DISTRIBUTIONS OF JOB PHYSICAL EXPOSURE DATA IN A POOLED STUDY OF LOW BACK PAIN PROSPECTIVE COHORTS

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Low back pain (LBP) is a common health problem and a major cause of lost productivity in workplaces. Lifting and lowering (LL) activities have traditionally been regarded as risk factor for LBP. In the literature, very little data have been reported describing industrial workers' exposures to measured job physical demands using comprehensive and quantitative method, such as the revised NIOSH lifting equation (RNLE). This study pooled physical exposure data for the RNLE commonly collected in three independent LBP prospective studies. In total, over one million subtasks (i.e., lifting/lowering activities) were included in this pooled study. Examination of the pooled dataset revealed an increased data distribution of the physical job demands quantified by the RNLE. Research using the pooled dataset will improve the overall statistical power and help address the weaknesses identified in previous studies.

BACKGROUND

Low back pain (LBP) is a common health problem and a major cause of lost productivity in workplaces (Feuerstein, Berkowitz, Haufler, Lopez, Huang, 2001; Schaafsma, Anema, van der Beek, 2015). Lifting and lowering (LL) activities have traditionally been regarded as risk factor for LBP (Kapellusch et al., 2014).

In the literature, a variety of methods have been used to measure job physical exposures, ranging from qualitative job title search to complex biomechanical models. Among these methods, the revised NIOSH lifting equation (RNLE) may be the most commonly used job assessment tool to quantify biomechanical stressors to worker's low back from manually lifting and lowering weights in workplaces (Garg et al., 2014a; Garg et al., 2014b). Based on job task variables, the RNLE combines seven individual physical risk factors of LBP into a single risk metric called lifting index (LI) (Waters, Putz-Anderson, Garg, Fine, 1993).

While many epidemiological studies have reported positive associations between RNLE outcomes and risk of LBP, conflicting results have been found across the body of evidence. Negative findings in individual studies may be due to lack of power to assess potential relationships between job physical exposures and LBP. Insufficient power may result from relatively small sample sizes, modest number of jobs evaluated, and low variance in measured job physical exposures. In addition, scattered literature has described the distribution spectra of job physical exposures, especially the RNLE biomechanical stressors and the associated RNLE multipliers measured from a large industrial cohort. The objective of this study was to pool job physical exposure data from multiple independent LBP studies (i.e., LBP research consortium), describe distributions of the RNLE task variables and multipliers across several study sites, and provide an overview of job physical exposures among this US working population.

METHODS

Population

This LBP consortium included job physical exposure data collected by 5 members (the National Institute for Occupational Safety and Health (NIOSH), the Ohio State University, the University of Wisconsin-Milwaukee, Texas A&M University and the University of Utah) in 3 independent LBP prospective cohort studies (#1: NIOSH; #2: OSU; #3: UWM, Texas A&M and UT were run as one study). This pooled study and the original cohort studies were approved by their respective Institutional Review Boards (IRBs). Methods for the original cohort studies have been reported elsewhere (Garg et al., 2013; Lu, Waters, Krieg, Werren, 2014; Marras, Lavender, Ferguson, Splittstoesser, Yang, 2010).

Workers were enrolled from a wide variety of manufacturing and service industries, such as appliance manufacturing, automobile part manufacturing, order-picking warehouse and grocery distribution centers, across 82 worksites in 6 US states (IL, MI, OH, TX, UT, WI).

RNLE Task Variables and Multipliers

All 3 original cohort studies used the RNLE to quantify job physical exposures. The RNLE task variables and whole body posture information were collected on site by trained ergonomists. During the data pooling process, the consortium recognized small methodological differences where Study #2 referred horizontal distance to the L5/S1 disc (H_disc) rather than the mid point of both ankles (H_ankle). In order to develop more comparable physical exposure datasets from all three studies, H_ankle data recorded from the Study #1 and #3 cohorts were converted and expressed as H_disc. To accomplish this, workers' original posture information was used to rebuild the corresponding subtasks using Michigan 3D Static Strength Prediction Program (3DSSPP, Ann Arbor, MI). For the purpose of this study, for a given subtask, if the difference between H_ankle and H_disc was greater than 10 inches, this subtask was excluded from further analyses. The consortium planned to address the potential influence of the conversion process in a follow-up paper.

