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Judith E. Gold , Jung-Soon Park & Laura Punnett

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JUDITH E. GOLD*†§, JUNG-SOON PARK‡ and
LAURA PUNNETT†

†Department of Work Environment, 1 University Ave, University of Massachusetts
Lowell, Lowell, MA 01854, USA
‡Zen Buddhist Temple, 1710 W. Cornelia Ave, Chicago, IL 60657, USA

Jobs in many modern settings, including manufacturing, service, agriculture and construction, are variable in their content and timing. This prompts the need for exposure assessment methods that do not assume regular work cycles. A scheme is presented for classifying levels of routinization to inform development of an appropriate exposure assessment strategy for a given occupational setting. Five levels of routinization have been defined based on the tasks of which the job is composed: 1) a single scheduled task with a regular work cycle; 2) multiple cyclical tasks; 3) a mix of cyclical and non-cyclical tasks; 4) one non-cyclical task; 5) multiple non-cyclical tasks. This classification, based primarily on job observation, is illustrated through data from a study of automobile manufacturing workers (n = 1200), from which self-assessed exposures to physical and psychosocial stressors were also obtained. In this cohort, decision latitude was greater with higher routinization level ($p < 0.0001$), and the least routinized jobs showed the lowest self-reported exposure to physical ergonomic stressors. The job analysis checklist developed for non-routinized jobs is presented, and limitations of the task analysis method utilized in the study are discussed. A work sampling approach to job analysis is recommended as the most efficient way to obtain a comparable unbiased exposure estimate across all routinization levels.

Keywords: Observation; Checklist; Task-based analysis; Work-sampling; Work organization

1. Introduction

A key feature of ergonomic job analysis by observation or direct measurement is that a sample of work time is assessed and then the results are usually extrapolated to a longer

*Corresponding author. E-mail: Judith.Gold@temple.edu
§Present address: Department of Public Health, 1700 N. Broad St., Temple University, Philadelphia, PA 19122, USA.

time period. Thus, it is essential that the sample be unbiased (i.e. representative of the job, on average) in order that the extrapolation be valid. In other words, the sample characteristics must be representative of the range of work time of interest from which the sample is drawn and to which the observations will be generalized. This requires knowledge of the full distribution of exposures, not only of those during the time period observed. Whether or not explicitly acknowledged by the investigator, assumptions are needed regarding generalizability of the study data on the basis of qualitative and/or quantitative information about unobserved exposures and potential sources of variability in exposure.

For example, the industrial engineer, supervisor or worker may be asked about the tasks performed and their sequence, durations and relative frequencies, and about whether these job features vary within or across days. Data may be collected on the product mix or range of services provided or on whether all employees use the same tools, equipment or workstation. Such preliminary assessment is a standard part of the job analysis procedure; it often informs selection of 'typical' work periods and determination of the number of observations and total length of observation time that will be required.

Mathiassen and Christmansson (2003) have discussed the ambiguity inherent in terms such as repetition and variation because of the multiple timescales over which exposures are assessed. They include the durations of individual exposures (e.g. a static posture), the length of the work cycle (if there is one), the time period within which job rotation or task variability may occur and the latency period of the health effect to be prevented (which is not always made explicit).

In many manufacturing settings, work tasks have been rather predictable from day to day for much of the past century. In other economic sectors (e.g. agriculture and construction) and certain types of occupations (e.g. cleaning and maintenance), work objectives are more often achieved through a set of activities that vary over time (Mathiassen and Christmansson 2003). The long-term time trend in this variability seems to be mixed; some services (e.g. data entry, laboratory analysis) have become more routinized, while some manufacturing operations have become less so as automation displaces human labour to monitoring and problem-solving functions.

Precision in exposure estimation requires more complicated and time-consuming strategies as the number of tasks increases and as the exposures within each task fluctuate more over time. However, few observational methods address explicitly how and when to observe a job. Typically, a protocol specifies how to categorize postures, loads and/or repetitiveness but does not specify whether to record the 'typical' posture or other exposure in a given task, the 'worst-case' or peak exposure, or something else. Even when exposures are assessed by direct measurement (instrumentation), the technical aspects are usually specified in detail but the job sampling strategy is again often ignored. Many methods of work analysis are designed (implicitly or explicitly) for evaluating fixed-cycle jobs with regular work cycles (Colombini and Occhipinti 2003). If the job is not composed of regular, short cycles, then the choice of the observation period may have very serious implications for the representativeness of the data obtained. (In this paper, 'observation' is used to refer to any job analysis method in which the investigators collect information on physical exposures, whether by visual inspection and professional judgement or by direct instrumentation, independent of the judgment of the worker.)

