CAN OBSERVATIONS AND INTERVIEWS BE USED TO ASSESS 90th PERCENTILE AND CUMULATIVE BACK MUSCLE LOADS IN HEAVY INDUSTRY?

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The purpose of this study was to develop prediction models for 90th percentile and cumulative low-back EMG activity, to enable lower-cost, more efficient exposure assessment for large-scale epidemiological studies. Mixed-effect models were developed to predict EMG from observed and self-reported postural, MMH, personal and job variables from 139 worker-days. More EMG variability was accounted for by models of 90th percentile compared to cumulative load (42.9% vs. 31% for models based on observed variables; 36 vs. 21% for models based on self-reported variables). Observed or self-reported variables can be used to estimate EMG exposure; their lower cost allows for a larger sample size and more repeated measurements, and provide an efficient choice for exposure assessment of EMG activity.

Keywords: Back Injury, Exposure Assessment, Epidemiology

LES OBSERVATIONS ET LES ENTREVUES PEUVENT-ELLES SERVIR À ÉVALUER LE 90^{E} RANG CENTILE ET LES CHARGES CUMULATIVES SUR LES MUSCLES DORSAUX DANS LE SECTEUR DE L'INDUSTRIE LOURDE?

La présente étude avait pour but de mettre au point des modèles de prédiction pour le 90^{e} rang centile et l'activité EMG cumulative sur le bas du dos ainsi que de favoriser des évaluations de l'exposition plus économiques et efficaces lors d'études épidémiologiques à grande échelle. Des modèles d'effets contrastés ont été développés afin de prédire l'activité EMG à partir de postures, de tâches de manutention et de facteurs variables personnels et de l'emploi observés chez les travailleurs ou signalés par ceux-ci au cours de 139 jours-travailleurs. Il a été possible de justifier une plus grande variabilité de l'activité EMG pour les modèles du 90^{e} rang centile comparativement à la charge cumulative (42,9 % vs 31 % pour les modèles basés sur les variables observées; 36 % vs 21 % pour les modèles basés sur les variables signalés par les travailleurs). Les variables observées ou signalées peuvent servir à calculer l'exposition à l'activité EMG; leur coût économique permet d'avoir une taille d'échantillon plus importante et de prendre des mesures répétées, et elles offrent un choix efficace pour évaluer l'exposition de l'activité EMG.

Mots clés : blessure au dos, évaluation de l'exposition, épidémiologie

INTRODUCTION

In order to investigate the causes of injury, identify opportunities for improvement, and evaluate interventions, epidemiological studies of ergonomic risk factors require exposure assessment techniques which are inexpensive and simple enough to use on large numbers of participants. Direct-measurement methods, such as electromyography (EMG), allow for accurate assessments of low-back injury risk factors (Burdorf and van der Beek, 1999), but are expensive and difficult to use in field settings (Trask C et al. 2007). Some less expensive methods such as observation or self-report offer the opportunity to capture a larger sample than studies using direct measurement methods. The purpose of this study was to develop EMG exposure prediction models for 90th percentile and cumulative EMG activity. Based on existing 'determinants of exposure' modeling methods (Burstyn and Teschke, 1999) two models were developed, one to identify determinants of exposure that could be collected via observation, and another to identify determinants that were self-reported during worker interviews. The larger goal was to help researchers efficiently and effectively measure ergonomic exposures for work-related back injury studies.

METHODS

Data Collection

EMG and observation data were collected for the full shift excluding breaks (range: 5.5 to 10.3 hours). This analysis was undertaken as part of a larger study of the risk factors for low back injury in heavy industry. Eighty-four workers from transportation, warehousing, forestry, construction, and wood and paper product industries participated; 55 (66%) were measured on two separate days resulting in 139 measurement days. Electromyography (EMG) measurements were made with portable data loggers (ME3000P4/ME3000P8, Mega Electronics, Finland) over the erector spinae muscles at the L4/L5 level. The reference contraction involved a static 45^{o} forward trunk flexion while holding an 11.5 kg weight. The reference contraction was performed twice for 5 seconds at the beginning of each shift. EMG data collected during the shift was expressed as a percentage reference contraction (%RC).

