ASSE Foundation Research

Video-Based Ergonomic Job Analysis

A practitioner's guide

By Victor L. Paquet, Svend Erik Mathiassen and Patrick G. Dempsey

WORK-RELATED MUSCULOSKELETAL disorders (WRMSDs) constitute a major problem in many industries in terms of frequency, cost to employers and impact on the daily lives of those injured. In 2004, WRMSDs accounted for one-third of the 1.3 million injury and illness cases resulting in days away from work (U.S. Bureau of Labor Statistics [BLS], 2005). They also are associated with a substantially higher number of days away from work than other types of injury and illness (BLS, 2005).

WRMSDs are impairments generally characterized by chronic pain and discomfort that may originate in nerves, tendons, tendon sheaths, muscles or blood vessels. These disorders include nerve compression disorders such as cubital tunnel syndrome, carpal tunnel syndrome and thoracic outlet syndrome, as well as inflammations of the tendons and sheaths such as tendonitis and tenosynovitus. However, a large proportion of WRMSDs cannot be associated with damage to specific tissues as identified by, for example, X-ray or ultrasound. Thus, while it is generally agreed that musculoskeletal disorders can be the result of adverse occupational loads, the mechanisms behind their causation and persistence are still largely obscure.

The contributing work-related factors for musculoskeletal disorders are fairly well established. In an analysis of the epidemiologic evidence, Bernard (1997) concludes that substantial evidence exists for an association between exposure to awkward postures and neck/shoulder disorders, for a combination of physical work factors leading to disorders of the elbow, hand/wrist and tendonitis, and for heavy lifting being connected with low back disorders. In an evaluation and discussion of a broader set of studies, members of the National Research Council Steering Committee for the Workshop on Work-Related Musculoskeletal Injuries (1999) concludes that for "those studies involving the highest levels of exposure to biomechanical stressors of the upper extremity, neck and back, and for those with the sharpest contrast among the study groups, the positive relationship between the occurrence of musculoskeletal disorders and the conduct of work is clear."

Therefore, the prevention of musculoskeletal disorders in the workplace often focuses on the evaluation of jobs in terms of the physical job requirements and the development of solutions to reduce the frequency, duration and/or intensity of the biomechanical stressors during work. Ergonomics job analysis (EJA) is performed to systematically:

- identify hazardous work situations that present peak exposures (e.g., extremely heavy lifting);
- determine whether exposure is beyond conventionally recommended levels (e.g., working in kneeling postures for more than 2 hours per 8-hour shift);
- rank order jobs for intervention;
- evaluate whether interventions actually reduce exposures associated with jobs.

Common questions that arise in ergonomics practice include:

- Is greater than 50 lb ever handled during a job?
- Do workers in a job spend more than 25% of the work time in trunk flexion?
- Which tasks or jobs are the most hazardous?

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Abstract: *Ergonomic job analysis is used to systematically identify hazards thought to result in work-related musculoskeletal disorders. Video-based ergonomics job analysis requires the identification of ergonomics problems via systematic analysis of video recordings that are made on a sample of work. While such analysis is commonly used to characterize the biomechanical stressors associated with work, little attention has been given to ensuring that the videos contain a representative sample of the biomechanical stressors that are likely to vary from one person to another, and over time with different work methods or productivity demands. Readers should gain an understanding of how the variability of these stressors can affect the results of the video-based ergonomic job analysis.*

• Did the lifting aid reduce the occurrence of manual materials handling or awkward body postures?

To obtain exposure information on various physical and environmental factors of a job, observational approaches—either in real-time or video—are often used. Such approaches allow many potential risk factors to be evaluated quickly; are generally less costly than instrumentation methods used in research; and may reduce the risk for information bias that appears to be present in self-reporting of ergonomics exposures (Wiktorin, Karlqvst & Winkel, 1993).

However, observational approaches—particularly those that involve video recordings—require substantial cooperation from workers since the accuracy of the observational EJA is dependent on viewing work methods and procedures that are performed as naturally as possible. This level of cooperation is best achieved only after workers have been educated on the health and job performance consequences of poor ergonomics, and the need for observations or video to identify problems with their job requirements.

Observational approaches are also susceptible to inaccuracies inherent to the data collection itself, since observations are typically made on few individuals per job over a short period (e.g., a few work cycles). The assumption when using such methods in EJA is that associated exposure is cyclical with little variability over time; therefore, exposures sampled over short periods and from few workers are thought to be indicative of those over long periods in a larger population. This is an extremely surprising assumption, since WRMSD risk factors are arguably among the most variable factors an SH&E practitioner must evaluate.

While practitioners surveying noise or airborne materials long have recognized that workplace hazards change with time, and they, therefore, use repeated walkthroughs or 8-hour continuous monitoring as a standard practice, this attitude has not transferred to ergonomics. The physical demands of even highly routine assembly jobs may change, for example, with delays in the industrial process, changes in production demands, availability of raw materials or components, and changes in machine reliability over time. Changes in experience levels, strength and body size can have an effect on the inter-individual variability of exposure, and changes in an individual's work methods over time may also contribute (Figure 1).