The aim of this paper is to present a classification system of routinization in modern work that can guide the development of exposure assessment strategies. Criteria are defined for classifying the level of routinization of a given job, and the taxonomy with data is illustrated from a large cohort study of automobile manufacturing workers that

addressed the risk of upper extremity musculoskeletal disorders in relation to ergonomic exposures (Punnett 1998, Punnett *et al.* 2004). An example is given of an ergonomic exposure assessment strategy designed to be suitable for both routinized and non-routinized jobs, some relevant methodological considerations are discussed and recommendations are offered for future methods development.

2. Methods

2.1. *Definition of routinization*

The definition of 'routinization' in this paper is based on the nature of the tasks performed by an individual worker. Routinization is not seen as a dichotomous concept. Rather, there are levels of job 'routineness' between the extremes. Two extreme ends of this continuum will be discussed first and then the more ambiguous middle of the range can be addressed.

A task is a set of specific cognitive and physical actions or work elements that are performed to achieve a 'functional objective' or goal (Drury *et al.* 1987). A task is here referred as 'routine' when it is performed regularly and contains no or few variable work elements, so that the frequency of occurrence, total work cycle (duration) and content (sequence of elements) all vary little or not at all. It may also happen that the ergonomic stressors (task-specific exposures) in a routine task are relatively constant over time, but this is not a necessary condition. It is also common that there is little or no 'idle' time between occurrences of the task, but this also is not a necessary part of the definition.

In contrast, 'non-routine' tasks have high variability in work element frequency, duration or content. At the most extreme, there is no easily defined work cycle at all and the worker's activity cannot readily be predicted for any given point in time. A non-routine task may contain repetitive elements or 'fundamental cycles' (Silverstein *et al.* 1986) (such as an engine repairer using a screwdriver or a metal finisher buffing a section of a scuffed-up part), even though neither the cycle length nor the frequency of the task is regular over time. A non-routine task does not necessarily imply low exposure to ergonomic stressors. While there is no single cyclical activity that occupies the entire workday, there could still be a frequent or constant exposure (such as static load on the shoulders or repeatedly using the hand as a hammer). Nevertheless, the unpredictable nature of the highly non-routine task may make it difficult to estimate what proportion of work time is represented by this task and, thus, the exposure data collected for it are not easily converted into any summary statistic for the job as a whole.

2.2. *Job routinization level*

It is proposed that, for any given job, its task frequency, duration and content determine the level of routinization. These levels describe routine and non-routine jobs, which in turn are defined on the basis of the tasks of which they are composed.

At one end of the continuum, an extremely routinized job consists of a single repeating, cyclical task with little variation in frequency, duration and elements and no unscheduled idle time. From the ergonomist's point of view, the key issues are that a work cycle can be defined and that it can be used as the basis for extrapolating from the estimated exposures to the entire workday (or longer period). The quintessential example of a highly routinized job is assembly on a fixed-pace production line with little or no product mix.

In the present study, it was generally true that the cyclical tasks were scheduled in advance while the non-cyclical tasks were not scheduled and difficult to anticipate. However, in principle, schedule variability (Mathiassen and Christmansson 2003) is an independent construct from within- or between-task variability and, therefore, this correlation might not be observed in other settings.

At the other extreme, a non-routinized job consists of non-cyclical and unscheduled tasks with unpredictable variation in frequency, duration and elements. The duration and frequency of time in between performance of work activities ('idle time') during the day will likely also be unpredictable. Examples of highly non-routine jobs include emergency responders, maintenance and repair personnel and university professors. Although it may be possible to define one or more work cycles, these are not necessarily useful as a basis for generalizing from the observed exposures to the total exposure profile. As the length of the cycle and the cycle frequency become more variable, it requires longer and longer continuous observation to describe the task elements and to quantify the variability in each one. Eventually, the conceptual work cycle retains no operational value for the job analyst. Between these two extremes lie many gradations of routinization and many jobs with both routine and non-routine elements.

