database; http://www.onetcenter.org), a job-title based database developed by the United States Department of Labor to enhance public access to occupation-specific information. O*NET provides information on a wide range of work variables for over 800 occupations, grouped using the 2000 Standard Occupational Classification system (SOC), used by US government statistical agencies to classify workers into discrete occupational

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categories for collecting and disseminating data.[16] O*NET data are gathered from work analysts and occupational experts, as well as from surveys of workers using standardised questionnaires.

The O*NET database contains occupation-specific qualitative and quantitative information organised into six major domains: worker characteristics, worker requirements, experience requirements, occupational requirements, workforce characteristics and occupation-specific information.[17] The O*NET database was designed primarily for use by human resources professionals, vocational counsellors, and as a career exploration tool for job seekers, rather than for epidemiological research. However, it has proven useful as a research tool, and several published studies have used O*NET variables to estimate diverse work exposures including psychosocial factors, job physical requirements and work organisation.[18–23] To assess inter-method agreement, recent studies have made direct comparisons between independently collected data and variables in the O*NET database.[24–27] D'Souza[24 25] compared expert consensus ratings of occupational exposures related to knee osteoarthritis to job-title based physical work exposure variables from O*NET. This study found positive correlations between expert ratings of lower extremity exposures and similar O*NET variables. More recently, the consistency and total agreement between O*NET and self-reported psychosocial exposures were compared in healthcare and other workers,[26 27] showing 'good' agreement at the job level, particularly on healthcare specific jobs.

Using job-title based physical work exposure information from an existing database such as O*NET is a potential alternative to using other methods of exposure assessment, particularly where job title is known and other exposure data are lacking. The aim of the current study was to compare self-reported and observed exposures to comparable upper extremity physical exposures obtained from O*NET 12.0.[28]

MATERIALS AND METHODS

Design and study sample

The current study was conducted as a secondary analysis of data from the Predictors of Carpal Tunnel Syndrome (PrediCTS) Study, an ongoing prospective longitudinal study on carpal tunnel syndrome (CTS). The PrediCTS study enrolled 1108 newly employed workers in construction, healthcare, manufacturing and biotechnology, recruited from eight employers and three trade union groups. Subjects completed repeated questionnaires (baseline, 6 months, 18 months and 36 months) about upper extremity symptoms, personal characteristics and occupational risk factors. The subset of data for the current study included 972 workers who completed the 6-month follow-up. Approximately one third of these subjects participated in additional data collection including a worksite observational exposure assessment at 6-month follow-up. All subjects provided written informed consent and this study was conducted under the guidelines and approval of the Institutional Review Boards of Washington University, Saint Louis, Missouri, and the Liberty Mutual Research Institute for Safety in Hopkinton, Massachusetts.

Physical work exposures

Self-reported exposures

Self-reported physical work exposure data were collected using a modified Nordstrom[1] questionnaire, including eight physical exposures related to CTS. Variables in the questionnaire included: bending of the hand and wrist, forearm rotation, use of pinch grip, use of hand-held vibrating power tools, finger or thumb pushing or pressing, forceful gripping, lifting objects weighing greater than 2 pounds, and assembly line tasks (see appendix A). An example of one question from the Nordstrom questionnaire in our study was as follows: "On average, how much time do you spend each day lifting, carrying, pushing or pulling objects weighing more than 2 pounds?".

Observed exposures

One of three occupational therapists trained in ergonomics carried out 1 h worksite visits for each worker; observers were blinded to workers' symptoms and self-reported exposure estimates described above. Worksite visits included brief interviews on work tasks with subjects and supervisors, work observations and approximately 20 min of videotaping work tasks. Using a consensus method developed by Latko and colleagues,[29] two or three research team members jointly assigned physical work exposure estimates for each worker using the videotape, interview data and prior knowledge from ratings of other workers in similar jobs. Latko and colleagues showed good reliability (r^2=0.88) using this consensus observation method,[29] and we showed similar results on a separate sample of previously scored observations (r^2=0.82, ICC=0.88).[30]

Each job was divided into three task groupings and each task group was rated for hand force, repetition and upper extremity postures. Repetition and hand force scales were adopted from the American Conference of Governmental Industrial Hygienists (ACGIH) hand activity level (HAL) threshold limit value (TLV) (see appendix A).[31] The HAL-TLV ratio is an assessment of risk factors for musculoskeletal disorders of the hand and wrist, based on hand repetition rate and the level of effort or force for a typical posture during a job. Since peak hand force and HAL-TLV ratings were completed at the task level, they were summarised to the job level using a time-weighted averaging method,[32] to allow comparisons with physical work exposure items from the O*NET database rated at the job level. Observational data were also rated using the same Nordstrom questions used in the self-reported data.

Job-title based exposure data

A trained research assistant assigned an O*NET job title and SOC code to each subject according to employer and job title information. SOC codes were verified by consensus between two raters. Occupation-specific, physical work exposure variables for each job title were extracted from the O*NET 12.0 database for comparison with the exposure estimates derived from self-report and observed ratings.