Given the inherent variability of biomechanical stressors, poorly designed sampling strategies regarding the number of people to observe and observation time can lead to errors in exposure assessment. The design of an appropriate sampling strategy requires knowledge of how exposures vary within and across individual workers over time.

While much work has been dedicated to the evaluation of chemical exposure variability for groups of workers performing a particular job or job task (Rappaport, 1991; Kromhout, Symanski & Rappaport, 1993; Rappaport, Kromhout & Symanski, 1993; Kromhout & Heederik, 1995; Preller, Kromhout, Heederik et al., 1995), what is known about the distribution of biomechanical stressors among workers and over time is limited to data on postural loading of the back or upper extremities, and muscle activation patterns of a few occupations (Burdorf, 1992; Burdorf, Verburgh & Elders, 1994; van der Beek, Kuiper, Dawson et al., 1995; Burdorf, 1995; Burdorf & van Riel, 1996; Mathiassen, Burdorf & van der Beek, 2002; Mathiassen, Moller & Forsmom, 2003; Moller, Mathiassen, Franzon et al., 2004). A few other studies have evaluated the sources of exposure variability in manual handling and offer strategies for exposure assessment in this case (Paquet, Punnett & Buchholz, 1999; van der Beek, Hoozemans, Frings-dresen et al., 1999; Hoozemans, Burdorf, van der Beek et al., 2001). However, the variability of other biomechanical stressors has not been evaluated as extensively, and the sampling strategies that have been recommended previously may have limited generalizability beyond the occupations and job analysis methods used in those studies.

A Survey of Video-Based EJA Practice

One popular observational job analysis approach involves the identification or evaluation of ergonomics risk factors from video recordings. The advantage of this approach over observational assessments made in real time is that videos can be replayed, or played in slow-motion or freeze-frame for a more careful assessment of exposures. This may reduce the risk of misclassifying exposures. On the other hand, video-based observations are generally more time consuming than other observational approaches.

To obtain a preliminary impression of how video-based EJA is practiced in industry, small surveys were conducted among loss prevention representatives from a large insurer of workers' compensation (n = 8), practitioners who attended an ergonomics conference (n = 9), and members of ASSE's Western New York Chapter (n = 5). While the sample size was too small for valid comparisons in responses between the three groups of professions, general trends of the complete sample (N = 22) suggested the following:

• Video-based EJA is a frequently used method of EJA.

• Video-based EJA is often used to identify problems, quantify exposures and present findings.

• Video-based EJA rarely involves more than three workers.

• Video recordings for a job usually involve less than 10 work cycles and the total duration is less than 5 minutes.

Although video-based EJA is an important tool for the safety and ergonomics practitioner, the survey results indicate that sampling approaches used in these types of analyses are limited in terms of number of workers, sampling length and number of sampling occasions.

Objectives

The purpose of this article is to provide the safety and ergonomics practitioner with guidelines that will allow informed decisions about what sampling strategy to use when performing video-based EJA. The analyses are designed to help the practitioner develop the appropriate strategy for:

1) assessing mean exposure level for a task in hazard surveillance or for evaluating the effect of an intervention on average exposure;

2) determining whether an exposure crosses a threshold limit indicating that intervention may be necessary;

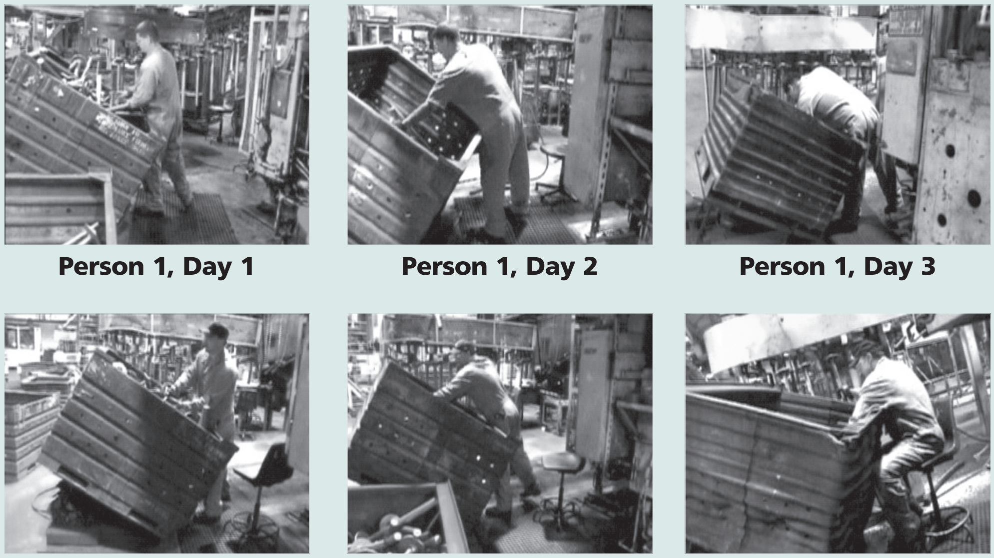
3) determining whether a "peak exposure" exists for a task.