For the purposes of job analysis in the autoworker cohort study cited above (Punnett 1998, Punnett *et al.* 2004), the continuum of routinization was categorized into five levels (table 1), which served to guide the selection of analysis method for each job. The example of this study is used to describe how the presence of non-routine tasks in a job has important implications for the method chosen to conduct an ergonomic job analysis. The extent of non-routinized work in these plants was also categorized over time as well as its effect on how these production jobs were observed.

3. Cohort study

3.1. *Study participants and analysis instruments*

A fixed cohort of about 1200 automobile manufacturing workers has been under study since 1992. The original participants were production workers in six selected areas of one engine and one stamping plant in or near Detroit, MI, USA. The baseline physical examination and questionnaire survey was conducted in 1992 ('T0') and provided data on

Table 1. Definition of routinization categories, with examples from an automobile manufacturing cohort.

Routinization category	Definition	Job example	
I	A single cyclical task	Assembly line worker without job rotation	Routine job
II	Multiple cyclical tasks	Assembly line worker with job rotation	
III	A mix of cyclical and non-cyclical tasks	Job setter (machine maintenance)	
IV	A single non-cyclical task	Engine or welding repair	
V	Multiple non-cyclical tasks	Pipe fitter; electrician	
			Non-routine job

1214 workers. The cohort members still employed were re-examined in 1993 ('T1') and 1998 ('T2'). In each survey, occupational exposures to upper extremity ergonomic stressors were assessed by interview using a series of psychophysical items, which were summed to construct an exposure index (Punnett 1998, Punnett and van der Beek 2000). This within-person difference in exposure index from T0 to T2 was also computed.

At T1 and T2, psychosocial conditions were assessed with the Karasek-Theorell Job Content Questionnaire (JCQ) and the core scales for job demands and job control were computed by the standard JCQ algorithms (Karasek *et al.* 1998). A question regarding job monotony (to what extent were work activities the same every day) was also included in the latter two surveys. A workforce roster provided by the company at T2 was used to determine job and department assignments, which were compared to prior information to identify workers who had changed position since the T0 survey.

3.2. *Baseline job analyses*

Ergonomic job analyses were first conducted during the year spanning the T0 and T1 surveys (Punnett 1998, Burt and Punnett 1999). In these 'baseline job analyses,' visual observation informed completion of a one-page checklist developed for this study but similar to those described by other investigators (Keyserling *et al.* 1993, McAtamney and Corlett 1993). Observations were supplemented by verbal information obtained on site from engineers, supervisors and workers. Checklist items included: production quota; tool and part weights; frequency of non-neutral postures of the shoulder, arm and wrist; local contact stress; segmental or whole-body vibration; and local or environmental cold.

The baseline checklist was designed for analysis of tasks with relatively fixed frequency and duration, and with the assumption that multiple work cycles could be observed if needed to capture each exposure dimension. The per-cycle frequency of each exposure was converted into a daily exposure frequency simply through multiplication by the production quota or cycle frequency. Jobs with multiple routine tasks were handled by observing each task, asking the worker or other plant personnel about task frequencies and computing time-weighted average exposures. An attempt was made to observe every job in all six production areas. However, about 10% of the study subjects were not observed because their work was too variable to permit meaningful definitions of work cycles or because detailed analysis would have been too labour-intensive; no method was available at that time to estimate ergonomic stressors in these jobs in a manner comparable to that for the routine tasks.

3.3. *Follow-up job analyses*

A second set of job observations, the 'follow-up job analyses,' coincided with the interviews and examinations at T2. At the beginning of the follow-up investigation, preliminary observations and discussions with plant personnel showed that substantial changes in production technology had taken place since baseline, with attendant work re-organization. More processes in each plant had become automated, and there was then also widespread job rotation in the stamping plant. In addition, many cohort workers had moved from routinized jobs such as welding assembler or press operator to less routinized jobs such as 'lineman' (on-site supervisor of a production line) and 'job setter' (trouble-shooter of automated processes). It became clear that the previous checklist would no longer serve for the entire range of jobs; in particular, an alternative procedure was needed to analyse the non-routine jobs through direct observation. Using the criteria

of task frequency, duration and content, the set of routinization categories in table 1 was developed.