O*NET 12.0 contains 12 databases with occupational information describing both job characteristics and worker characteristics. We identified three of these 12 databases that contained data related to upper extremity physical work exposures: Abilities, Work activities and Work context. From these databases, we identified 12 discrete data 'elements' that could describe exposures of the upper extremity. We compared the similarity of O*NET questionnaires to the Nordstrom questionnaires completed by our subjects to reduce this list of 12 O*NET upper extremity data elements to eight discrete elements which most closely resembled our self-reported and observed exposures (table 1).

Physical work exposure handling variables

The O*NET database contained two variables related to handling objects, abbreviated in the data tables as 'handling/moving objects' and 'handling/controlling objects' (see appendix A for complete definitions). We hypothesised that these O*NET

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Table 1 Selected O*NET databases and data elements involving the upper extremities

O*NET database	Data element	Element ID	Short description	Scale	Exposure property
Work activities	Handling and moving objects	4.A.3.a.2	Handling/moving objects	1–7	Intensity
Work context	Spend time using your hand to handle, control or feel objects, tools or controls	4.C.2.d.1.g	Handling/controlling objects	1–5	Duration
Work abilities	Static strength	1.A.3.a.1	Static strength	1–7	Intensity
Work abilities	Dynamic strength	1.A.3.a.3	Dynamic strength	1–7	Intensity
Work abilities	Manual dexterity	1.A.2.a.2	Manual dexterity	1–7	Intensity
Work abilities	Finger dexterity	1.A.2.a.3	Finger dexterity	1–7	Intensity
Work context	Spend time making repetitive motions	4.C.2.d.1.i	Making repetitive motions	1–5	Duration
Work abilities	Wrist–finger speed	1.A.2.c.2	Wrist–finger speed	1–7	Frequency/intensity

These selected O*NET variables were then mapped to the Nordstrom and ACGIH HAL-TLV variables based on similarity of measured domains (table 2). Decisions were made a priori regarding the expected relationships among variables. Further descriptions of the Nordstrom, ACGIH HAL-TLV and job-title based physical work exposure variables are included in appendix A. ACGIH HAL-TLV, American Conference of Governmental Industrial Hygienists hand activity level threshold limit value; O*NET, Occupational Information Network.

handling variables would show strong correlations with the Nordstrom variables for lifting objects weighing more than 2 pounds, use of a pinch grip and HAL.[31] However, many of the Nordstrom and ACGIH HAL-TLV variables implicitly refer to object handling and manipulation, thus Spearman correlations and intraclass correlation coefficients (ICCs) were completed for comparisons of the O*NET handling variables with each of our independently collected items.

Physical work exposure strength variables

Two O*NET variables related to strength demands required for job performance, static strength and dynamic strength (see appendix A for detailed descriptions). The Nordstrom variables of lifting, forceful gripping and pinching were selected for comparison with these O*NET strength variables, along with the HAL-TLV variables (table 2).

Physical work exposure dexterity variables

Two O*NET dexterity variables were selected for comparison with our data, manual dexterity and finger dexterity. The manual dexterity variable refers to gross motor movements and object manipulation abilities, whereas the finger dexterity variable refers to finely coordinated movements of the fingers (appendix A). Given the general description of these dexterity variables and the inherent use of dexterity with many upper extremity tasks, these two O*NET variables were mapped to many of the Nordstrom variables and to HAL (table 2).

Physical work exposure repetition variables

Repetition is not explicitly characterised by any of the Nordstrom variables but may be implied within several self-reported variables including wrist bending, assembly line tasks and forearm rotation. In addition, repetition relates to the hand activity level of the HAL-TLV as well as two of the O*NET variables, making repetitive motions and wrist–finger speed (appendix A).

Data analysis

We estimated agreement between workers' self-reports of physical workplace exposure, observed ratings of exposure and job-title based exposure variables (defined as O*NET variables), by calculating both Spearman rank correlations[33] using SAS v 9.1 and intra-class correlation coefficients (ICCs)[34] using SPSS 15.0. Spearman rank correlations evaluated general strength and direction of agreement. ICCs estimated the level of agreement or reliability for each comparison, since scoring for the O*NET variables was averaged at the job level and observer ratings were consensus scores for each subject. A two-way random effects model was specified for the following comparisons versus the corresponding O*NET variables:

- Self-reported exposure for the Nordstrom variables
- Observed exposures for the Nordstrom variables
- Observed exposures for the HAL-TLV variables.

