EXPOSURE ASSESSMENT STRATEGIES TO EVALUATE TRUNK POSTURES DURING HEAVY MANUFACTURING WORK

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The objective of this study was to identify the sources of temporal variation in trunk postures for self-paced cyclic jobs in a forging plant in order to inform job analysis sampling strategies intended to reliably estimate average long-term exposures to these postures. Repeated video recordings were made on three different individuals in each of the three different jobs over a period of fourteen days. Multimedia Video Task Analysis™ was used to evaluate the percent of time individuals spent in mild trunk flexion (i.e., exceeding 20 degrees) for each of the observation periods. Analysis of variance was used to quantify the within and between worker sources of exposure variability within shifts and across days. The within and between worker components of variability in trunk flexion was very different across the occupations. While in one occupation, no exposure to mild trunk flexion was found, the within- and between-worker components of variance were quite different for the other two occupations. This suggests that different sampling strategies may be needed to reliably estimate the average percentage of time individuals spend working in flexed trunk postures even for cyclic production jobs.

INTRODUCTION

Inadequacies in exposure assessment contribute to the lack of understanding about relationships between work related exposures and musculoskeletal disorders MSDs (Burdorf and Riel, 1996), as well as hinder the evaluation of ergonomic exposures in practice.

Current assessments of mechanical load by observational and direct methods are usually restricted to a short period for a selected group of subjects, typically covering only few work cycles or short time intervals. The temporal aspects of the action are not frequently assessed (Burdorf and Riel, 1996).

This is primarily due to the labor intensive nature of most ergonomic job analysis methods. However, the reliability of the data obtained may be jeopardized as the physical demands of even cyclic jobs may differ due to, for example, process changes and differences in work methods employed over time. Sampling strategies that minimize the time and effort associated with quantifying exposures reliably are needed.

Most jobs in auto manufacturing are physically demanding, associated with risk factors such as awkward postures of trunk and upper extremities, repetitive upper extremities motion and frequent manual material handling (Lavender et al, 1997, Engstrom and Medbo, 1997). Forging is perhaps one of the most physically demanding industrial processes in this industry. Forging requires heavy manual repetitive material handling, with high production demands, often exceed over 1000 units per shift.

The objective of this study was to characterize trunk posture exposure variability across workers and over time in order to inform job analysis sampling strategies intended to reliably estimate average long-term exposures to these postures for forging and similar types of cyclic but heavy production work.

METHOD

Study site and Occupations

The study site chosen was a forge facility that employed approximately 700 workers. Various forged components required for automobile axles are manufactured at the factory. The production operators in each section were engaged in the operation of the presses and extruders. Many of the production jobs have very short work cycle times (e.g., <20 seconds) and had little task variety. Three production jobs were chosen for study: axle extrusion, relay rod upsetting, and gear forging operators. These jobs were highly repetitive but self paced.

Data collection

For each of the three jobs studied, three operators volunteered to participate. Ten to fifteen continuous work cycles were video recorded for each of the operators on one to three occasions per day on four to five different days over a work period of eight weeks. The repeated measures for each worker were spread across the entire shift.

Data analysis

Data management. A total of 156 videos were copied into a personal computer using video editing software (Studio DV, Pinnacle Inc.). The videos were trimmed in Studio DV to eliminate any obvious interruptions or unusual events. Approximately ten continuous work cycles of each observation period were used for analysis. Multimedia Video Task Analysis™ (MVTA™) software (University of Wisconsin, Madison) was used to estimate the time spent in trunk flexion exceeding 20^0 during the observation period. The software allowed frame-by-frame, slow speed and full speed analysis of video recordings. All were used in the coding of trunk flexion.

Analysis of exposure variance. The data were analyzed in the Statistical Analysis Software (SAS) (SAS Institute, 1992) using the PROC VARCOMP procedure. The nested design used by Burdorf, Verburgh and Elders (1994) was modified for unbalanced data to evaluate the variance in time spent in trunk flexion across workers, as well as the temporal variance across days and within shift. Operator, days and shift, were treated as random effects variables. The percent of total variance attributed among and within workers was calculated from the variance estimates produced by the model.

RESULTS

For relay rod upsetting, 54 video recordings were made on 14 different days over a 3-week period. The operators spent an average of 24.81% time in mild trunk flexion while working. The day to-day variability explained 33.9% of the total variability of mild trunk flexion, and between operator differences explained 32.4% of the total variability. For axle extrusion, there were fifty-six videos recorded over a period of 13 days. The average time workers spent in mild trunk flexion was similar (23.66%) to that of relay rod upsetting, but the components of variability were quite different. The variance across days composed about 22.7% of the total variance, but the between operator variability explained only 0.3% of total variability. Trunk flexion exceeding twenty degrees was not observed in any of the recordings of the gear forging operators, demonstrating no between or within worker variability in trunk flexion within the samples collected for our analysis. (Table 1)

	Percentage of total variance in exposure to Trunk Flexion $>20^0$		
Job	Across workers	Across days	Within shift
Axle extrusion	0.3	22.7	77.0
Relay rod upsetting	32.4	33.9	33.7
Gear forging	No exposure variability		

Table 1. Components of variance for exposure to mild trunk flexion in three cyclic production jobs.