Physical exposure data were pooled at the subtask level (by definition, a worker performed one job in a workday, which may consist one or more tasks; a task may have one or more subtasks; a subtasks was defined as an LL activity with a unique combination of biomechanical stressors). Subtask level was selected because 1) it was available in all three studies, 2) it specified a unique LL activity, and 3) it provided unprocessed information regarding an individual worker's exposures to job physical demands.

As a summarization of the first step in the data pooling process, this study focused on the geometry of the LL activity using a subset of RNLE task variables, including 1) load weight (W), 2) horizontal location from the L5/S1 disc (H), 3) vertical location (V), 4) vertical travel distance (D), 5) asymmetry angle (A) at the origin and destination of an LL activity.. Then, respective RNLE multipliers were calculated according to the NIOSH manual (Waters, et.al., 1993), including horizontal multiplier (HM), vertical multiplier (VM), distance multiplier (DM), and asymmetric multiplier (AM). Frequency independent lifting index (FILI) was also calculated according to the NIOSH manual (Waters et.al., 1993).

Statistical Analyses

Tests comparing the mean/median values of the continuous RNLE task variables were performed using analysis of variance (ANOVA) or Mann-Whitney-Wilcoxon test, depending on the distributions of data. Tukey's honest significant difference (HSD) tests were used for post hoc comparisons between the studies. Box-and-whisker plots were plotted for the RNLE multipliers. Correlation analyses were also performed between the RNLE variables (i.e. stressors, multipliers, and FILIs). The Pearson product-moment correlation coefficients (r) were used to quantify the degree of correlation between two RNLE task variables. All statistical analyses were performed using the R statistical software (v.3.4.3, The R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was at p value < 0.05.

RESULTS

A total of 1,239,127 LL activities (i.e., subtasks) performed by 1,645 workers were observed and measured across the three cohort studies. There were 98 subtasks involving no load weight (i.e., W=0). They were determined irrelevant to this study and excluded from the subsequent analyses. Out of the remaining subtasks, 5,820 subtasks were excluded due to the large differences (>10 inches) between H_disc and H_ankle. Additionally, 6,340 subtasks were determined as one-handed and also excluded from the final analyses. As a result, 1,226,869 (99%) subtasks were included in the pooling process.

Significance differences ($p<0.05$) existed among the studies for all comparisons of RNLE task variables (Table 1). Study #3 had the highest load weight (W), vertical travel distance (D), and horizontal locations from the L5/S1 disc (H_disc) at origin and destination. Study #1 had the highest vertical locations (V) and asymmetry angles (A) at origin and destination.

Significant differences ($p<0.05$) were also found among the studies for all comparisons of RNLE multipliers. Distributions of pooled RNLE multipliers data are plotted from Figure 1 to Figure 4. In terms of horizontal multiplier (HM), study #1 had the highest value while study #3 had the lowest. However, the actual differences among the studies were very small (≈0.05, Figure 1). Pooling the data also did not considerably increase the range of the HM compared to the range of values from single cohort studies.