The point estimates of the ICCs were interpreted according to the parameters developed by Landis and Koch[35] for the κ coefficient, which is interpreted similarly to the ICC.[36] An ICC

Table 2 Expected relationship between job-title based physical work exposure variables and self-reported and observed variables

	Job-title based variables from O*NET							
Self-reported and observed variables	Handling/moving objects*	Handling/controlling objects†	Static strength*	Dynamic strength*	Manual dexterity*	Finger dexterity*	Making repetitive motions†	Wrist–finger speed*
Lifting >2 pounds†,‡	••	••	••	••				
Forceful grip†,‡	•	•	••	••				
Vibrating tools†,‡	•	•						
Wrist bending†,‡	•	•			•		•	•
Assembly line tasks†,‡	•	•			••		•	
Pinch†,‡	••	••	•	•	••	••		
Thumb press†,‡	•	•			••	•		
Forearm rotation†,‡	•	•			•		•	
Peak hand force*,§	•	•	••	••				
HAL*,§	••	••	•	•	•	•	•	••
TLV*,§	•	•	•	•				

HAL, hand activity level; O*NET, Occupational Information Network; TLV, threshold limit value; •, weak correlation expected; ••, moderate to strong correlation expected.
*Scale of this variable is for intensity;
†scale of this variable is for duration;
‡data values for Nordstrom observed and self-reported variables;
§data values for observed variables only.

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greater than 0.81 represents almost perfect agreement, an ICC between 0.61 and 0.80 represents substantial agreement, a value between 0.41 and 0.60 represents moderate agreement, and ICCs below 0.40 represent fair to poor agreement.[35]

Each O*NET database includes data fields describing the quality of individual data values, including the sample size and SE. Users of the O*NET data are discouraged from using data values with an SE greater than 0.51, or for values that are rated as 'not relevant' to particular jobs.[37] Data elements from the Abilities and Activities databases offer two ratings scales, the 'importance' and 'level' (or magnitude) of the element. If at least 75% of O*NET raters described a data element as 'not important', the 'level' rating was defined as 'not relevant' and the data value was excluded from our analyses. We used only the data values for the 'level' rating scale, as the two scales were strongly correlated (Spearman correlation >0.90).

The 'level' scale anchors for the items in the Activities and Abilities databases represented either exposure intensity within tasks or frequency of task performance (table 1). The 'level' scale ranges from 1 to 7 with unique verbal descriptors included for points 2, 4, 6 for each data element, and point 7 identified as 'highest level'. In contrast, the Work context database uses a five-point ordinal scale, for the duration of each exposure in each occupation (table 1).

In order to assess total agreement between our three different exposure methods using ICCs, some of the measurement scales had to be transformed to the same scale. For each exposure comparison (ie, self-reported vs job-title based exposure), original values were analysed when the compared scales were the same. If the scales were different (ie, five vs seven level ordinal scales), then both scales were transformed using a method similar to that of Cifuentes *et al*[26 27] for comparing consistency and total agreement between O*NET exposures and self-reported psychosocial exposures. In all, 38 of 84 scales were transformed to percentages of maximum (100%) values of their original scales in order to calculate the total agreement between job-title based items and our independently collected data. Similar transformation methods have been used by other researchers in order to compare O*NET data elements with measures of similar constructs with differing scales.[38–41]

RESULTS

Subject characteristics

Demographic and occupational characteristics of the study population are presented in table 3. In total, 972 of the 1108 recruited subjects (87.7%) completed a self-reported questionnaire at the 6-month follow-up. Worksite exposure observations were completed on a subset of 396 subjects, a mean of 26 days from receipt of the self-reported questionnaire (range 0–480). We found no relationship between the differences in self-reported and observed responses and the time interval between collection of questionnaire data and work observations. No statistically significant differences in self-reported work exposures were shown by χ^2 and t tests between the subset of workers who received a worksite observation and the study population as a whole.

Table 3 Demographic and occupational characteristics

Characteristic	Self-report, N=972	Observed, N=396
	Mean (SD)	Mean (SD)
Age (years)	30.5 (10.3)	32.7 (11.1)
	N (%)	N (%)
Gender		
Male	631 (65)	224 (57)
Female	341 (35)	172 (43)
Race/ethnicity		
Caucasian	616 (63)	225 (57)
African American	312 (32)	149 (38)
Asian/Asian American	20 (2)	7 (2)
Hispanic/Latino	7 (1)	4 (1)
Other	14 (2)	9 (2)
Level of education		
Grade 8 or less	9 (1)	2 (1)
Some high school	55 (6)	22 (5)
Graduated high school or GED	417 (43)	165 (42)
2-Year college or technical school	179 (18)	93 (23)
Attended 4-year college, did not graduate	95 (10)	36 (9)
Graduated from 4-year college	141 (14)	46 (12)
Attended graduate or professional school	75 (8)	31 (8)
Hand dominance		
Right	843 (88)	348 (89)
Left	103 (11)	39 (10)
Ambidextrous	12 (1)	3 (1)
SOC occupational category (SOC major group code)		
(47) Construction and extraction	383 (39.4)	148 (37.4)
(37) Building and grounds cleaning and maintenance	153 (15.8)	85 (21.5)
(29) Healthcare practitioners and technical	118 (12.1)	70 (17.7)
(43) Office and administrative support	80 (8.2)	36 (9.1)
(35) Food preparation and serving related	45 (4.6)	16 (4.0)
(13) Business and financial operations	40 (4.1)	4 (1.0)
(15) Computer and mathematical	36 (3.7)	10 (2.5)
(17) Architecture and engineering	32 (3.3)	4 (1.0)
(19) Life, physical and social science	19 (2.0)	3 (0.8)
(51) Production occupations	12 (1.2)	0
(31) Healthcare support	11 (1.1)	10 (2.5)
Other*	43 (4.5)	10 (2.5)

