

The Washington State SHARP Approach to Exposure Assessment

Stephen Bao
Barbara Silverstein
Ninica Howard
Peregrin Spielholz
*Washington State Department of
Labor & Industries*

44.1	Introduction	44-1
44.2	Exposure Parameters, Measurement Strategy, and Measurement Methods	44-1
	Methods • Direct Measurement Methods	
44.3	SHARP Study Exposure Assessment Methods	44-8
	Job Sampling • On-Site Data Collection • Job Analysis (Significant Force Analysis) • Posture Analysis, Event Based vs. Time Based • Repetitive Exertion Analysis • Repetitive Movement Analysis • Work Organization Measurement	
44.4	Summary	44-19

44.1 Introduction

Understanding the relationships between workplace exposure parameters and the health outcomes of the musculoskeletal system is the basis for preventing and reducing work-related musculoskeletal disorders. Quantification of exposure parameters is critical in epidemiological studies as well as ergonomics applications. Methods used for the exposure assessment vary depending on the purpose of the applications and feasibilities of using these methods. This chapter discusses the various exposure parameters at workplaces related to work-related upper extremity disorders, measurement strategies, and some exposure assessment methods used in epidemiological studies. The exposure assessment approach used by SHARP in a large prospective study of upper extremity musculoskeletal disorders is presented and discussed.

44.2 Exposure Parameters, Measurement Strategy, and Measurement Methods

Workplace exposure parameters associated with the development of upper extremity musculoskeletal disorders include work organization variables and various physical exposures of the jobs. The National Institute for Occupational Safety and Health (NIOSH) published a critical review of the evidence for

work-related musculoskeletal disorders of the neck, upper extremity, and low back and summarized major findings on the various exposure parameters (NIOSH, 1997). In 2001, the National Research Council published a comprehensive review of the evidence on work-related musculoskeletal disorders in which they concluded that repetition, force, and vibration, as well as high job demands and job stress, were particularly important risk factors for upper extremity disorders (Panel on Musculoskeletal Disorders and the Workplace, 2001). They also found that modification of these factors could substantially reduce the risk for these disorders.

The way work is organized and performed often determines subsequent physical/mechanical and psychological job demands on individual workers. Work organization also encompasses the organizational practices and production methods that affect job design. These include the temporal aspects of work (e.g., work–rest schedules, work shifts, hours of work, work pacing), job content (e.g., repetitiveness of tasks, use of skills, vigilance, participation in decision-making), compensation arrangements (salary, hourly, quota, piece rate), work status (fulltime, part-time, seasonal, temporary), social interactions (isolated, various levels of team work), task (single, rotating, multiple), and opportunities for development (Kasl, 1992; Sauter and Swanson, 1996). Consideration of work organization provides information at the group level and enables multilevel analysis. Work organizational observational exposure assessment methods that are potentially relevant for assessing relationships with musculoskeletal disorders include those of Rohmert and Landau (1983), Ergonomic Workplace Analysis (Ahonen et al., 1996), Meaning of Work (MOW International Research Team, 1987), and the Occupational Stress Index (Belkic et al., 1995).

Typically, physical exposures identified in workplaces include forceful exertions (Stetson et al., 1993; Fransson-Hall et al., 1996; Roquelaure et al., 1997), such as gripping a high force demanding hand tool, lifting a heavy object, pushing a fully loaded cart. Non-neutral postures of hands and upper extremities (Frost and Andersen, 1999; Punnett et al., 2000; Viikari-Juntura et al., 2000), such as bending the wrist when using a hand tool and raising the hand above the head when performing a task, increase force requirements. Highly repetitive motions of the hand, wrist, and upper arms (Veiersted and Westgaard, 1993; Blanc et al., 1996; Nordstrom et al., 1997; Punnett, 1998) are found in hand-intensive jobs such as assembly and data entry. Some other physical demand parameters at workplaces include hand–arm vibration, wearing gloves, and some environmental conditions such as extremely cold or hot temperatures. Work organization parameters such as work methods, social content, and task pacing may also influence the development of work-related upper extremity disorders.

Different measurement strategies may be used to meet the various needs of the exposure assessments. For example, most cross-sectional epidemiological studies measure exposure parameters at a certain point in time, while most prospective epidemiological studies require the quantification of the exposures for the days, weeks, and years on the job. Thus, data collected for prospective studies should make it possible to calculate cumulative exposures. For example, a worker performs two different tasks in a workday. Exposure from both tasks should be measured and the compound exposure for the whole day should be calculated depending on the task distribution (time spent on the two tasks). If the worker's exposure is changed during the course of the study (e.g., job changes), a new exposure measurement should be performed, and the accumulated exposure is then calculated. If the purpose of the measurement is to assess exposure differences among two or several conditions, measurement can be done for each of the conditions.