Variables	Study #1	Study #2	Study #3
Stressors			
W (kg)	5.0±3.7 [0.7 - 39.0]	7.2±4.2 [1.5 - 40.8]	11.0±6.1 [0.2 - 54.4]
D (cm)	19.3±17.3 [0.0 - 152.4]	27.7±25.9 [0.0 - 157.5]	35.1±30.7 [0.0 - 163.1]
At Origin			
H (cm)	36.1±10.2 [5.3 - 85.6]	42.9±13.5 [2.0 - 110.0]	44.7±12.2 [0.5 - 99.3]
V (cm)	109.5±19.1 [29.5 - 192.3]	89.2±31.0 [5.1 - 209.8]	90.4±31.0 [0.0 - 206.0]
A (degree)	27.1±22.0 [0.1 - 121.8]	13.2±11.4 [0.0 - 90.0]	4.9±8.9 [0.0 - 78.5]
At Destination			
H (cm)	39.6±13.5 [1.8 - 36.7]	41.1±12.4 [2.0 - 106.2]	46.7±11.9 [9.1 - 99.3]
V (cm)	111.8±21.8 [22.4 - 188.7]	103.9±30.5 [13.7 - 204.5]	98.3±35.6 [7.1 - 197.4]
A (degree)	25.9±20.3 [0.1 - 104.5]	12.8±10.8 [0.0 - 89.8]	4.1±8.3 [0.0 - 75.4]
Multipliers			
HM	0.6±0.2 [0.3 - 1.0]	0.6±0.2 [0.2 - 1.0]	0.5±0.1 [0.3 - 1.0]
VM	0.9±0.1 [0.7 - 1.0]	0.9±0.1 [0.6 - 1.0]	0.9±0.1 [0.6 - 1.0]
DM	1.0±0.0 [0.9 - 1.0]	1.0±0.1 [0.9 - 1.0]	1.0±0.1 [0.9 - 1.0]
AM	0.9±0.1 [0.6 - 1.0]	0.7±0.1 [0.4 - 1.0]	1.0±0.0 [0.8 - 1.0]
FILI	0.5±0.4 [0.1 - 6.7]	0.7±0.5 [0.1 - 4.3]	1.2±0.8 [0.0 - 7.6]

Table 1. Summary of comparisons among the cohort studies (Mean±SD [Range])

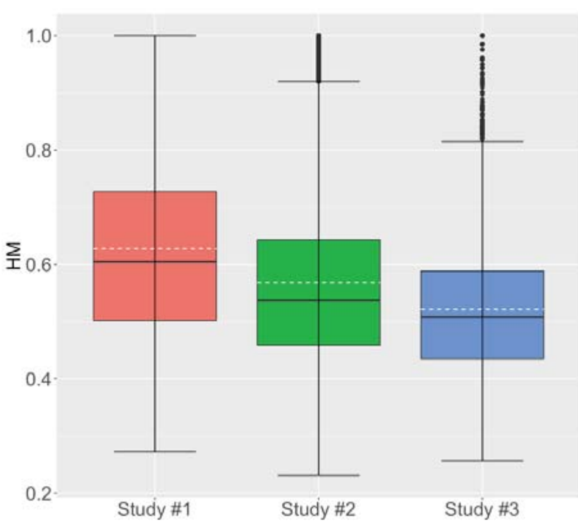

Figure 1. Box-and-whisker plots for the distributions of HM (white dotted lines represent mean values)

Significant ($p<0.05$) but negligible differences were also found in comparisons of VM (≤ 0.01, Figure 2) and DM (≤0.03, Figure 3). Similarly, pooling the data did not considerably increase the ranges of the VM and DM compared to the range of values from single cohort studies.

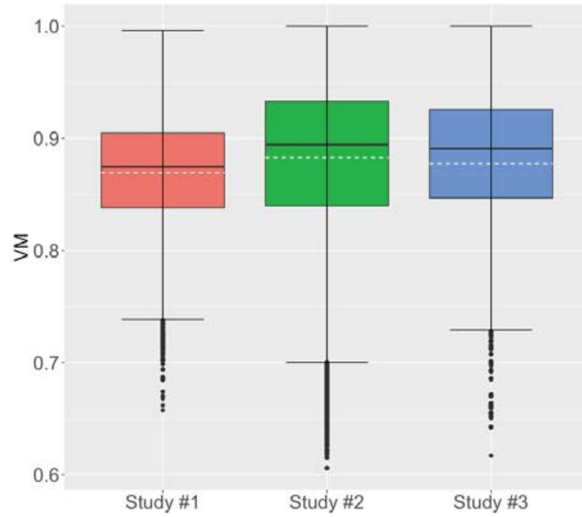

Figure 2. Box-and-whisker plots for the distributions of VM (white dotted lines represent mean values)