GED, General Equivalency Diploma; SOC, 2000 Standard Occupational Classification system.
*Other includes: Management; Legal occupations; Education, training, and library; Arts, design, entertainment, sports, and media; Protective services; Personal care and service; Sales and related occupations; Installation, maintenance, and repair; Transportation and material moving occupations.

Comparison of exposure methods

Handling-related variables

Handling/moving objects

The O*NET exposure variable representing handling/moving objects positively correlated with six of eight observer-rated Nordstrom variables (table 4): forceful gripping (0.75), lifting (0.69), vibrating tool use (0.63), wrist bending (0.44), pinching (0.38) and forearm rotation (0.37). All eight self-reported exposures positively correlated with the O*NET handling/moving objects variable. However, Spearman correlations were substantially stronger between more of the O*NET variables and observer comparisons (forceful gripping, lifting, wrist bending) than between O*NET and self-report comparisons.

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Table 4 Spearman correlation coefficients of self-reported and observed exposures to job-title based physical work exposure variables

Job-title based physical work exposure variables	Handling/moving objects*		Handling/controlling objects†		Static strength*		Dynamic strength*		Manual dexterity*		Finger dexterity*		Making repetitive motions†		Wrist–finger speed*	
Self- and observed variables	Observed, n=391	Self-report, n=939	Observed, n=396	Self-report, n=972	Observed, n=347	Self-report, n=767	Observed, n=316	Self-report, n=709	Observed, n=380	Self-report, n=867	Observed, n=390	Self-report, n=924	Observed, n=396	Self-report, n=972	Observed, n=267	Self-report, n=639
Lift >2 pounds†,‡	0.69 (<0.01)	0.53 (<0.01)	0.59 (<0.01)	0.50 (<0.01)	0.64 (<0.01)	0.36 (<0.01)	0.65 (<0.01)	0.26 (<0.01)	—	—	—	—	—	—	—	—
Forceful grip†,‡	0.75 (<0.01)	0.50 (<0.01)	0.64 (<0.01)	0.54 (<0.01)	0.74 (<0.01)	0.37 (<0.01)	0.72 (<0.01)	0.29 (<0.01)	—	—	—	—	—	—	—	—
Vibrating tools†,‡	0.63 (<0.01)	0.66 (<0.01)	0.54 (<0.01)	0.59 (<0.01)	—	—	—	—	—	—	—	—	—	—	—	—
Wrist bending†,‡	0.44 (<0.01)	0.26 (<0.01)	0.46 (<0.01)	0.28 (<0.01)	—	—	—	—	0.38 (<0.01)	0.20 (<0.01)	—	—	−0.03 −0.56	0.10 (<0.01)	0.02 −0.77	0.08 −0.05
Assembly line tasks†,‡	−0.11 0.03	0.02 0.58	−0.11 0.03	−0.02 0.48	—	—	—	—	−0.04 −0.40	−0.02 −0.56	—	—	0.15 (<0.01)	0.08 −0.02	—	—
Pinch†,‡	0.38 (<0.01)	0.33 (<0.01)	0.31 (<0.01)	0.27 (<0.01)	0.26 (<0.01)	0.23 (<0.01)	0.22 (<0.01)	0.20 (<0.01)	0.41 (<0.01)	0.31 (<0.01)	0.39 (<0.01)	0.30 (<0.01)	—	—	—	—
Thumb press†,‡	−0.18 (<0.01)	0.14 (<0.01)	−0.10 0.04	0.14 (<0.01)	—	—	—	—	−0.10 (0.05)	0.12 (<0.01)	0.02 −0.76	0.15 (<0.01)	—	—	—	—
Forearm rotation†,‡	0.37 (<0.01)	0.39 (<0.01)	0.29 (<0.01)	0.39 (<0.01)	—	—	—	—	0.27 (<0.01)	0.31 (<0.01)	—	—	−0.11 −0.02	0.07 −0.03	—	—
Peak hand force*,§	0.71 (<0.01)	—	0.64 (<0.01)	—	0.66 (<0.01)	—	0.66 (<0.01)	—	—	—	—	—	—	—	—	—
HAL*,§	0.38 (<0.01)	—	0.41 (<0.01)	—	0.38 (<0.01)	—	0.44 (<0.01)	—	0.40 (<0.01)	—	0.27 (<0.01)	—	−0.15 (<0.01)	—	0.12 −0.05	—
TLV*,§	0.69 (<0.01)	—	0.65 (<0.01)	—	0.65 (<0.01)	—	0.66 (<0.01)	—	—	—	—	—	—	—	—	—

Numbers in parentheses represent p values for the Spearman correlation coefficients. HAL, hand activity level; TLV, threshold limit value.
*Scale of this variable is for intensity;
†scale of this variable is for duration;
‡data values for Nordstrom observed and self-reported variables;
§data values for observed variables only.