EJA findings from repetitive self-paced manufacturing jobs are used as a case study to demonstrate the degree of variability that can be expected in these types of jobs and how use of multiple videos taken across multiple workers can improve the reliability of the EJA in some cases.

Figure 1

Video Sampling

The work methods used, postures and environment may change between people and over time for the same job—in this case, axle inspection and loading. The sampling approach used may have an important effect on the quality of the exposure information that results.



Person 1, Day 1 **Person 1, Day 2** **Person 1, Day 3**

Person 2, Day 1 **Person 2, Day 1** **Person 3, Day 1**

Methods

Data Collection

To research the effectiveness of sampling strategies, it is desirable to have an accurate understanding of the true long-term exposure levels for individuals working. These, however, are never available. As an alternative, a large set of exposure data not typically collected in practice can be used as the closest approximation to the actual exposures associated with a job.

Exposure values obtained with smaller subsets of the data that represent more typical sampling strategies used in practice (e.g., monitoring one or two workers for a few minutes) can be compared with values obtained with the larger data set in order to evaluate the trade-off between amount of data collected and accuracy of the results.

In this study, a video-based exposure assessment method was used to provide quantitative estimates of various ergonomic exposures in two repetitive self-paced manufacturing tasks in an automotive forging plant:

1) **Axle inspection and loading** (shown in Figure 1). For this task, operators lifted axles from a bin and inspected parts for defects using a handheld gauge. If the axle passed the inspection it was loaded onto a conveyor, which carried the axle to the extruder.

2) **Relay rod upsetting.** For this task, operators were required to heat rods taken from a pallet with an electrical heater. The operators held the rod in different positions in a die to achieve the multistage upsetting so that it would form the desired shape. Rods of different sizes were formed.

Both of these jobs required frequent body movement and repetitive material handling. The prerequisites for selecting the production jobs for this study were that the occupation had at least three workers assigned to the same job tasks and workstation designs on the same shift, and that no job rotation was taking place across tasks or other jobs. Thus, the tasks were representative of complete jobs. For each job, a task description and the weights of parts handled were obtained from written job descriptions, observations and interviews with employees and/or supervisors, and direct measurement (e.g., measuring workstations, weighing tools and parts handled). For each job studied, 10 to 15 work cycles were video recorded for each of three operators on one to three occasions per day spread across the shift on 4 to 5 different days covering a period of 8 weeks.

Thus, the large data set for the two jobs consisted of a total of 107 videos and was assumed to represent the closest approximation of the distribution of exposures across people and over time. The videos were copied into a personal computer using video editing software.

Exposure Variables Studied

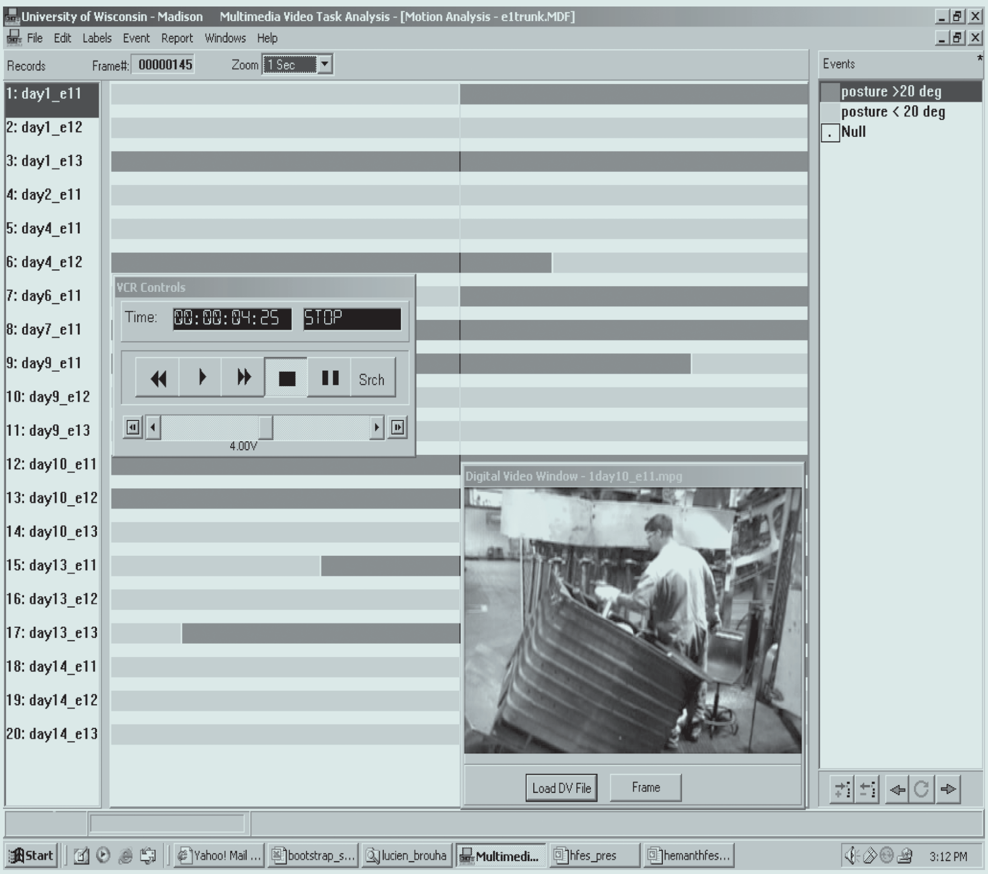
A computerized video analysis package that synchronizes video data with ergonomics assessment methods (MVTA™, NexGen Ergonomics Inc.) was used to determine the following for each video clip:

1) **Percentage of time workers spent in mild trunk flexion** (equal to or exceeding 20 degrees). The percentage of time individuals spend in trunk flexion has been found to be associated with the incidence of low back injuries (Punnett, Fine, Keyserling et al., 1991). Checklists often require practitioners to determine

Figure 2

MVTA Analysis

The dark shaded bars represent the time for which an individual is exposed to trunk flexion equal to or exceeding 20 degrees, while the light shaded bars represent the time for which this exposure is not present. Different rows represent exposure profiles for different worker-day combinations (videos). The video and recording control features of the software are shown.



whether the percentage of time individuals are exposed to trunk flexion exceeds some cutoff point, often in the range of 25% to 33% (Keyserling, Brower & Silverstein, 1993). The safety or ergonomics practitioner may want to know whether the percentage of time an individual spends in trunk flexion while working exceeds such a cutoff point or whether an ergonomics intervention reduces the mean percentage of time individuals spend in mild trunk flexion to below this point.

2) **Mean work cycle time.** This variable can serve as a crude proxy for work repetitiveness and can be used as a measure of productivity as well. The safety or ergonomics practitioner might want to know the overall mean cycle time for a particular job to determine whether a job is excessively repetitive (by comparing values to some threshold or peak value), or to determine how a production and/or ergonomics intervention may have affected the overall mean cycle time for job.

For the MVTA analysis of each video clip, the different job components were coded to identify work cycles and exposure to mild trunk flexion. The video recordings could be played in slow motion or at full speed with the software. The video player was synchronized with a clock and time line provided in the software, and the two exposure variables were coded over time (Figure 2).

Descriptive Analysis of Exposure Variability across Workers & with Time

Data analysis began with an evaluation of the overall distribution of each variable within each occupation. To estimate the contribution of exposure variability across workers, across days and within day, a two-way analysis of variance (ANOVA) with repeated measures was performed.

Evaluation of Sampling Strategies

Five sampling strategies were selected for analysis. The first required only one video to be recorded for one worker. Three strategies required recording 3 videos for different combinations of days and workers in the same occupation. The last strategy required recording 3 videos per worker each day across 5 days for a total of 45 videos (Table 1).

An empirical approach based on sampling with replacement (i.e., bootstrapping) was used to evaluate the reliability of the different strategies tested in this study. Bootstrapping first requires the construction of an empirical probability distribution from a sample by placing a probability of $1/N$ (where N is the number of measurements in the sample) at each of the original sample's points. A sample (or set) of size n (where n is a number $\leq N$) is then drawn with replacement from the empirical probability distribution. A large number of such "resampled" data sets is created, typically on the order of 1,000 to 2,000. The variable of interest is calculated for each set, and the overall distribution of the variable is assessed on the basis of these 1,000 to 2,000 empirical values. Bootstrapping has been used previously to estimate the optimal sample size to obtain a reliable estimate of exposures or for power calculations in laboratory studies involving electromyography (Burdorf & van Riel, 1996; Hoozemans et al., 2001; Mathiassen et al., 2002; Paquet, Punnett, Woskie et al., in press). (For those interested, a more detailed description of how the statistical approach can be applied for the evaluation of ergonomics exposures is offered by Hoozemans et al. [2001].)

Table 1

Sampling Strategies

Different strategies tested for the video-based ergonomic job analysis of self-paced manufacturing jobs.

Strategy	Sample size (no. of video clips)
1 worker observed once on 1 day	1
1 worker observed 3 times on 1 day	3
3 workers, each observed once on 1 day	3
3 workers, each observed once on each of 3 different days	3
3 workers, each observed 3 times on each of 5 different days	45

For each of the selected sampling strategies (Table 1), 2,000 resamples using the appropriate sampling scenario were taken with replacement using a bootstrapping approach conceptually similar to one used by Mathiassen, et al. (2002). The selection of a video into a resampled data set required randomly selecting a worker within the occupation, the day (date in which the data were collected for the identified worker), and the video among those in the appropriate worker-day combination. This type of approach ensures that each individual has an equal probability of being selected for study. Each resample then consisted of the appropriate number and combination of the 1, 3 or 45 videos, depending on the strategy used. To investigate the reliability of the different sampling approaches, values obtained in the bootstrap simulations were compared to the exposure values of the complete data set for each occupation. The most efficient strategy was identified as the one that required the fewest video recordings without sacrificing exposure measurement reliability.