The jobs held by cohort members were assigned to these categories on the basis of information obtained through interviews with individual workers and supervisors as well as of preliminary job observations. For example, an assembly line job with no job rotation was placed into the most routine job grouping (Category I), while an assembly line job with job rotation among the various stations on the line was labelled as Category II. The work of some job setters (Category III) consisted of both regularly scheduled, cyclical tasks (such as hand gauging of machined parts) and non-scheduled, non-cyclical tasks (such as changing drill bits when they broke). Those repairing engines or repairing bad welds performed a single task, but with unpredictable frequency (Category IV). Electricians, maintenance workers such as pipe fitters, and linemen were grouped into Category V due to the unpredictable nature and frequency of their tasks.

Subsequently, all jobs held at baseline were assigned retrospectively, using the same criteria but relying primarily on department and job classification and knowledge about how the work had been organized 6 years previously.

The exposure assessment strategy employed at T2 was both worker-based and task-based. Following identification of each worker's job on the shop floor, its routinization level was designated in order to select the correct checklist. For all jobs, the sampling strategy comprised identification of each task performed and its frequency, according to the worker and/or supervisor, followed by observation of each task in turn to identify exposures and estimate duration. Whenever possible, the task was observed more than once.

Ergonomic exposures in jobs consisting of one or more routine tasks (Categories I and II and routine elements in Category III) were observed with a checklist similar to that used at baseline. The presence or absence of non-neutral postures in a typical work cycle was recorded, along with separate items for static and forceful exertions in these postures. Other elements were the presence of segmental or whole body vibration and mechanical stress. The Latko (Latko *et al.* 1997) rating system was used to evaluate hand activity level. The cycle time of the task was utilized to estimate the daily duration of these exposures.

For observation of non-routine jobs (Categories IV and V) and non-routine elements in Category III, a new checklist, given in appendix 1, was developed. The observation strategy for these jobs relied on the observer's qualitative judgement, based on information from workers and supervisors on the sources and the extent of variability in task exposures, to decide how many observations to make, for how long to observe and the timing of observations. For Categories III and V, the goal was then to construct a time-weighted average of each exposure as far as possible, corresponding to those estimated for the routinized tasks. For Category IV, it was assumed that the exposure that was sampled would serve as an estimate of the total exposure.

The second checklist was designed to collect exposure information as comparable as possible with the data collected on routine jobs, without surpassing observers' short-term memory capacity. The method involved the analyst's integration of multiple elements of a long task so that all observations could be made during a single performance of the task. Instead of trying to observe each individual non-neutral posture, 'non-neutral posture frequency' (frequency of all posture changes at each joint, per unit time, averaged over the entire observation period) was rated, by body part, using an ordinal scale based on the Latko method. 'Static loading duration' (sustained non-neutral posture and/or prolonged effort against external resistance) and 'forceful exertion frequency' were rated,

by body part, on similar ordinal scales. These scales were simplified from the Latko rating system by using either a 3- or 4-point rather than the original 11-point scale.

4. Results

In 1992, over 85% of cohort members were working on machine-paced assembly lines or in other highly routinized jobs (table 2). In 1998, as noted above, the proportions were almost reversed; about two-thirds of cohort members who were observed on the floor worked in jobs with varied tasks and content.

At the 6-year follow-up survey (T2), 430 workers were observed on the plant floor performing 570 tasks (figure 1). In addition, a number of non-repetitive tasks were assessed in a preliminary manner by obtaining basic descriptive information from worker and supervisor interviews on the floor, along with informal job observations. This qualitative information was sufficient to determine the appropriate routinization category, although detailed ergonomic analyses by formal observation and checklist were not performed. In total, 767 cohort members were assigned routinization categories.

Only the workers in the first routinization category could be observed with one single observation (which could entail viewing of repeated work cycles). The other jobs all required multiple observations. As expected, more time was required for observation of the less routinized jobs and disproportionately fewer observations could be completed for these jobs (figure 1). Almost all (n = 189 or 91%) workers in Category I were observed, while only four (2%) were formally observed in Category V (figure 1). Jobs that entailed rotation between two or more highly routinized tasks were simpler to analyse; those with tasks that varied greatly in length or content from one occasion to another were especially time-consuming.