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There was a strong positive correlation between handling/moving objects and observer-rated peak hand force (0.71) and the TLV (0.69), but a weaker correlation with HAL (0.38).

In assessing total agreement between the Nordstrom and O*NET variables using the ICCs, handling/moving objects (table 5A) showed substantial agreement with observed forceful gripping (0.81) and lifting (0.69), moderate agreement with vibrating tool use (0.55), and substantial agreement with peak hand force (0.71) based on the interpretation of the point estimates.[36]

Handling/controlling objects

Handling/controlling objects showed strong positive Spearman correlations with the observer ratings (table 4) for forceful gripping (0.64), lifting (0.59), vibrating tool use (0.54), TLV (0.65) and peak hand force (0.64), with weaker correlations for all other comparisons. The majority of comparisons between O*NET variables and observer ratings (except for vibrating tool use, thumb press and forearm rotation) showed stronger Spearman correlations than with self-reports, with the most notable differences for forceful gripping and wrist bending. With respect to the ICCs, the self-reported exposures for vibrating tools and forearm rotation showed better total agreement with the O*NET variable of handling/controlling objects than did observer ratings, whereas observer ratings were stronger for wrist bending and pinching (table 5A).

Strength-related variables

Static strength

Spearman Rank correlations (table 4) for the O*NET variable representing static strength were correlated most strongly with the observer-rated Nordstrom variables forceful gripping (0.74), lifting (0.64), peak hand force (0.66) and TLV (0.65). Comparisons between O*NET variables and observer ratings for the Nordstrom variables showed stronger correlations than our collected self-reports for two of three comparisons (forceful gripping and lifting). ICCs (table 5A) showed substantial agreement of static strength with the observed peak hand force (0.66) and moderate agreement with the observed forceful gripping (0.53) and HAL (0.47), with fair to poor agreement for all other observed and self-reported variables.

Dynamic strength

O*NET dynamic strength results were similar to those observed for static strength; the strongest Spearman correlations were found for observed ratings of forceful gripping (0.72), peak hand force (0.66), TLV (0.66) and lifting (0.65) (table 4). Weaker correlations were found for observed ratings for HAL (0.44) and pinching (0.22), and for all self-reported ratings versus O*NET dynamic strength. Observer-rated Nordstrom and HAL variables exhibited moderate ICCs for peak hand force (0.45) and HAL (0.40); agreement was fair to poor for all of the observed and self-reported Nordstrom and TLV variables (table 5A).

Dexterity variables

Manual dexterity

With respect to the O*NET manual dexterity variable, observed ratings for pinching (0.41), HAL (0.40) and wrist bending (0.38) were positively correlated using Spearman rank correlations, however there was little to no agreement with the other observed Nordstrom variables. Positive correlations between self-reports were found for forearm rotation (0.31), pinching (0.31) and wrist bending (0.20) (table 4). Observed ratings showed stronger Spearman correlations with the O*NET physical work exposure manual dexterity variables than self-reports, however,

Table 5A Intraclass correlation coefficients of self-reported and observed exposures to job-title based physical work exposure handling and strength variables