Evaluation of Mean Exposures

This allows the observer to prioritize jobs that require intervention due to their mean exposure levels and evaluate the effectiveness of interventions designed to reduce mean levels of exposure. In this study, the reliability of the estimates of mean exposure to trunk flexion and mean cycle time was defined by a 95% confidence interval around the mean exposure estimate (Hoozemans et al., 2001), with a smaller confidence interval indicating higher reliability.

Comparison of Exposures to a Threshold Value

In this scenario, the observer needs to estimate whether the mean value of an exposure is less than or exceeds a threshold value to determine whether a job is problematic. A threshold value of 20% (time spent with the trunk flexed more than 20 degrees) was chosen as a realistic and illustrative case. Since the overall mean value of working time spent in trunk flexion for both tasks in this case was approximately 24%, an effective sampling approach would have a high probability of showing that the mean exposure was, indeed, greater than 20%. For the evaluation of cycle times, the threshold value of 15 seconds was selected. An effective approach would have a high probability of identifying axle inspection and loading (overall mean cycle time = 9.5 seconds) as a "highly repetitive" (i.e., mean cycle time < 15 seconds) and relay rod upsetting (overall mean cycle time = 18.4 seconds) as not highly repetitive.

Identification of Peak Exposures

This requires the observer to determine whether the exposure exceeds a certain "peak" value at any point during the job for any one individual. For trunk flexion, a "peak" value of 45% (time with the back flexed more than 20 degrees) in a video was selected because this value was exceeded only in a few of the axle inspection and loading videos, and only once in the relay road upsetting videos. An effective approach would demonstrate that the observed time an individual spent in trunk flexion could, in fact, exceed 45% of the working time. The relatively high proportion of low cycle times in this study prevented a meaningful analysis of "peak" exposures to low cycle times.

Results

Descriptive Analysis of Exposure Variability across Workers & with Time

Table 2 shows the mean, standard deviation and range of the exposure values for each occupation and for workers within each occupation. The results of the ANOVA are presented in Table 3. The descriptive analysis of the exposure variables for the axle extruders and relay rod upsetting workers suggested that exposure variability was fairly large, and that exposure often varied more considerably over time (either across days or within a day) than across workers.

Evaluation of Sampling Strategies

Evaluation of Mean Exposures

Similar trends in the reliability of the methods for the estimation of mean exposure were found for both jobs (Figure 3). As expected, the strategy with the mean of 45 samples had the narrowest confidence interval, but it was not always dramatically different from the strategies that required only 3 videos. The size of the confidence interval around the mean for a sample size of 3 differed across strategies. The confidence interval tended to be smallest for the strategy where the 3 samples were distributed across days and workers at different times and tended to be largest when 3 samples were taken on one person on the same day. A 27% to 48% reduction in the confi-

Table 2

Observed Exposures

Descriptive exposure information for the jobs overall and for each worker included in the full data set.

Job (no. of videos)	Trunk flexion (% of observed time)			Cycle time (seconds)		
Axle inspection and loading (*N* = 53)	**Mean**	***SD***	**Range**	**Mean**	***SD***	**Range**
Overall	23.6	10.3	7.8 - 48.3	9.5	3.2	4.8 - 20.7
Worker 1	21.7	6.8		8.9	1.8	
Worker 2	22.2	9.7		9.6	3.2	
Worker 3	26.7	13.0		10.1	4.1	
Relay rod upsetting (*N* = 54)	**Mean**	***SD***	**Range**	**Mean**	***SD***	**Range**
Overall	24.8	15.1	0 - 53.6	18.4	4.1	13.8 - 35.0
Worker 4	15.3	12.6		18.3	13.7	
Worker 5	36.4	10.0		20.3	5.2	
Worker 6	22.5	14.7		16.9	2.4	

Table 3

Exposure Variability

Distribution of exposure variability between workers, days (nested within worker) and videos (nested within day). The contribution of each source of variability is expressed as a percentage of the total exposure variance.

	Trunk flexion			Cycle time		
Job	**Worker**	**Day**	**Video**	**Worker**	**Day**	**Video**
Axle inspection and loading	1	22	77	0	26	74
Relay rod upsetting	32	34	34	8	56	36

dence interval was observed when the 3 samples were taken across different workers on different days compared to when only one sample was recorded.

Comparison of Exposures to Threshold Values

The evaluation of video strategies used to identify whether the mean values of trunk flexion (percentage of working time) and cycle time (seconds) exceeded the threshold limits used in this study ranged from fairly modest to extremely reliable (Figure 4). The classification with respect to a 15-second cycle time threshold was highly reliable regardless of the sampling strategy used (Figure 5). This improvement is in part because of the lower variability in the cycle times as compared to the percentage of time spent in trunk flexion, as well as the choice of the threshold values.