The routinization categories were developed to guide job analysis, not necessarily as *a priori* indicators of exposure. However, there was a post-hoc trend of increasing decision latitude at work, as defined by the JCQ scale, with increasing level of routinization (table 3). A simple linear regression model of decision latitude gave a parameter estimate of 2.05 ($p < 0.0001$), representing the increase in job control per step in the routinization category.

About 40% of those in routinization categories IV and V at follow-up had department assignments that were markedly different from those at baseline (table 3). In contrast,

Table 2. Members of automotive cohort at baseline and at 6-year follow-up, by routinization category.

Routinization category	At T0 (1992): All cohort members	At T0 (1992): All follow-up interviewees	At T2 (1998): All follow-up interviewees	At T2 (1998): All subjects observed*
I	659 (51%)	246 (47%)	167 (32%)	207 (27%)
II	443 (35%)	206 (40%)	48 (9%)	77 (10%)
III	103 (8%)	38 (7%)	106 (20%)	150 (20%)
IV	} 78 (6%)	} 29 (6%)	91 (18%)	148 (19%)
V			107 (21%)	185 (24%)
Total	1283 (100%)	519 (100%)	519 (100%)	767 (100%)

*Includes some cohort members who were not interviewed at follow-up.
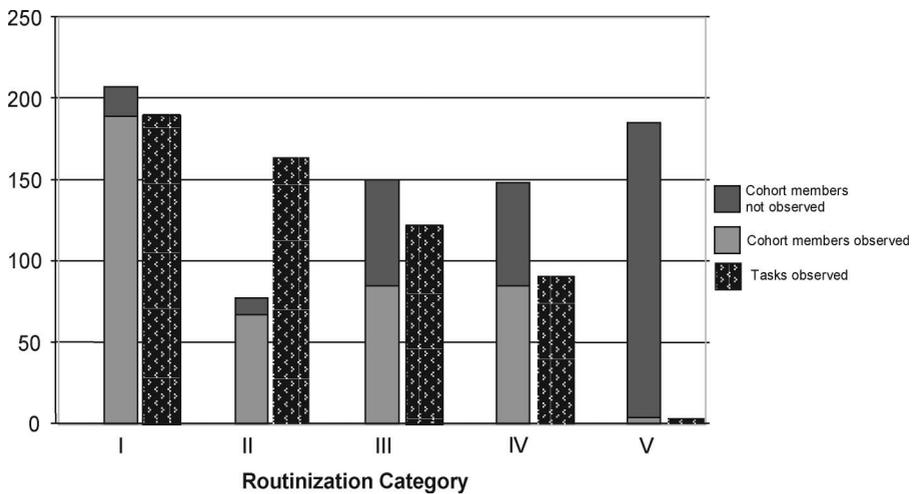*Note*: Percentages do not sum to 100% due to rounding error.

Figure 1. Number of cohort members observed and not observed, and number of tasks observed, by routinization category at T2 (n = 767).

nearly all of those in categories I and III had remained in the same types of production departments through the follow-up period. Although there was no overall trend in physical exposure by routinization level, those in the least routinized jobs at T2 also had the lowest exposure scores at T2 and the largest decrease in physical exposure scores, as denoted by the change in ergonomic exposure index from baseline to follow-up. Since the vast majority of workers in non-routinized jobs at T2 had been in more routinized jobs at T0, this trend suggests that moving to less routinized jobs was reflected in lower exposures, on average.

5. Discussion

A classification system for job routinization has been proposed to guide selection of an appropriate exposure assessment strategy for a given occupational setting. While other investigators have utilized work sampling in practice as the basis for analysing jobs that do not have regular (short) work cycles (e.g. Harber *et al.* 1992, Mattila *et al.* 1993), the literature is surprisingly silent regarding the principles of how to choose a job analysis strategy in light of the organizational features of the workplace(s) of interest. Within a given study population, all jobs might lie in one single category of job routinization (i.e. all workers perform a single routine task or multiple non-routine tasks) or there may be a mix of job types. An observational methodology that is appropriate for one type of job may not serve for others. If different routinization levels are found within the study population or workplace of interest, the methodology selected should give comparable exposure information for all jobs and workers. Mathiassen and Christmansson (2003) called for alternatives to counting work cycles when analysing jobs with 'non-cyclic tasks or work containing more than one task'. This is the need that the present study seeks to address.