Job-title based physical work exposure variables	Handling/moving objects*		Handling/controlling objects†		Static strength*		Dynamic strength*	
Self-reported and observed variables	Observed, n = 391	Self-report, n = 939	Observed, n = 396	Self-report, n = 972	Observed, n = 347	Self-report, n = 767	Observed, n = 316	Self-report, n = 709
Lift >2 pounds†,‡	0.69 (0.39, 0.81)	0.64 (0.40, 0.76)	0.64 (0.56, 0.71)	0.66 (0.61, 0.70)	0.30 (−0.21, 0.66)	0.22 (−0.24, 0.56)	0.19 (−0.12, 0.55)	0.11 (−0.15, 0.39)
Forceful grip†,‡	0.81 (0.77, 0.84)	0.67 (0.62, 0.71)	0.59 (−0.08, 0.80)	0.61 (0.37, 0.74)	0.53 (−0.31, 0.81)	0.30 (−0.30, 0.61)	0.36 (−0.20, 0.72)	0.17 (−0.24, 0.49)
Vibrating tools†,‡	0.55 (−0.26, 0.81)	0.71 (0.61, 0.77)	0.28 (−0.22, 0.65)	0.50 (−0.15, 0.74)	—	—	—	—
Wrist bending†,‡	0.53 (0.08, 0.73)	0.44 (0.23, 0.58)	0.60 (0.51, 0.67)	0.48 (0.41, 0.54)	—	—	—	—
Assembly line tasks†,‡	−0.06 (−0.33, 0.24)	0.00 (−0.04, 0.04)	−0.01 (−0.08, 0.06)	−0.01 (−0.03, 0.03)	—	—	—	—
Pinch†,‡	0.56 (0.46, 0.64)	0.36 (0.03, 0.55)	0.41 (0.04, 0.62)	0.20 (−0.25, 0.49)	0.18 (−0.25, 0.47)	0.26 (0.15, 0.36)	0.13 (−0.20, 0.42)	0.18 (0.03, 0.30)
Thumb press†,‡	−0.59 (−1.54, −0.07)	0.18 (0.07, 0.29)	−0.31 (−1.75, 0.60)	0.14 (−0.10, 0.32)	—	—	—	—
Forearm rotation†,‡	0.16 (−0.22, 0.47)	0.52 (0.46, 0.58)	0.06 (−0.09, 0.27)	0.42 (0.03, 0.62)	—	—	—	—
Peak hand force*,§	0.71 (0.26, 0.86)	—	0.40 (−0.21, 0.75)	—	0.66 (−0.06, 0.85)	—	0.45 (−0.26, 0.78)	—
HAL*,§	0.33 (−0.19, 0.59)	—	0.16 (−0.17, 0.49)	—	0.47 (0.29, 0.60)	—	0.40 (−0.28, 0.69)	—
TLV*,§	0.08 (−0.14, 0.33)	—	0.04 (−0.05, 0.19)	—	0.18 (−0.24, 0.50)	—	0.30 (−0.24, 0.59)	—

HAL, hand activity level; TLV, threshold limit value.
*Scale of this variable is for intensity;
†scale of this variable is for duration;
‡data values for Nordstrom observed and self-reported variables;
§data values for observed variables only.

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Table 5B Intraclass correlation coefficients of self-reported and observed exposures to job-title based physical work exposure dexterity and repetition variables

Job-title based physical work exposure variables	Manual dexterity*		Finger dexterity*		Making repetitive motions†		Wrist–finger speed*	
Self- and observed variables	Observed, n=380	Self-report, n=867	Observed, n=390	Self-report, n=924	Observed, n=396	Self-report, n=972	Observed, n=267	Self-report, n=639
Lift >2 pounds†,‡	–	–	–	–	–	–	–	–
Forceful grip†,‡	–	–	–	–	–	–	–	–
Vibrating tools†,‡	–	–	–	–	–	–	–	–
Wrist bending†,‡	0.20 (−0.23, 0.54)	0.16 (−0.24, 0.44)	–	–	−0.02 (−0.23, 0.15)	0.14 (0.02, 0.24)	0.01 (−0.06, 0.09)	0.02 (−0.07, 0.12)
Assembly line tasks†,‡	−0.03 (−0.19, 0.11)	−0.01 (−0.09, 0.06)	–	–	0.05 (−0.09, 0.23)	0.02 (−0.07, 0.12)	–	–
Pinch†,‡	0.30 (−0.31, 0.63)	0.33 (0.23, 0.41)	0.28 (−0.28, 0.54)	0.26 (0.16, 0.35)	–	–	–	–
Thumb press†,‡	−0.25 (−0.84, 0.12)	0.11 (−0.01, 0.22)	−0.05 (−0.23, 0.12)	0.12 (−0.01, 0.23)	–	–	–	–
Forearm rotation†,‡	0.23 (−0.24, 0.52)	0.30 (0.00, 0.49)	–	–	−0.02 (−0.13, 0.11)	0.10 (−0.02, 0.20)	–	–
Peak hand force*,§	–	–	–	–	–	–	–	–
HAL*,§	0.52 (0.38, 0.63)	–	0.30 (0.11, 0.45)	–	−0.08 (−0.55, 0.29)	–	0.11 (−0.20, 0.36)	–
TLV*,§	–	–	–	–	–	–	–	–

HAL, hand activity level; TLV, threshold limit value.
*Scale of this variable is for intensity;
†scale of this variable is for duration;
‡data values for Nordstrom observed and self-reported variables;
§data values for observed variables only.

the differences were not significant. ICCs for observed HAL (0.52) (table 5B) showed moderate agreement with manual dexterity, whereas the Nordstrom variables showed fair to poor agreement for all observed and self-reported ratings.

Finger dexterity

Spearman correlations with our observed and self-reported data were fair for the O*NET variable for finger dexterity with observed (0.39) and self-reported (0.30) pinching and the observed HAL (0.27) (table 4). Similar relationships were observed using ICCs with fair to poor agreement for observer-rated HAL (0.30) and observed (0.28) and self-reported pinching (0.26) (table 5B).

Repetition variables

Making repetitive motions and wrist–finger speed

We found little to no agreement between observed and self-reported ratings and the O*NET physical work exposures for making repetitive motions and wrist–finger speed, based on Spearman rank correlations (table 4) and intraclass correlation coefficients (table 5B).