When considering the measurement strategy to be used, one should also consider the three main dimensions of physical exposure: amplitude, frequency, and duration, rather only one single dimension. This is because the physiological significance is dependent on the combination of these exposure dimensions. Therefore, exposure quantification should include the measurement of exposure amplitude (e.g., level of hand force, degree of a joint angle), exposure frequency (e.g., number of exertions per minute), and exposure duration (e.g., length of time in hours). Other aspects of physical exposure may also need to be quantified, such as duty cycle and speed.

After deciding on the measurement strategy, one should consider the selection of exposure quantification methods to be used. There are numerous exposure quantification methods available.

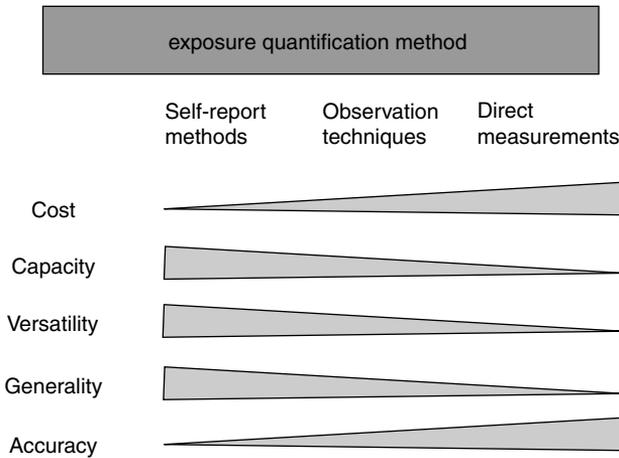


FIGURE 44.1 General characteristics of the three types of exposure quantification methods. (After Winkel, J. and Mathiassen, S.E. (1994) *Ergonomics* 37: 979–988. With permission.)

However, different methods may have different specificity, validity, and reproducibility. Depending on the types of methods, they may also require users with varied expertise. The time and cost required for data collection and analysis could also vary significantly.

Although risk estimation from job titles has been used as the normal exposure quantification in many epidemiological studies, they may only give vague or invalid exposure assessment in musculoskeletal epidemiological studies. This is because workers under the same job title could perform very different activities due to differing technologies and machines used, individual work techniques, and work organizational differences between different companies. Commonly used exposure quantification methods in work-related musculoskeletal studies can usually be divided into the following three categories: (1) self-report questionnaires; (2) observational methods; and (3) direct measurement techniques. Each of these has its own strengths and weaknesses and may be used in different applications depending on the study purposes. Figure 44.1 illustrates some general characteristics of the different methods, and can serve as a guide for selection. In general, direct measurement with instrumentations gives the most specific and accurate exposure estimation, but involves significant costs. This method would be impractical for individual exposure assessment in very large populations of large-scale epidemiological studies because of the significant resources and expertise that would be required. Self-reporting using questionnaires or interview methods can access large populations with reasonable cost, but the data, in general, have low validity with respect to exposure level and variation. Observational methods are usually considered to be in between the direct and self-reporting methods in terms of the different characteristics. The following sections discuss some of the commonly used methods of the three groups.

44.2.1 Self-Report Questionnaires

Self-report questionnaires are appealing due to their relative ease of administration and low cost in comparison to direct measurement methods. The questionnaires can be self-administered or through interviews. They could be used among large population samples within a short period of time and with relatively low cost. However, the obvious drawback is the resulting information may be potentially less reliable and more easily influenced by environmental and personal factors. This type of method also has low specificity so that they may not be able to detect differences between groups, which could otherwise be detected by different exposure measurement methods. Self-report questionnaires have

been used with other methods in industry by several researchers with varying levels of success (Baty et al., 1986; Burdorf and Laan, 1991; Holmstrom et al., 1992; Wiktorin et al., 1993; Punnett, 1998).