It is particularly important not to assume that all jobs comprise fixed-length cycles, because this may lead to jobs with important exposures being omitted from investigation. For example, although a single exposure to high force may result in a fracture or other

Table 3. Change from baseline to 6-year follow-up in routinization level and ergonomic exposure index, and psychosocial characteristics at follow-up: 487 automotive manufacturing workers interviewed in 1992 and 1998.

Routinization category	Number of subjects at follow-up (T2)	In category I or II at baseline (T0)	Major change in department assignment from T0 to T2	Job is 'the same every day' (T2)	Psychological demands (T2): mean ± SD	Job control (T2): mean ± SD	Ergonomic exposure index* (T2): mean ± SD	Change in exposure index* (T2-T0): mean ± SD
I	167	95%	3%	70%	29.0 ± 3.7	59.6 ± 9.7	11.6 ± 5.1	− 1.4 ± 6.0
II	48	98%	33%	69%	28.7 ± 3.5	63.2 ± 10.2	12.6 ± 4.7	− 2.0 ± 4.7
III	106	80%	6%	74%	28.5 ± 3.3	64.2 ± 8.5	11.7 ± 5.1	− 1.3 ± 5.4
IV	91	86%	42%	55%	29.0 ± 3.6	65.1 ± 7.5	11.4 ± 4.6	− 1.6 ± 6.3
V	107	78%	41%	56%	28.4 ± 3.6	66.9 ± 9.9	9.5 ± 5.4	− 4.0 ± 5.8

*Based on psychophysical ratings from interview (index range = 0 − 25).

acute injury, and the elevated risk associated with repetitive high forces has been well described (Silverstein *et al.* 1986), the role of infrequent peak exposures in musculoskeletal disorder causation is still being evaluated. Peak forces or moments are thought to affect the risk of musculoskeletal disorders (Marras *et al.* 1995, Norman *et al.* 1998), yet the frequency of such forces has not been explicitly addressed in either biomechanical models or epidemiological studies.

Limiting the investigation of ergonomic exposures to highly routinized work has also been reported as a consequence of the difficulty in analysing jobs without fixed task cycles (e.g. Sauter *et al.* 1991). This is an undesirable course of action because it prevents a full description of the range of ergonomic exposures or the sources of variability in exposures. The jobs omitted are inherently less repetitive and thus the scope of exposures available for study is truncated.

The sequence of categories III and IV in the routinization scheme could be debated. It was found that the presence of one or more routine tasks in a mixed job makes it easier to observe, at least in part. On the other hand, one might argue that a job with only one task, even if it is non-routine, is a simpler job to define and thus to observe. However, the list need not be ordinal, as long as the distinctions among these types of jobs are recognized and taken into account in any exposure assessment effort. There might be other ways to categorize job 'routineness'. The important point is that a job analysis method should ideally be able to cover the whole range of the population under study. Otherwise, the population variability in exposure may be artificially reduced by the constraints of the methodology. Additionally, it is important to keep in mind that the routinization level of a particular job may be dynamic through time, as over the duration of a prospective cohort study, for example.

5.1. *Choice of observational methodology and strategy: task-based or work sampling approach*

In this study, a task-based approach was used to estimate ergonomic stressors in a cohort of automobile manufacturing workers in both routine and non-routine jobs. However, this approach was not without its difficulties. It was not always possible to observe workers performing their job tasks due to several factors.

Perhaps the most important reason was that the time between (unscheduled) tasks often comprised a significant portion of the total workday. This resulted in many unsuccessful investigator visits for observations. Second, it was sometimes difficult to locate workers whose jobs required them to move around the plant (e.g. janitors or fork-lift drivers). Additionally, certain tasks were scheduled at lengthy intervals (e.g. changing a drill bit every 3 months) and some of these infrequently executed tasks were not available during the allocated time for observation in the field.

A further limitation to this task-based method resulted from unsuccessful estimation of daily task duration through interviews with employees on the shop floor. Workers in non-routine jobs found it increasingly difficult to estimate task duration as their task elements became more unpredictable. Additionally, they often gave a range of task frequencies rather than one average or typical value.