Observations were recorded once every minute by trained observers using the BackEST observation tool (Village J et al. 2007). The minute-by-minute records were summed over the whole day (200-500 records) to develop cumulative daily time totals (for cumulative models) and proportions of time (for 90th percentile models) exposed to each work activity/exposure. A post-shift interview was conducted with each worker to assess self-reported exposures during that day's shift. Using diagrams of activities and postures as a visual cue, workers were asked to identify the presence and duration of time spent in a posture or performing an activity; this was converted to a percentage of total work time exposed. A copy of the final survey instrument can be obtained from the study website at www.cher.ubc.ca/backstudy.htm Both observations and interviews included data on work tasks and activities , items in hand, items worn (such as a tool belt); body postures (such as standing, walking, kneeling); trunk postures (twisting, lateral flexion, and categories of trunk flexion); presence of trunk supports; and manual materials handling ((MMH), type of load, horizontal distance, weight/force estimate).

Statistical analysis

Mixed-effect models to predict 90th percentile and cumulative EMG activity outcome measures (%RC) were developed using backwards stepwise multiple linear regression in SAS 9.1 (SAS Institute Inc., Cary, NC USA). Separate models were constructed for observation variables and self-reported variables as determinants of exposure for the EMG activity measures. Independent variables that were significantly related to the dependent variable in univariate analysis (but were not correlated with other independent variables) were offered to a mixed model with 'subject' as a random effect term. Variables were combined and offered in 'conceptual groups', i.e., all postural variables were offered in a group, followed by manual materials handling variables, demographic variables, and then job factors. The proportion of variance explained by each model was estimated using the R^2 value from simple linear regression of predicted versus measured exposure levels.

RESULTS

EMG exposures in heavy industry

Mean, 90th percentile, and cumulative muscle activities for each industry are shown in Table I. The two exposure metrics gave similar rankings across the five industries, except that cumulative exposure was substantially higher in forestry than in construction, indicating the impact of a longer mean duration of exposure (7.4 hours vs. 5.8 hours, respectively).

Table I: EMG exposure metrics (in % of reference contraction) for five heavy industries

Industry group	**Mean %RC (sd)**	**90th %ile of %RC**	**Cumulative %RC-sec**
Construction (n=25 worker days)	49.1 (14.1)	103.4	993,943
Forestry (n=30 worker days)	41.9 (23.8)	84.2	1,084,283
Transportation (n=33 worker days)	28.7 (12.2)	67.5	681,270
Warehousing (n=23 worker days)	39.8 (21.5)	84.9	982,756
Wood products (n=27 worker days)	37.8 (24.1)	80.0	895,931
All industries (n=138 worker days)	38.9 (20.5)	83.1	918,320

Final observation models

The final models for the observed and self-reported variables for each EMG outcome measure are found in Table II. Cumulative EMG was significantly increased by: total time with trunk bent 10-20^o or 45-60^o, and handling 10-20 kg loads, but was decreased by sitting. Estimated 90th percentile EMG was significantly increased by percent time standing, trunk bent between 20-45 or more than 60^o, and handling a load with two hands or at an extended distance. Both 90th percentile and cumulative EMG were increased by handling 4.5-10 kg loads. The model based on observation variables explained 42.9% of the variability in 90th percentile EMG activity and 30.7% of the variability in cumulative EMG.

Final self-report models

The models based on self-reports predicted less of the variability in EMG exposure than models based on observations, explaining 36.0% for 90th percentile and 21.0% for cumulative EMG. Cumulative EMG was significantly increased by total manual materials handling time and walking with trunk twisted. Both 90th percentile and cumulative EMG were significantly decreased by sitting with trunk twisted but increased by handling loads at extended distance. Predicted 90th percentile EMG was decreased by sitting, increased by handling 4.5-10 kg loads. Industry was also a significant predictor of 90th percentile EMG, with construction and forestry showing the highest increase compared to transportation.

DISCUSSION

With the exception of 'Industry', all variables included in the models related to posture or manual materials handling. Many of the same variables were significant for self-report and observation models, such as sitting, handling 4.5-10 and 10-20 kg loads, and handling extended loads. This suggests that these variables can be assessed either by observation or by self-report for the prediction of EMG measures. The observed percent time in seated posture decreased the predicted 90th percentile muscle activity, presumably because it requires the least amount of muscle activity, and takes time away from more dynamic activities. Walking with the trunk twisted was a significant predictor of cumulative muscle activity although this was not a common work exposure (only 30% of worker-days involved any walking while twisted). Although gross body postures (i.e. sitting, walking) were significant in the final models, gradations of trunk flexion did not remain in the final self-reported models. This may reflect workers' inability to categorize working postures more specifically by cut-points. Since self-reported variables are related to a worker's *perception* of his or her exposure, model significance may be driven by exposures which are recalled the most readily and reliably (especially those that are the most physically demanding).