Self-report questionnaires tend to be both reproducible and relatively close to observational and direct measurement for gross levels of activity (Baty et al., 1986; Wiktorin et al., 1993, 1996). Wiktorin et al. (1996) reported acceptable reproducibility in the 0.5 to 0.8 range for questions relating to overall physical activity, whole body working postures, and specific leisure activities. Some success has been reported in subjective estimates of impulses or forces on the hands (Freivalds and Eklund, 1993). However, both reproducibility and reliability dropped significantly compared to other measurement methods when specific questions relating to bent postures and levels of loads were asked (Holmstrom et al., 1992; Wiktorin et al., 1993). Viikari-Juntura et al. (1996) reported moderate correlation (0.42 to 0.55) between self-reports and observations of physical workload factors such as frequency of manual handling, duration of trunk flexion, neck rotation, hands above shoulders, and squatting or kneeling. The correlations, in general, were higher for those without low back pain than for those with low back pain. Pope et al. (1998) compared results from a self-report questionnaire on physical demands (postures, manual handling, repetitive upper limb movements) to direct simultaneous observations in six different occupational settings. Agreement was good for most of the manual material-handling activities. However, minutes of repetitive arm and wrist movements appeared to be the least accurate (overestimates). These authors concluded that dichotomous recall is satisfactory (i.e., ever, never) and that exposure magnitude recall can also be satisfactory for some risk factors.

Toomingas et al. (1997) tested the hypothesis that those who rate health outcomes high on self-reports would also rate exposures high on self-reports, thereby biasing risk estimates. Conducting separate analyses by age, gender, and socioeconomic status, correlations were close to zero for fixed and nonfixed stimuli, including symptoms and physical exposures, indicating no systematic differences by rating behavior. Punnett (1998) reported consistent findings of good comparability in estimates, when comparing self-reported physical exposures with observations by researchers blinded to health status. Kerr et al. (2001) reported good agreement between back injury cases and job-matched controls on self-reported physical demands of the job ($ICC = 0.6$), suggesting a lack of symptoms-related bias in estimates. Bernard et al. (1994) compared observational analysis to self-reports of exposure among symptomatic newspaper workers and referents. Both groups reported a longer duration of typing time (approximately 50% more) than the observational analysis. Similar results by Spielholz et al. (1999) showed consistent overestimation of upper extremity risk factors by most individuals. These studies indicate that self-reports may provide valuable information regarding task duration/frequency and whole body postures but are generally neither accurate nor reliable for measurement of hand/arm exposure to risk factors in terms of duration and frequency.

44.2.2 Observational Methods

Observational measurement methods are frequently used in field studies as a compromise between questionnaire and direct measurement methods. Observational methods present the best compromise for individual exposure assessment in large-scale epidemiological studies. Observational measurement systems are usually categorized into two types: event based and time based.

Event-based methods such as the NIOSH lifting equation (NIOSH, 1994), the rapid upper limb assessment method or RULA (McAtamney and Corlett, 1993), and the rapid entire body assessment method or REBA (Hignett and McAtamney, 2000) are applied to the complete event of a task or subtask and give a score or index to represent the risk level. This type of method, though widely used by ergonomics practitioners for its simplicity, does not provide detailed information on changes in exposure during task performance. Often these types of methods are used in field-based risk assessment. In addition, no one measurement method has been widely accepted as a standard, although several are currently being developed to fill this role.

One event-based method used as a standard is the ACGIH hand activity level (HAL) threshold limit value (ACGIH, 2001). This method adopts the previous work of Latko et al. (1997) to set levels of

physical exposure for the hand and the wrist. The HAL is applicable to single-task jobs, although some approaches have been attempted to extend its use in multiple-task situations. The RULA method (McAtamney and Corlett, 1993) is used to assess the postures of the neck, trunk, and upper limbs, muscular effort, and the external loads on the body. This postural exposure assessment system has been used in several different formats and adopted for use in many different types of industries (Lueder, 1996; Hignett and McAtamney, 2000).

Time-based methods such as OWAS (Karhu et al., 1981), VIRA (Persson and Kilbom, 1983; and Kilbom et al., 1986), ARBAN (Holzmann, 1982), and PEO (Fransson et al., 1991) require the analyst to observe the job performance continuously or at specific time samples during the task performance. The analyst records the exposure changes based on predefined categories, such as, hand with weight versus hand without weight, and neck flexion between 0° and 20° versus greater than 20°. Observations can be performed on-site with a computer or off-site where video-tapes are analyzed. Advantages of the time-based methods are that they more closely represent the true exposure during the task performance. The disadvantage is that it is time consuming and may also limit the number of exposure parameters that an analyst can observe if the method is used on-site.