A consistent but in some cases marginal improvement in reliability was noted when 3 videos were recorded over multiple days rather than within the same day. The 3-video strategy that required sampling multiple workers on multiple days most consistently outperformed the 1-video approach. The use of repeated videos on the same worker during 1 day, however, did not enhance the reliability of the measurements and in one case was outperformed by the 1-video approach. This was perhaps due to the limited sample size and related assumptions of the bootstrapping approach.

Identification of Peak Exposures

The 1- and 3-video strategies were not effective for identifying the rare occasions in which individuals spent more than 45% of their cycle time in mild trunk flexion during at least 1 video. The proportion of time that these strategies correctly identified that peak exposures could occur ranged from 0.05 to 0.21. While the 45-video strategy consistently led to identification of peak exposures for the axle inspection and loading job, the peak exposures in relay rod upsetting were missed even with this strategy about 14% of the time (Figure 6).

What Do the Results Suggest?

The descriptive analysis of exposure variability suggests the following:

1) A large amount of exposure variability exists, even for cyclic, self-paced production jobs, at least for the variables presented here.

2) The components of exposure variability and the amount of variability differ across exposure variables and between jobs. Variability between workers in the cycle times and percentage of time spent in

mild trunk flexion during axle inspection in loading was very low or negligible as compared to the variability in exposure attributed to different days within worker and measurement period within worker and days. Between-worker differences in variability to trunk flexion during relay rod upsetting were larger. Since the reliability of a sampling strategy is affected by the relative significance of different sources of exposure variability, the optimal strategy is likely to differ across jobs.

The evaluation of exposure assessment strategies suggests the following:

1) For the evaluation of mean exposure values, the reliability of the 1-video approach was very low as compared to the other approaches. The 3-video approach in which different workers were observed on different days consistently outperformed the other 3-video approaches. The 45-video approaches were superior to more restricted strategies, but in some cases the difference was not very pronounced.

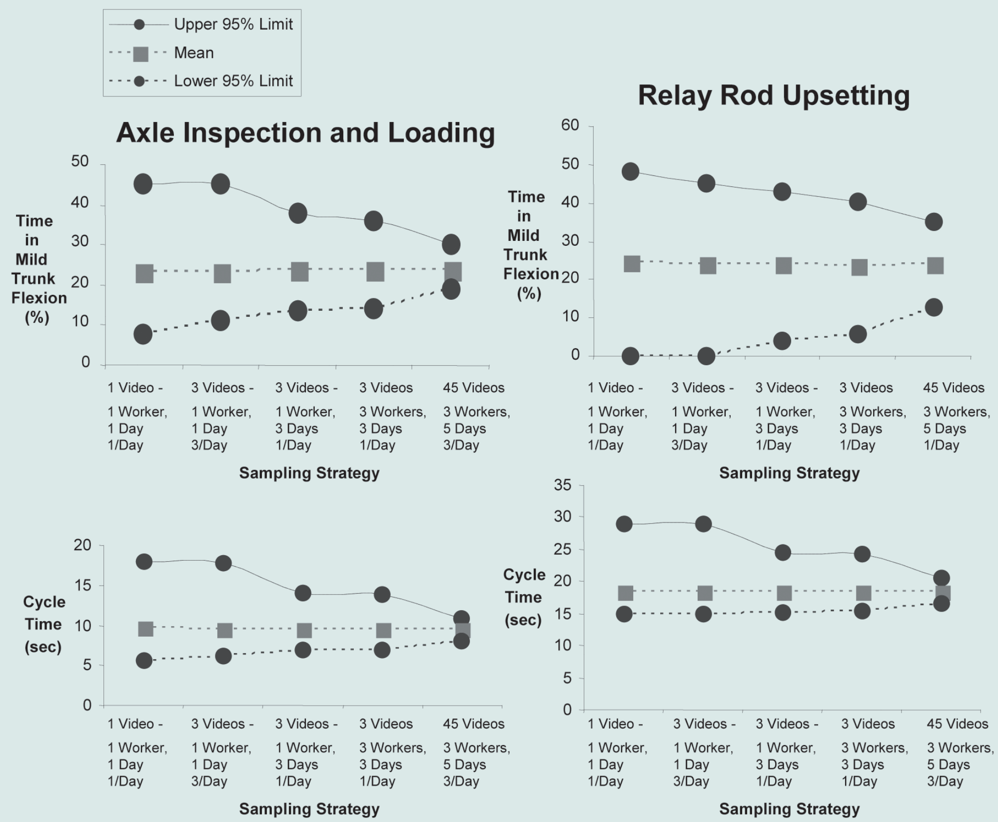
2) For determining whether a mean exposure value exceeded a threshold limit, the reliability of at least some of the 3-video approaches was very good, although the degree of reliability of each of the strategies differed across the exposure variables and occupations. For the more variable exposure (percentage of time spent in trunk flexion) the approach in which different workers were observed on different days also appeared to provide the most reliable results when compared to the other 3-video and 1-video strategies.