Table II. Observed and self-reported variables associated with 90th percentile, and cumulative EMG exposure metrics in final multiple regression equations.

Variable	**90th percentile %RC†**		**Cumulative %RC-sec ‡**	
Observation	**β (slope)**	***p***	**β (slope)**	***p***
Intercept (average for all subjects)	43.8	-	595895	<.0001
Standing	0.166	0.316	-	-
Sitting	-	-	-3118	0.041
Trunk position 10-20^o	-	-	7295	0.0004
Trunk position 20-45^o	0.970	0.01		
Trunk position 45-60^o	-	-	17182	0.0004
Trunk position >60^o	1.23	0.0014	-	-
Handling load at extended horizontal distance	0.660	0.229	-	-
4.5-10kg load in hands	0.987	0.009	22581	<.0001
10-20 kg load in hands	-	-	7534	0.114
Handling loads with two hands	0.299	0.289	-	-
Self-report				
Intercept (average for all subjects)	78.7	<.0001	627029	<.0001
Sitting	-0.376	0.0009	-	-
Walking with trunk twisted	-	-	22566	0.0012
Sitting and twisting	-0.498	0.0403	-7157	0.0268
Manual materials handling	-	-	1333	0.159
4.5-10 kg load in hands	0.165	0.3367	-	-
Handling load at extended horizontal distance	0.710	0.004	5215	0.124
Construction industry	24.339	0.0131	-	-
Forestry industry	20.0178	0.0323	-	-
Wood product industry	4.1501	0.6498	-	-
Warehousing industry	13.8399	0.1581	-	-
Transportation industry	*	*	-	-

†all variables expressed as % of shift ‡ all variables expressed as total time * reference category

Handling any load increases back muscle loading (Waters et al. 1993), some MMH variables may be predictive because they were more common in the present study. 4.5-10 kg loads accounted for 3.7% of observed time compared to 2.1% for 10-20 kg loads and less than 1% for heavier loads. Observed and self-reported handling loads at extended distances was a logical predictor, since this increases the moment arm of loads in the hands and requires more torque to be generated by the back extensor muscles (Waters et al. 1993). While it is clear that the horizontal distance of loads from the body is important to muscle loads, it is not clear why this result wasn't significant in the observation model for cumulative EMG . Observation-based estimates were recorded by trained, impartial observers, but work that involved movements throughout the worksite (i.e. maintenance or forklift driving) proved challenging to record and resulted in some missing data within the work shift which may explain a differential finding for the cumulative exposure model. EMG measurement also has limitations; worksite conditions can include extreme heat, cold, wet, dust, and vibration, as well as artifacts caused by contact from tight spaces, seat backs or safety equipment; sweating caused by extended exertion; or tension on the electrode cables (Trask C et al. 2007).

Is explaining 20-40% of the variability in EMG activity is adequate for epidemiological study? In occupational hygiene, 'determinants of exposure' models of airborne exposure typically explain 30-60% of the variance in a directly-measured exposure (Burstyn and Teschke, 1999) and are used successfully in subsequent studies investigating the relationship between exposure and health outcomes. Previous studies of back disorders have found relationships with individual self-reported and observed work variables (Burdorf and Sorock, 1997). The models developed here combine multiple observed or self-reported variables to predict a measured risk factor: EMG. We expect that this should enrich epidemiological analyses, by combining the benefits of direct and indirect measures for exposure estimation.

Conclusion

Although the determinants of exposure model for 90th percentile EMG activity was stronger than the model for cumulative muscle activity, both can be estimated using observed and self-reported determinants of exposure. The utility of such EMG activity models depends on the variability of exposures within the target population, the hypothesis of the study, and the size of the sample. Models using self-report predicted slightly less of the variance than models using observed variables. However, given that self-report is less costly and would allow for a much larger sample size and more repeated measurements, self-report may be an efficient choice for exposure assessment of cumulative muscle exposures.

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