Video-based off-site techniques often use categorical scoring of body positions, movement frequency, type of grip, and force based on either sampled or real-time recording (Karhu et al., 1977; Corlett et al., 1979; Holzman-Voigt, 1979; Kemmlert and Kilbom, 1986; Keyserling, 1986; Armstrong et al., 1982). The method employed by Armstrong et al. (1982), for example, sampled postures several times a second and classified wrist postures into five categories: (1) neutral, (2) flexion, (3) extreme flexion, (4) extension, and (5) extreme extension. In general, video-based analysis may be the most appropriate observational method for risk factor quantification and definition of work activities for large-scale epidemiological studies because it allows the analysts sufficient time to estimate the postures of the various body parts and provides the possibility to reanalyze the data for quality control purpose.

With the availability of newer computer technologies, time studies of task performance and postural analysis can now be carried out on computers. A recently developed multimedia video task analysis (MVTA) system (Yen and Radwin, 1995) is able to set accurate time codes on videotapes and perform time analysis on various time-based events (e.g., tasks, postures, and hand exertions). With its flexible design, users can set their own parameters to be studied (e.g., tasks, wrist flexion and extension postures, hand exertions) and define their own categories of the different parameters (e.g., for the parameter of task with two levels: computer keyboarding and writing notes; for the parameter of wrist flexion/extension with four categories: flexion 0 to 30°, flexion >30°, extension 0 to 30°, and extension >30°). A drawback of this type of analysis is that the analyst has no control on the angles of observation, and has to depend on the quality of the videotapes. Therefore, to obtain reliable and adequate exposure information, it is important to take good-quality video. Another disadvantage with the computer-based observation systems is that one cannot obtain direct measurements such as object weight and forces required to operate a tool while the analyst is sitting in his or her laboratory. In contrast, when the observation is done on-site, the analyst can most often communicate or interact with the operator to obtain the information. Therefore, if the analysis is performed off-site, it is important to obtain the required information on-site and be prepared for use in the off-site analysis.

Falling within the scope of observational field methods are methods based on workloads. These methods define a system of quantifying an overall load score (Helliwell et al., 1992) or classify workers into classes based on work levels (Nathan et al., 1993). The Strain Index developed by Moore and Garg (1995) identified six risk factors, each given a categorical 1 to 5 score, that give an overall severity index (SI) score when multiplied together. This tool has been used in meatpacking and has shown data that support its validity in predicting morbidity (Moore and Garg, 1995). Although the Strain Index method was originally designed for single-task jobs, the authors have made attempts to extend this method to multiple-task jobs.

Force quantification often presents a problem in observational methods. Hand force cannot be seen. Consequently, it must be estimated, which can be achieved using several methods. A simple dichotomous classification of either high or low force has commonly been used, typically using manipulation of a

4-kg object or its equivalent force for power grip or 1-kg object or its equivalent force for pinch grip as the determinants of class (Silverstein et al., 1987; Stetson et al., 1991). Several researchers have used a modified Borg scale, which classifies an expert estimate on a 10-point categorical scale ranging from zero to maximal exertion (Borg et al., 1985; Lloyd et al., 1991). Another approach is to estimate the tendon force based on hand geometry, assumed friction, and object weight (Helliwell et al., 1992). Despite the provision of an actual force value, this method relies on the estimation of every factor and may not be any more reliable than scaling techniques. A continuous method used by Latko (1997) employs expert consensus rating of average and peak force on 10-cm visual–analog scales. Reproducibility estimates of this method have been between 0.6 and 0.8, showing promise as a continuous scaling method.

Psychophysical studies use a subject's perception of sensation to measure a factor of interest. This has been applied in the field of exposure observation. Snook et al. (1995) developed guidelines for hand/wrist flexion and extension based on psychophysical studies. Analysts observe the hand/wrist postures during task performance and give subjective ratings on the postures. Previously, Snook (1978) also used perception of object weight to develop acceptable guidelines for lifting based on location, lift frequency, and weight. A more recent method developed by Latko et al. (1997) employed expert group rating of physical components of work on visual–analog scales. This study evaluated the use of rating several risk factor exposure metrics on continuous visual–analog line scales. The technique shows great promise in terms of reproducibility and reliability of quantifying hand activities (Latko et al., 1997). These scales have been incorporated into primary measurement methods of the American Conference of Government Industrial Hygienists (ACGIH, 2001) TLV on hand activity.