To obtain valid information on daily duration spent at non-routine tasks may require significant effort. Although work diary logs, direct observations and production and maintenance records, as well as interviews with workers and supervisors, can all be used, it may prove extremely time-consuming. Moreover, because if the time associated with any single task cannot be estimated, the time-weighted average exposure value cannot be

computed for the entire job. In contrast, with work sampling, if the rare tasks are not observed it is still possible to compute an unbiased estimate of average exposure levels. If it is assumed *a priori* in the injury/illness model that occasional exposures are a risk factor for the musculoskeletal disorder under study, a task-based approach might be more likely to capture exposures aetiologically relevant to morbidity in those jobs with rare but high exposures, although this would also depend on the task frequency and the frequency of observations. A work-sampling approach is therefore generally advocated for all routinization levels in future investigations.

Very recent work has shown that exposure assessment (of electromyographic (EMG) gap frequency and gap time) based on task may be only marginally more efficient (in terms of precision of the mean exposure estimate) or in some cases even less efficient in comparison to estimating exposures using naïve random sampling techniques (Mathiassen *et al.* 2003, Mathiassen 2004). Utilizing a decision tree (Mathiassen *et al.* 2003) to determine the most efficient sampling strategy, at least for EMG parameters, jobs in routine Categories IV and V would most appropriately be assessed using a fixed or random sampling interval, and in Categories I, II or III using a random sampling interval. For all jobs, exposures can then be estimated from the sampled values without regard to task. In addition, if it is practical to note the particular task being performed at each observation, task-specific exposures could subsequently be calculated if desired, as the authors have done elsewhere (Buchholz *et al.* 1996, 2003, Paquet *et al.* 1999, 2001, Moir *et al.* 2003, Forde and Buchholz 2004).

5.2. *Checklist for all routinization levels: recommendations for further revision*

The non-routine checklist was designed to be as comparable as possible to the routine checklist. Through preliminary field evaluation of the non-routine checklist it was determined that only three categories ('1 = none/low, 5 = moderate and 9 = high') could be differentiated for posture frequency, static load and peak force frequency in contrast to the 11 categories of the Latko scale. This was especially true for jobs with highly irregular tasks, because the method potentially required holding a long work period in short-term memory and then mentally finding an 'average' or 'mode' exposure value by an algorithm not well defined.

Nonetheless, it was still difficult to establish good inter-rater reliability for these elements of the checklist. This is probably due to the lack of sufficiently descriptive verbal anchors. That is, examples of tasks with low, moderate and high postural stressors may have enabled the evaluators (n = 3) to agree on a coding for such stressors when observing the same job. Such an approach was used by Latko in developing the hand activity level tool (Latko 1997, Latko *et al.* 1997). For instance, to properly categorize peak force, the following verbal anchors were given: picking up or holding light objects (such as a rear view mirror, small handle . . .), 0 – 3 range; driving screws with a pneumatic driver, 3 – 7 range; and upholstering, 7 – 10 range (Latko 1997). It is assumed that a similar system would enhance the inter-rater reliability of the ergonomic stress rating section. Future studies are planned to determine appropriate verbal anchors as well as quantification of the none/low, moderate and high delineations by observing jobs in various industries, particularly in those with non-routine tasks. Despite these present limitations, the non-routine checklist (as seen in appendix 1) could serve as a starting point for an ergonomic analysis instrument based on a work-sampling approach.

6. Conclusions

Increasingly, job rotation and tending of automated equipment produce complex patterns of work organization, in both industry and service sectors. For estimation of occupational exposures, it is important to employ a methodology and sampling strategy appropriate to the job routinization characteristics of a study population. This requires advance identification of both the component task(s) and the routineness of the task(s) in each job. It is recommended that researchers explicitly characterize their study population in terms of work routinization level in order to design an appropriate ergonomic exposure assessment effort. Furthermore, to facilitate better understanding of the close link between work organization and ergonomic exposure assessment methodology, ergonomists should describe: 1) the conditions under which a methodology is developed and used; 2) the range of the study population or the characteristics of jobs to which a specific methodology can be applied.