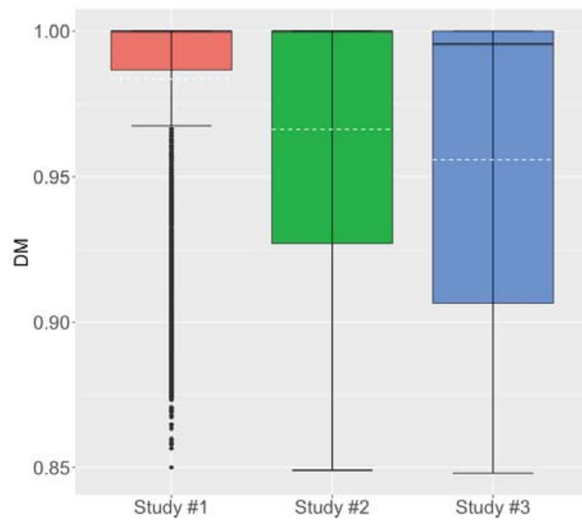

Figure 3. Box-and-whisker plots for the distributions of DM (white dotted lines represent mean values)

On the other hand, significant differences ($p<0.05$) were found in comparisons of AM (Figure 4). The greater differences (≈0.3) indicated that pooling the data increased the range of the AM compared to the range of values from single cohort studies.

Distributions of subtask level FILIs are presented in Figure 5. Significant differences ($p<0.05$) were found in comparisons of FILIs across the studies. Pooling the data increased the range of the FILI compared to the range of values from single cohort studies. For example, Study #3 added more high-demanding LL activities (i.e., higher LIs) to the consortium, while Study #1 added more low-demanding subtasks (i.e., lower LIs).

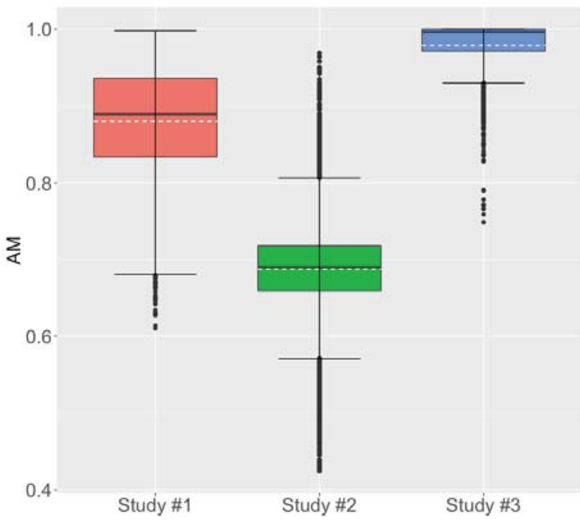

Figure 4. Box-and-whisker plots for the distributions of AM (white dotted lines represent mean values)

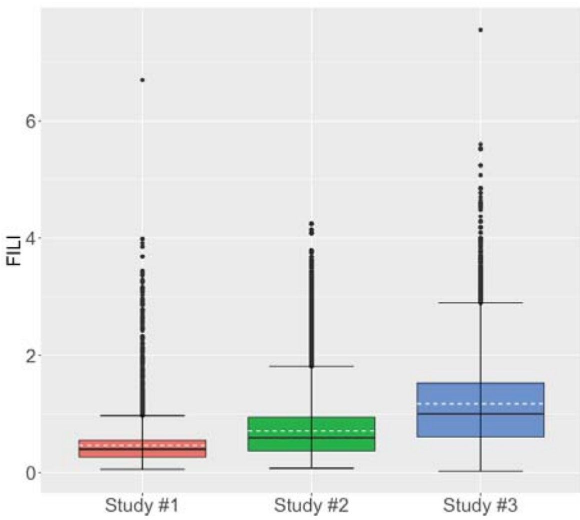

Figure 5. Box-and-whisker plots for the distributions of FILI (white dotted lines represent mean values)