Although there have been major advances in observational methods and they have been widely used in musculoskeletal epidemiological studies, some drawbacks exist. One of the major drawbacks is that the observational methods are based on the subjective judgment of the individual analyst. Some variations within and between analysts are unavoidable. Measures to reduce such variation should be taken. Another common problem associated with observational methods in epidemiological studies is that different researchers have used different predefined exposure categories. This makes it difficult to compare results from different studies.

44.2.3 Direct Measurement Methods

Direct measurement aims to provide the standard by which the validity and reliability of all other methods are measured. However, much work remains in developing accurate systems that can be used in the field to measure posture, motion, and force. The two most commonly used methods to measure posture and motion, electrogoniometry and video-based motion tracking systems, have only recently been used in field studies for the upper extremities (Hägg et al., 1997). This is in large part due to issues of feasibility and measurement error.

Video motion tracking systems, which typically operate by using computer-aided edge detection to follow markers placed on a worker, are not widely used in the field due to feasibility issues. In order to perform unobstructed tracking in three dimensions, the worker must be in view of three cameras. This, however, does not eliminate the analysis of many obstructed-view estimations and makes recording of dynamic work or work inside enclosures impossible, as work is often performed outside the field of view of the cameras.

Electrogoniometers, physically placed on the hand/wrist and forearm, do not have the obstructed-view problems associated with video tracking, and systems have been developed which may easily be used in the field (Moore et al., 1991). Continuous angle recordings may be analyzed to determine the length of time in specified body postures, repetitiveness of motion, and angular velocity and acceleration (Marras and Schoenmarklin, 1993; Radwin et al., 1993). However, measurement error largely due to cross-talk between recording channels has been a pervasive problem in past studies (Moore et al., 1991; Buchholz and Wellman, 1997). Cross-talk can be thought of as the bias created by the distortion of the resistive strain gauges in the electrogoniometers by movement on one or both of the axes.

Several researchers have evaluated electrogoniometers and the introduction of significant cross-talk in flexion/extension measurements and deviation measurements from extreme forearm rotation (Armstrong et al., 1993; Smutz et al., 1994; Buchholz and Wellman, 1997; Roberts, 1997).

Researchers have developed procedures that may reduce errors caused by cross talk (e.g., Smutz et al., 1994; Buchholz and Wellman, 1997; Roberts, 1997). These results show promise for the use of an electrogoniometer and electrotorsiometer in tandem to measure motions and allow for error correction. Researchers appear to agree that an electrotorsiometer and electrogoniometer can be used in a telemetric system to perform angle measurements with errors less than 5° (Armstrong et al., 1993; Smutz et al., 1994; Buchholz and Wellman, 1997).

Force exerted by muscle groups is commonly measured by force transducers placed in the line of action or by the use of surface electromyography (EMG) (Armstrong and Chaffin, 1979). Force transducers may provide accurate information if specific conditions exist where their placement does not affect the work.

EMG has become relatively easy to perform in the field with the use of disposable surface electrodes and portable measurement devices (Winkel and Gard, 1988; Hägg et al., 1997). Typically, EMG data may be measured and analyzed for either physical signs of fatigue or for comparison of static force levels (NIOSH, 1992). Electrodes transmit motor unit action potentials from the underlying muscles. These signals, when root-mean-square (RMS) transformed or integrated, have shown a linear or exponential relationship ($r^2 > 0.90$) to developed static force (NIOSH, 1992).

Direct estimation, an alternative to EMG for calculation of hand force, can be classified as a direct measurement method. Field practitioners and consultants commonly use this method to obtain job force requirements. Direct estimation can be done simply by measuring the force requirements of a tool or piece of equipment with a force gauge. When this is not possible, estimation of force can also be accomplished through the reproduction of the exertion on a force gauge in the same orientation and type of grip as performed by a worker. Kingdon and Wells (2000) conducted a laboratory study on the accuracy of matching a manual gripping force using a hand dynamometer. Initial findings have shown that force matching may be relatively accurate and consistent at lower force levels. A study published by the Safety & Health Assessment & Research for Prevention (SHARP) program on 113 government workers showed that with the use of a hand dynamometer, the force matching method can be quite accurate and consistent in estimations of power grip force and pinch grip force (Bao and Silverstein, 2005). These results support the use of this method as an alternative to more time-consuming and expensive instrumentation techniques for quantifying hand force levels in large epidemiological studies.