3) Rare peak exposures could not be effectively identified by the 1- and 3-video strategies. Thus, short video recordings even when taken repeatedly across workers at different times on different days may not be effective for identifying peak exposures if they do not occur frequently.

Figure 3

Confidence Intervals

Empirical 95% confidence intervals with five strategies for estimating the mean percent time spent in trunk flexion (upper panels) and the mean cycle time (bottom panels) for two self-paced manufacturing jobs.



Discussion

The study differs from previous studies that have investigated the reliability of EJA strategies in two important ways. First, this research focused on sources of physical ergonomic risk factor variability among self-paced manufacturing work. While studies of routine industrial assembly work have appeared (Moller et al., 2004), most previous studies are concentrated on nonroutine work such as dairy factory work (Burdorf et al., 1994) or construction work (Paquet et al., in press), or on physiological monitoring in laboratory studies (Mathiassen et al., 2002; 2003). Second, this research focused on video-based job analysis methods, which appear to be commonly used in ergonomics practice to quantify or identify ergonomics problems. Other studies have primarily focused on discrete-interval observational sampling of work (a modified form of work sampling) or bioinstrumentation methods, which are more often used in research than in practice.

Based on the results of this study, there appears to be a fair amount of exposure variability for at least some ergonomics risk factors in self-paced manufacturing jobs. Because of this, the use of 1-video sampling over a limited set of work cycles does not appear to provide a reliable measure of the ergonomic risk factors. The reliability of the measurement appears to improve when 3 videos are used in the assessment, particularly when videos are collected on different workers and different days.

Overall, the reliability of the mean exposure estimates used for the prioritization of jobs for ergonomics intervention was not extremely high for the 1- or 3-video sampling strategies. This result may not be as

Figure 4

Mean Exposure: Mild Trunk Flexion in Each Task

Proportion of samples in each exposure assessment strategy which correctly identified that the mean exposure to mild trunk flexion (% time) exceeded a predefined threshold.

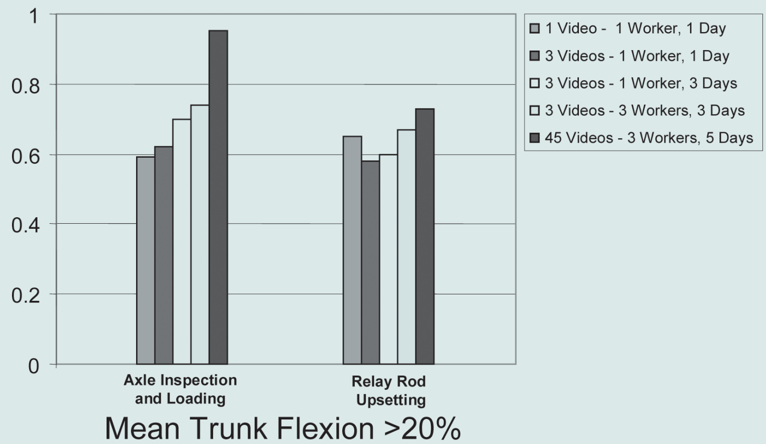
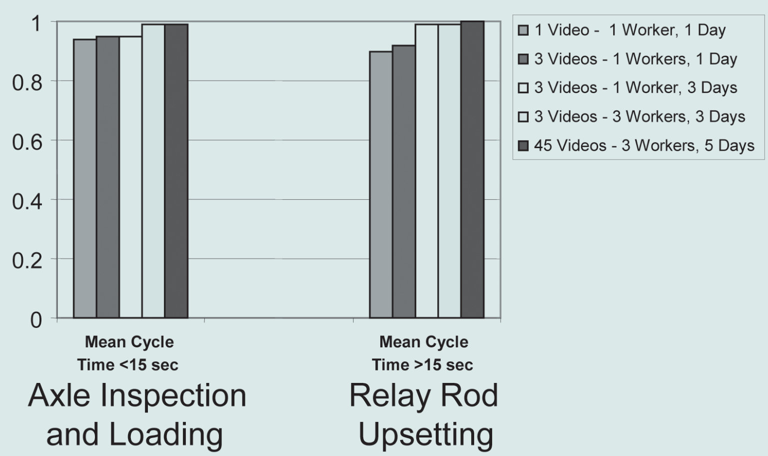


Figure 5

Mean Cycle Time: Both Tasks

Proportion of samples in each exposure assessment strategy which correctly identified that the mean cycle time was below (axle inspection) or above (relay rod upsetting) 15 seconds.



discouraging as it seems. While it is unlikely that a safety or ergonomics practitioner could accurately rank order a series of self-paced manufacturing jobs which had fairly similar work demands, the results of these analyses suggest that video-based EJA may offer a reasonable approach to discriminate between jobs which might have high versus low mean exposure levels, particularly when 3 or more videos are recorded across workers and days.