Acknowledgements

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Appendix 1

UAW/Chrysler Ergonomics Data Sheet (2) Version 2.6 (7/28/98)

Operation Information

Date: _____ Time: _____ Analyst:_____ ObsID#: _____

Plant: _____ Department: _____ Line (operation #):_____

Operation Name/description:_____

Worker Name:_____ Team:_____Job Class: _____

Cohort Member: _____ Cohort ID #: _____

Hours per day:_____ Days per week: _____ Shift:_____

Job Description * List of main tasks, task description, total time spent on each task per day or per week, frequency of tasks, tools and parts information*

	Task descriptions	Frequency	Duration
#1			
#2			
#3			
#4			
#5			

Total daily idle time duration _____

Pacing: 1) Rigid line speed _____2) Off-line, partially machine-paced _____

3) Work ahead/on demand_____4) Non-routine _____5) Time pressure_____6) Time binding_____

Content   1) Monotonous _____   2) varied _____

Job subgroup →

Observation Strategy → 1) routine task observation _____   2) work sampling _____

Observation Number: _____out of _____   Obs/ID# _____

Date/Time of Observation: /   /98,   From :   To: a.m. / p.m.

Duration of observation: _____ (min)

If work sampling, idle time observed _____ (min)

Task # from the list _____

General Workstation and Environment

Posture: 1) Stand _____ 2) Sit/Stand_____ 3) Seated w/o functional backrest _____
           4) Seated w/backrest   _____   5) Move around _____

Check if present: Floor mat _____   Footrest _____

Machine activation **Yes / No** Buttons above shoulders **Yes / No** Buttons below buttocks: **Yes / No**

Vibration: Segmental   **1) Yes2) No** Part or tool #:   _____
                WBV   **1) Yes2)No**   Continuous   **1) Yes 2) No**   Impact **1) Yes 2) No**

Cold: Ambient **1) Yes 2) No**   Manual   **1) Yes 2) No**

Heat: Ambient **1) Yes 2) No**   Manual   **1) Yes 2) No**

Gloves: **1) Yes 2) No** Thick, bulky _____   Thin _____

Mechanical stress:**1)Yes   2)No**
            Body Part: **Hand L / R / B   Forearm/elbow   L / R / B   Legs L / R / B   Abdomen**

Use of a finger to press button **1) Yes**   (thumb/other) **2) No**

Hand/arm (H/A) **motion speed** (when moving) rating: _____

0	2	4	6	8	10
H/A mostly idle	H/A idle often	Slow motion of H/A	'Normal' motion	Rapid motion	Frenzied motion

Hand/arm pause duration/ frequency **rating: _____ (work period)**

[0	**1**	2]	[4	**5**	6]	[8	**9**	10]
Nearly continuous pause	Prolonged pause with occasional exertions		Frequent pauses >5 seconds between exertions		Regular short pauses between exertions		No regular pauses between exertions	Never a pause

Obs ID# _____
Parts and Tools

ID#/Description	Unit weight	# Parts Held	Weight Held	Hand Use *L,R,B*	Pinch Grip *L/R*	Hold Time 5lb+
1.						
2.						
3.						
4.						
5.						

Ergonomic Stress Ratings   Each rating scored 0–10 (OK to use 1=none/low, 5=moderate, 9=high)

Posture frequency rating: Number of changes in posture at each joint, per unit time

Static load rating: Proportion of total work time with static loading on each body part
Forceful effort rating: Frequency of peak exertions by each body part, as number per unit time

	Left			Right		
	Posture frequency 1 - 5 - 9	Static load 1 - 5 - 9	Peak force frequency 0 - 1 - 5 - 9	Posture frequency 1 - 5 - 9	Static load 1 - 5 - 9	Peak force frequency 0 - 1 - 5 - 9
Hand/Wrist *Wrist flex(>30), Wrist ext(>45), Ulnar dev (>30)*						
Arm *Forearm Pron/Sup (>60)* *Elbow exten (>150)*						
Shoulder *Elevation (>60)* *Extension (>20)*						
	Posture frequency	Static load	Peak force frequency			
Back *Flexion (>20)* *Twist/Lat.bend(>20)*						

Ergonomic stress ratings: significant exposures not recorded elsewhere

- *Push/Pull (over 5 lb) : **frequency rating → N / L / M / H ; Static rating →N / L / M / H***

- Neck Group (Flexion >30, Extension >30, L. bend >30/twist >45),

- Static posture of extremely long duration; specify:_____

- Other_____