DISCUSSION

The objective of this study was to evaluate the agreement between job-title based exposure estimates for the upper extremity and estimates derived from self-reported and observed exposures. In this study of 972 workers, we found mixed results with respect to the correlation and agreement between self-reported, observed and job-title based physical work exposures. The highest levels of agreement were seen with the O*NET variables related to handling objects and strength demands. Weaker agreement was seen for dexterity variables, and almost no agreement for repetition variables.

In a previous study, we compared observed and self-reported exposures of the upper extremities using the Nordstrom scale in this same population.[30] We found substantial agreement for lifting and use of vibrating tools (weighted kappa (k_w)=0.67 and k_w=0.61), fair to moderate agreement for forceful gripping and wrist bending (k_w=0.58 to 0.23) and little to no agreement for other variables studied including finger pinch, forearm rotation, assembly line tasks and pressing with the thumb. In this present study, we saw similar patterns of agreement between job-title based exposure estimates and these other methods.

We found better agreement when we compared items that involved the same dimension of exposure in the rating scales. The scales from self-reports, observations and O*NET for the handling/controlling objects item all captured time and generally showed good agreement. Similarly, the scales for the O*NET strength items assessed intensity of force and agreed with observed force ratings. The handling/moving objects item from O*NET used scale responses that described the intensity and frequency of tasks. This item showed good agreement with both self-reported and observed ratings that involved either duration or intensity. There was generally poorer agreement when comparing items from self-report or observed ratings to O*NET when the exposure dimension within the scales was not similar. One exception was comparison of repetitive motions that used duration of time in all scales but overall had poor agreement. Furthermore, the influence of these different dimensions of exposure (ie, time vs intensity) is an important consideration of the impact of physical work exposures on musculoskeletal injury clinically as well as statistically and is an interesting area for future epidemiological studies.

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Study limitations

There are several limitations in comparing our self-reported questionnaire to the other measures of physical work exposure. Low prevalence of exposures may contribute to the lack of precision of results. The assembly line item was the only self-reported variable that captures the repetitiveness of jobs, although very few subjects in our study (<6%) performed assembly line tasks. In addition, we were restricted to the available variables and response scales, so in some comparisons there was a mismatch in the measured dimensions (duration vs intensity). We found lower agreement when the scales differed in the characterisation of the exposure.

Furthermore, many of the workers in this cohort irregularly performed some tasks, so time estimates for total duration may have been difficult for both workers and observers to accurately quantify. In general, highly variable exposures in tasks are more difficult to recognise. In addition, the sampling method used for the observed exposures may not have adequately captured all job exposures, particularly for highly variable jobs. This problem would likely contribute to lower agreement between the observed values and O*NET. Our results showed substantially better agreement between job-title based exposure estimates and observed exposures than for self-reported physical exposures. Generally, past studies report less precise exposure estimates from self-reported data,[42–44] although worker self-reported ratings have shown more accuracy with forceful tasks.[45]

Limitations of job-title based physical work exposure data

There are several potential limitations inherent in using a job-title based database as a source of exposure estimates. The O*NET database provides the user with a number of parameters for each exposure variable. The exposure estimates utilised from the O*NET database were average values for each exposure variable. These average values are based on sample sizes that ranged widely from approximately eight to 200 ratings, with the majority of ratings based on sample sizes of less than 50. Smaller sample sizes can introduce potentially large standard errors. This is an acknowledged limitation of the O*NET data and the developers recommend that users exclude ratings with less precision (typically an SE of greater than 0.51).[28] By assigning exposure information to individual workers based on job title (or an average value), there is also the potential for exposure misclassification, as exposure may differ among individuals with the same job title. In some situations, group mean values based on job title may be more appropriate for use in an analysis than individual-level values, but there is a trade-off in precision between these forms of data.[46 47] Exposure misclassification is a recognised limitation across all exposure methods,[8] particularly for jobs with higher variability in job tasks.

The O*NET databases include ratings of physical work exposures from industry experts referred to as 'analysts' and 'occupational experts' and current workers in a given job described as 'job incumbents'. 'Analyst' and 'expert' ratings are gradually being replaced by surveys of 'incumbents'. O*NET data elements that we extracted for this analysis included ratings from all of these potential sources. As such, our agreement analyses of our own collected self-reports and observations were compared with O*NET physical work exposure data which also included both self-reports and expert ratings. This important and interesting characteristic of the O*NET data warrants future investigation with analyses to make distinctions between O*NET self-reported and observed data.

Strengths

The main strength of this study is the simultaneous comparison of three measurement methods: job-title based physical work exposures using O*NET, observer-rated exposures and self-reports. In addition, this study is the first to assess the reliability of selected O*NET physical exposure variables with respect to upper extremity exposures. Previous studies have examined the reliability of O*NET variables with respect to lower extremity exposures and psychosocial factors, but no previous studies have assessed the reliability of the upper extremity physical work exposures. Several studies have begun to use job-title based data as a supplemental source of occupational information, however, further validation of these data is necessary to determine the utility of the job-title based databases in large-scale epidemiological studies in the absence of more accurate but costly and time-intensive expert observations or self-reported questionnaires.