For intervention evaluation in self-paced manufacturing jobs, it appears that random sampling of workers and over time requires many videos for a reliable estimate of ergonomics exposures. Many sources of variability, including differences in the time devoted to specific tasks, changes in work methods and pace of individuals, as well as changes in the physical environment and production schedules appear to have an impact on the exposure levels. Alternative methods of intervention evaluation may be much more efficient such as evaluating how an intervention affects exposures on the same individuals while performing only the task that the intervention is intended to affect. Of course, such approaches may be susceptible to information bias or other sources of measurement error that could mask the true overall effect of the intervention, and should be used cautiously. Also, it is important to realize to what extent the job exposure is determined by other activities that are not addressed in the intervention and, thus, cannot be expected to change.

The results also suggest that limited video-sampling of self-paced manufacturing work may be useful when determining whether exposures exceed a predefined threshold limit, but may not be useful for identifying rare peak exposures. For the evaluation of whether risk factors exceeded predefined threshold limits that were fairly close to the likely mean of the true exposure, the 1- and 3-video sampling strategies generally had moderate to high levels of reliability. The use of 3 videos taken on different days resulted in the most dramatic improvement over the 1-video strategy. The 1- and 3-video strategies were not very successful at detecting rare peak exposures; therefore, the safety or ergonomics practitioner would have a low probability of detecting a rare exposure using limited sample video-based approach.

Limitations

Perhaps the greatest limitation of the study is the limited sample size for which the sources of exposure variability and the exposure assessment strategies were evaluated. First, only two occupations and two exposures were studied and, therefore, the generalizability of the results to other self-paced manufacturing work and other exposure variables may be called into question. Second, only 3 individuals per occupation were included in the analysis, which results in a large uncertainty about the actual importance of between-worker differences in exposure. Lastly, workers were observed on 5 separate days covering only an 8-week period and, therefore, the sources of exposure variability over time may not be generalizable to greater observations periods (e.g., exposures taken over a 1-year period).

Recommendations

Despite the limitations mentioned, some recommendations about the appropriate video-based sampling strategies jobs can be made:

1) Determine whether video-based EJA will provide the required information. If the EJA information will be used for presentation or training purposes, reliable exposure may not be critical. If, however, reliable quantitative estimates of ergonomics risk factors are needed to rank order jobs in terms of

exposure levels or for intervention evaluation, careful consideration must be given to the exposure assessment strategy that is used.

2) Ergonomics exposures in self-paced manufacturing jobs may vary with time and across workers; therefore, a quick-and-dirty 1-sample observation may not provide a reliable assessment.

3) Do not use a video-based approach as described in this study to identify the presence of peak exposures unless they are expected in advance to occur frequently.

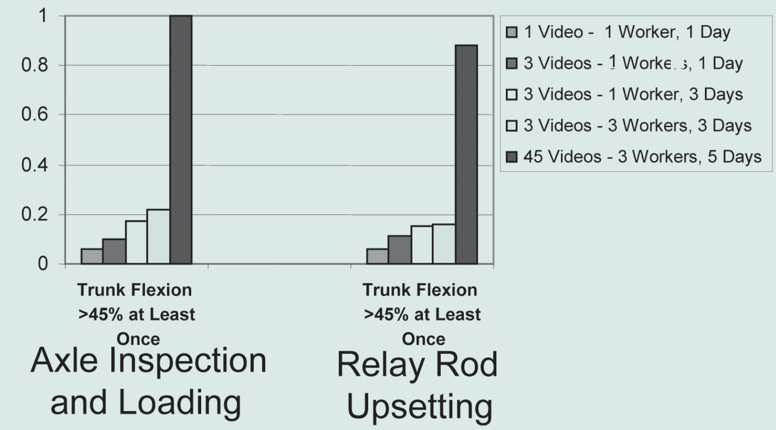
4) If a video-based analysis is to be used, avoid recording multiple videos on the same worker for 1 day since the improvement in exposure assessment reliability above using only 1 video may be negligible, at the price of tripling the resources used for processing the videos. If exposure variability over time and/or individuals is a potential concern, use at least 3 video recordings from multiple workers on different days.

5) Pilot test the strategy to determine whether it is going to provide a reliable measure of the exposure of interest within a particular occupation. Highly variable exposures will require more video recordings. If it is not feasible to pilot test by collecting a preliminary set of videos and estimating the sources of exposure variability, it may be possible to make assumptions based on previous studies or experiences. ■

Figure 6

Trunk Flexion: Both Tasks

Proportion of samples in each exposure assessment strategy which correctly identified that the trunk was flexed more than 20 degrees for more than 45% working time in at least one video.



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Acknowledgments

This work was supported by the ASSE Research Fellowship conducted at the Liberty Mutual Research Institute for Safety in Hopkinton, MA, NIOSH (Grant No. R03 OH04105-02), and Centre for Musculoskeletal Research, University of Gävle, Umeå, Sweden. The authors thank Hemant Prabhu, M.S., for his efforts in data collection and Helen Wellman for her advice on the statistical analyses used in the study.