Table 2 shows the correlation coefficients (r) between the RNLE task variables collected at the subtask level. Using the descriptive categories according to the correlation coefficients (1-perfectly correlated, 0.81-0.99-almost perfectly correlated, 0.61-0.80-substantially correlated, 0.41-0.60-modestly correlated, 0.21-0.40-fairly correlated, 0.00-0.20-slightly correlated, and 0.00-not correlated), the results suggested slight or no correlation among most RNLE task variables (≤0.20). Fair correlations were found between vertical locations at origin and destination (r=0.25), between horizontal locations at origin and destination (r=0.23), between vertical travel distance and vertical location at origin (r=-0.24) and at destination (r=0.31), between horizontal locations and the corresponding asymmetry angles (r=-0.24 at origin and r=-0.25 at destination, respectively), and between horizontal location and vertical location at destination (r=-0.29).

	W	D	Ho	Vo	Ao	Hd	Vd	Ad
W	1.00	0.02	0.09	-0.11	-0.03	0.12	-0.20	-0.06
D		1.00	0.03	-0.24	0.01	0.00	0.31	0.03
Ho			1.00	-0.14	-0.24	0.23	-0.05	-0.06
Vo				1.00	0.04	-0.04	0.25	0.03
Ao					1.00	-0.08	0.01	0.12
Hd						1.00	-0.29	-0.25
Vd							1.00	0.17

Table 2. Correlation coefficients between RNLE task variables

DISCUSSION

This study has shown that within a consortium of industrial cohorts, workers' physical exposures varied significantly from study to study. The data pooling process has substantially increased the spectra of physical exposures across the individual independent studies, suggesting increased generalizability of a physical exposure and LBP response relationship using the pooled dataset. The current findings are in accordance with previous surveys of manual material handling jobs, in which large variations in job physical exposures were also observed and reported (Ciriello and Snook, 1999; Ciriello, Snook, Hashemi, and Cotnam 1999; Dempsey, 2003).

A majority of these subtasks (97%) were collected in Study #2 across 21 distribution centers in which workers handled a variety of products, including groceries/food products, automotive parts, apparel, hardware, furniture, and other general merchandise. Workers assessed in Study #1 and #3 were primarily in manufacturing/fabrication industry.

In the literature, inconsistent exposure-response relationships between job physical demands and work-related musculoskeletal disorders (MSDs) have been attributed to lack of variance within observations and insufficient statistical power (Stock, 1991). Some survival effects in the range of LI > 3.0 were speculated in previous studies (Waters, Lu, Piacitelli, Werren, Deddens, 2011; Garg et al., 2014a; and Lu et al., 2014). With the increased sample size in the pooled data analysis, this consortium may be able to shed some light on the potential survival effects. Geographical, financial and resource constraints limit individual studies to certain types of industries and result in narrow job physical exposure data distribution. The main strengths of this work-related LBP consortium are the large sample of diverse job types and greater spectra of physical exposure variables, which will improve the overall statistical power. These features should help address the weaknesses identified in previous studies. It may also be helpful to improve our understandings of the relationship between human anthropometric characteristics and the risk of low back pain (Rubin, 2007; Sesek et al., 2014), since some studies have reported associations between body anthropometry and the geometry of lumbar spine and paraspinal muscles (Gungor et al., 2015a; Gungor et al., 2015b; Tang et al., 2016).

CONCLUSIONS

This large pooled dataset of the measured job physical factors (i.e., RNLE task variables) has greater exposure variance with likely increased statistical power to investigate the relationship between the job physical risk factors and work-related LBP. Strengths of this pooled study include the prospective study design, large numbers of workers, large variance in job demands, and comprehensive and quantitative physical exposure assessment methods. Pooling physical exposure data from different independent studies should increase the potential to detect associations and interactions between the incidence of LBP and RNLE variables.

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