Figure 1 illustrates that the between-worker and between-day variability in exposure to mild trunk flexion for the axle extrusion and relay rod

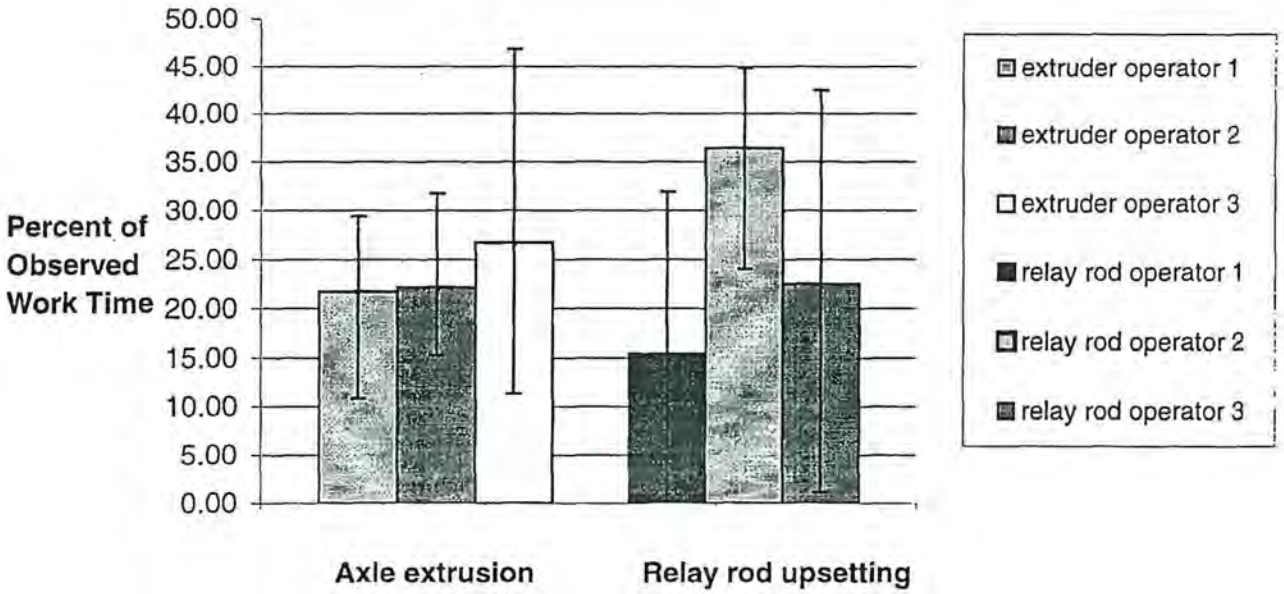

Figure 1. Mean percentage of time workers spent in trunk flexion for two different production jobs. Error bars represent the range of an individual's estimated mean exposure to mild trunk flexion across days.

upsetting jobs. For individuals of both jobs, there was large variability in the percent of time spent in mild trunk flexion measured across shifts. The worker-to-worker variability in exposure to time spent in mild trunk flexion, however, was substantially less in axle extrusion than in relay rod upsetting.

DISCUSSION

The sources of variability of exposure to trunk flexion were different for each of the jobs studied. In order to obtain a reliable estimate of long-term exposure to mild trunk flexion in axle extrusion, it would appear that the measurements taken on multiple days may be needed. Measurements made on both multiple days and for multiple workers would be needed for relay rod upsetting. Since no exposure to mild trunk flexion was found for the samples of forge press operation taken in this study, a very modest ergonomic job analysis effort may have been used to reliably estimate the average time spent in mild trunk flexion for this job.

Multiple observations were made on individuals across shifts and the unexplained variance in the ANOVA models used for this study is thought to largely represent the within-shift variability in exposure to mild trunk flexion. For axle extrusion this represented about 77% of the total variance in the exposure data. This job required unloading a bin full of parts for inspection and as the bin became increasingly empty during the shift, the amount of trunk flexion required when performing the task increased. The ANOVA results suggest that, at least for this job, it might be important to make observations repeatedly across the shift. In a study with dairy workers, Burdorf, Verburgh and Elders (1994) also found within shift variance to be the principal source of variation of back load.

The large between-worker and between-day variability in the percent of time operators spent in trunk flexion while performing upsetting tasks may

be attributed to changes in production requirements and anthropometric differences across operators, among other things. The parts being manufactured changed in size, weight and design across days but remained the same within each day, which may in part explain why the within shift variance of time spent in trunk flexion was a less dominant variance component for this occupation.

The importance of understanding the temporal nature of trunk flexion in less repetitive work has been reported previously (e.g., Van der Beek, et al. 1995; Burdorf and Riel, 1996). The current research quantifies and explains within- and between-worker sources of variance to mild trunk flexion in typical automotive forging jobs, for which exposures were thought to be less variable than those studied previously. Based on the findings, it appears that, even for cyclic jobs, there may sometimes be significant exposure variability across workers and over time.

In summary, the components of variability to working time spent in mild trunk flexion differed across the production jobs studied here, and therefore different exposure assessment strategies would be recommended for each of the jobs. Regardless, quantitative ergonomic job analysis of cyclic production jobs based on one or a few brief observation periods may not provide a reliable estimate of the average percent of time workers spend in mild trunk flexion while working.

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