

Assessment Strategies for Ergonomic Risk Factors in Automotive Manufacturing

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Introduction

Most methods for evaluating occupational risk factors of musculoskeletal disorders in practice and in research assume that the work is cyclical, having little variability over time, and therefore exposures over short periods are thought to be indicative of those over long periods. This is often not a valid assumption as the physical demands of even highly routine assembly jobs may change, for example, with delays in the industrial process and changes in individual work methods. Poorly designed sampling strategies can lead to errors in the assessment of exposure required in ergonomics research and practice.

Objectives

The objective of this study was to evaluate the sources of ergonomic exposure variability and develop appropriate job assessment strategies for production and skilled trades work in automotive manufacturing. It was hypothesized that the within occupation sources of exposure variability would vary considerably across occupations and therefore different strategies would be needed to evaluate exposures reliably for each occupation.

Methods

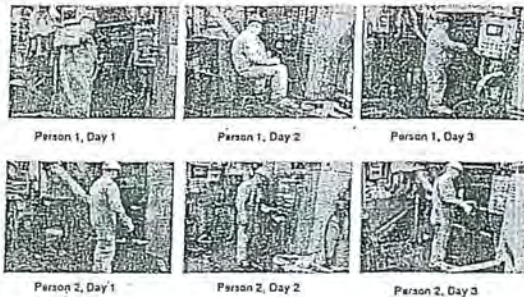
Multiple ergonomic exposures were evaluated repeatedly within and across multiple days for groups of workers in 3 production jobs and 1 skilled-trades occupation (millwrights).

For each of the production jobs studied, 10-15 work cycles were video recorded for each of 3 operators on 1 to 3 occasions per day spread across the shift on 4 to 5 different days, covering a work period of 8 weeks. The videos were copied into a personal computer using video editing software, and Multimedia Video Task Analysis (MVTA) software (University of Wisconsin, Madison) was used to estimate for each video clip the time operators spent in various awkward body postures, handled loads, and performed specific work tasks. Employees each rated the required muscular exertion for specific muscle groups during each of the tasks on a Borg CR-10 scale. Based on the task duration within each cycle and the ratings of muscular exertion, an estimation of the muscular fatigue experienced by the operator was made by applying a quantitative fatigue accumulation prediction model. Approximately 150 video recordings were analyzed.

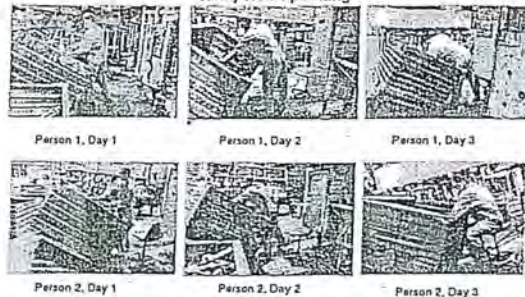
For the millwrights work, discrete-interval observations using a work-sampling based method known as PATH were made on small groups of workers simultaneously on multiple days throughout the course of the day. Exposure frequencies were calculated for ergonomic exposure variables that included any non-neutral trunk posture, trunk flexion >20°, lateral bending or torsion >20°, arms at or above shoulder height, kneeling, moderate or heavy load handling, MMH activities, and tool use. Approximately 9,000 observations representing 50 person-days of observation were made.

Analysis of variance (ANOVA) was used to evaluate the exposure variability across workers and across days for the production jobs and the millwrights work. A statistical re-sampling technique, bootstrapping, was used to evaluate the reliability of different

Forge Press Operation



Relay Rod Upsetting



Differences in the work methods, experience levels, strength and body sizes of individuals are some of the potential contributors to inter-worker exposure variability within job. Differences in production demands, changes in machine reliability over time and availability of raw materials contribute to the inter-day exposure variability.

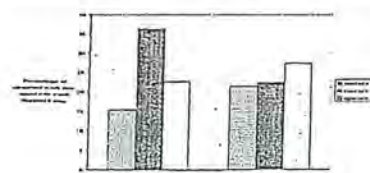
Sampling strategies should account for exposure variability across workers and days for a reliable estimate of average exposure and to capture peak exposure levels for production and skilled trades work.

Job	# of Recordings	Range of Average Cycle Times (sec)
Extruding	56	5-21
Relay Rod Upsetting	54	13-35
Forge Press Operation	48	3-6

Average cycle time varied considerably for two of the three production jobs.

Job	Percentage of Total Variance in Exposure to Trunk Flexion >20°			Percentage of Total Variance in Estimated Fatigue Accumulation for the Right Shoulder		
	Across Workers	Across Days (within shift)	Error	Across Workers	Across Days	Error (within day)
Extruding	0.3	27.7	77.0	72.8	0	27.2
Relay Rod Upsetting	32.4	33.9	33.7	86.1	0	3.9
Forge Press Operation	No exposure variability.			56.0	3.6	0.4

Percentage of total variance attributed to workers and days for exposure to trunk flexion >20° and estimated fatigue accumulation rate of the right shoulder for the three production jobs.



Percentage of time workers spent in trunk flexion >20° for three production jobs.

Results

For 2 of the 3 production jobs, average cycle times varied considerably across observation periods. The importance of the sources of exposure variability differed greatly across occupation and across exposure variables within occupation. For example, in one production job, time spent in trunk flexion >20° was found to be significantly different over days ($F=19.5$, $d.o.f. = 7, 27$, $p<0.01$), explaining 34% of the total variability in the data, with significant between operator differences ($F=5.2$, $2, d.o.f. = 7, 27$, $p<0.01$) constituting 32% of the total exposure variability. For a second production job, the variability in trunk flexion across days composed about 23% of the total, with less than 1% attributed to differences across workers. For the third production occupation, trunk flexion >20° was not observed in any of the recordings, demonstrating no between or within worker variability. The fatigue accumulation estimated for production jobs demonstrated higher variability across workers than the postural exposure variables, suggesting a greater need to include multiple workers within job for measures that require psychophysical ratings of muscular exertion.

Generally, the variability in exposures across workers and days was larger for millwrights work than for the production jobs.

Bootstrapping of the exposure data collected for production and millwrights work indicated that the most efficient strategies (reliable with the least person-time of assessment) ranged from assessing exposures for 1 to 2 individuals once on 1 to 2 different days to assessing groups of workers multiple times per day for periods exceeding 1 week. These results suggest that the assessment strategy required for a reliable estimate of exposure may differ across occupations and exposure variables.

Conclusions

This research quantifies the sources of variance for ergonomic risk factors in typical automotive manufacturing jobs. Based on the findings, it appears that even for some cyclic jobs, there may sometimes be significant exposure variability across workers and over time. Additionally, the categories of exposure and types of exposure data recorded will affect the variability of exposure across workers and over time, ultimately affecting the required sampling strategy.

Current strategies of exposure assessment based on a single observation period may not result in a judicious estimate of the exposures associated with a job. Repeated measurements of exposure over time and/or across workers may be needed to obtain a reliable estimate of exposure even for cyclic repetitive self-paced jobs such as those studied here. Such measurement strategies are clearly needed to provide reliable estimates of many exposures in millwrights skilled trades work.

Acknowledgements

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