One important strength of the O*NET physical work exposure data, is that they can easily be appended to large general population datasets that contain health outcomes data but limited or no exposure data apart from job titles. For example, O*NET exposure data can be used for historical cohort studies where other methods are not possible or feasible, and may offer a convenient way to rank exposures in different jobs in the absence of better data.

The job-title based database is a relatively new source of occupational exposure data that is beginning to attract increased attention and usage among researchers conducting epidemiological studies. While some studies have successfully used job-title based data as a supplemental source for job information,[18–21] few have provided estimates of data quality of the job-title based physical work exposure estimates used as exposure measures as compared to similar data collected via self-reports or expert observations.[24–27] Our study is the first to examine job-title based physical work exposure data related to upper extremity exposures and the overall results suggest that there is moderate agreement between self-reported and observer-rated exposures, but as previous studies have concluded, the job-title based physical work exposure data warrant further study to determine their use as either covariates or independent risk factors in epidemiological research.

For epidemiological research in upper extremity musculoskeletal disorders, it is important to understand both the magnitude and the direction of the potential information bias of our self-reported exposures, as well as to allow for any correction or attenuation in the effect estimates induced by the measurement error.[48] Future analyses may explore the effects of bias in this data and possible recommendations for correction. Better understanding of the accuracy and reliability of exposure evaluation methods will allow us to more closely examine specific items in self-reported and observed exposures for modification in future studies, or the use of aggregate measures from job-title based physical work exposures as supplemental or surrogate estimates of exposure in epidemiological studies.

CONCLUSIONS

Job-title based physical work exposures, self-reported and observer-rated exposures showed moderate to good levels of agreement for some exposures of the upper extremity, including lifting, forceful grip, use of vibrating tools and wrist bending. These findings suggest that job-title based physical work exposures may be useful for some epidemiological study designs. Improved understanding of inter-method agreement will better

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inform research on the health effects of occupational physical exposures.

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Competing interests None.

Ethics approval This study was conducted with the approval of the Institutional Review Boards of Washington University, Saint Louis, Missouri, and the Liberty Mutual Research Institute for Safety in Hopkinton, Massachusetts.

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APPENDIX A: DESCRIPTIONS OF SELF-REPORTED, OBSERVED AND JOB-TITLE BASED PHYSICAL WORK EXPOSURE VARIABLES

Nordstrom variables: self-report and observer-rated

Variable name	Description
Lifting >2 pounds	Lifting, carrying, pushing or pulling objects weighing more than 2 pounds?
Forceful grip	Using your hand in a forceful grip?
Vibrating tools	Working with hand-held or hand-operated vibrating power tools or equipment?
Wrist bending	Bending or twisting your hands or wrists?
Assembly line tasks	Working on an assembly line?
Pinch	Using your hand in a finger pinch grip?
Thumb press	Using the tip of a finger or thumb as a pressing or pushing tool?
Forearm rotation	Doing tasks where there is twisting, rotating or screwing motion of the forearm?

Each question worded as: "On average, how much time do you spend each day…?".
Rating scale: 1—7 level ordinal scale.
Exposure property: duration of task performance (from not at all to > 4 h).

HAL-TLV variables: observer-rated

Variable name	Description	Rating scale	Exposure property
Force	Peak finger force	0—10, with verbal anchors on even-numbered points	Intensity
HAL	Hand activity level	0—10, with verbal anchors on odd-numbered points	Intensity
TLV	Threshold limit value	Ratio of force and hand activity level ratings: TLV=Force/(10—HAL)	Intensity

Job-title based physical work exposure variables from the Occupational Information Network (O*NET) database

Variable name	Description	Rating scale	Exposure property
Abilities database	Each question worded as: "What level of the ability is needed to perform your current job?"	1—7 level ordinal scale	
Static strength	The ability to exert maximum muscle force to lift, push, pull or carry objects		Intensity
Dynamic strength	The ability to exert muscle force repeatedly or continuously over time. This involves muscular endurance and resistance to muscle fatigue.		Intensity
Manual dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate or assemble objects		Intensity
Finger dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate or assemble very small objects		Intensity
Wrist—finger speed	The ability to make fast, simple, repeated movements of the fingers, hands and wrists		Frequency/intensity
Work context database	Each question worded as: "In your current job, how often do you spend time…?"	1—5 level ordinal scale	Duration
Handling/controlling objects	Using your hands to handle, control or feel objects, tools or controls		
Making repetitive motions	Making repetitive motions		
Work activities database	Each question worded as: "What level of the activity is needed to perform your current job?"	1—7 level ordinal scale	Intensity
Handling/moving objects	Using hands and arms in handling, installing, positioning and moving materials, and manipulating objects		

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Reliability of job-title based physical work exposures for the upper extremity: comparison to self-reported and observed exposure estimates

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