In conclusion, no method is perfect and different methods may be used in different situations for different purposes. Direct measurement using current techniques represent the most accurate and reliable exposure assessment method. Work by Spielholz et al. (1999) comparing self-reports, video observation, and direct measurement showed that video observation may have approximately 30% more error than direct measurement in some risk factor measurements. Direct measurement would be the preferred method given unlimited resources; however, modern video observation techniques have the advantage of providing larger numbers of evaluated participants due to less time-consuming data collection and analysis.

Due to the population size requirement of most epidemiological studies, direct measurement of all participants would require resources well beyond what is available from a granting agency. Video-based observational assessment in combination with direct measurement and estimation of forces is the only method that would allow measurement of all participants with an acceptable level of accuracy and reliability. Additionally, discrimination calculations by Spielholz et al. (1999) show that the estimated tenfold increase in number of measured participants (100 to 1000) possible with video-based techniques over direct measurement will give a more accurate exposure assessment at the group level despite the increased measurement error. For these reasons, video-based observation and direct force estimation techniques used previously by the SHARP (1999) program were chosen as the primary exposure assessment method in a large prospective study of upper extremity musculoskeletal disorders conducted by SHARP (referred to as the SHARP Study in the subsequent text).

44.3 SHARP Study Exposure Assessment Methods

The “SHARP Study” involves health assessments (structured interview, physical examination, nerve conduction studies, and psychosocial questionnaires) and exposure assessments (collected by different teams blinded to either health or exposure status) of workers at 13 different worksites, collected at baseline and 4-month intervals over 3 yr. Work organizational factors are collected at the departmental level by the exposure assessment team. If there is a significant job change, exposure assessment is repeated. In the following sections, the exposure assessment methods used in the SHARP Study will be presented and discussed. The discussion starts with job sampling followed by on-site data collection, and then discussions of the various exposure assessment methods (e.g., job analysis, posture analysis, repetitive exertion analysis, repetitive movement analysis, and work organization measurement).

44.3.1 Job Sampling

It is impractical to follow a worker for a whole workday to document his or her exposure at the job for large-scale epidemiological studies with a large population. If one has to follow each of 1000 subjects for 8 h to document exposure, the total measurement time for just the baseline would be 8000 h. This is not feasible for most epidemiological studies. However, it is also important to obtain exposure measurements for individual workers. Many previous studies used a group exposure measurement approach. This is done by measuring exposure among a small number of subjects in a specific job or job category and assuming the same exposure for the whole group. The large within-group variance in some exposure parameters could unravel specific risk factors for work-related musculoskeletal disorders (Fallentin et al., 2001). Individual exposure assessment is the alternative. For this type of assessment some sort of job sampling method is necessary to obtain exposure measurement over a short period of time during a representative workday. Job sampling has been a common procedure in industrial engineering time studies. The requirement for job sampling is that exposure results taken from some short periods of time can be used to represent the whole day exposure with reasonable accuracy.

Job samples should be taken from a typical workday where the employee performs his or her usual type of work at a normal pace without any restrictions by process limitations. This is usually confirmed at the beginning of the measurement period by asking supervisors and workers.

In the field of industrial engineering, the length of observation or the number of cycles that should be studied in order to arrive at an equitable standard is a subject that has caused considerable discussion among time study analysts as well as union representatives (Niegel, 1988). Since the activity of the job, as well as its cycle time, directly influences the number of cycles that can be studied from an economical standpoint, one cannot be completely governed by the sound statistical practice that demands a certain size sample based on the dispersion of the individual element readings. There are no generally agreed upon criteria for recording length or number of cycles in epidemiological studies. Most often, common practice, personal judgment, and available resources play a more important role than strict statistical procedures in determining the number and length of job samples. In the SHARP Study, the recording time was determined after reviews of other similar studies and feasibility considerations based on available resources.

As in many industries, workers can be assigned to different tasks during a workday. For example, an electronic assembly worker can be assigned to an assembly task for 6 h and a packaging task for 2 h in an 8-h workday. Therefore, job samples are usually taken at the task level, instead of at the job level. When a task is cyclic (i.e., repetition of the same activities), the exposure variation within a single task is usually smaller than between different tasks. Some tasks may have no repetitive pattern, that is, activities may not be repeated regularly and can happen at different times of the day without any specific patterns. This type of task can be labeled as a noncyclic task. Exposure variation within this type of task is usually large. Exposure measurement obtained from a continuous job sample of this type of task may not represent the real exposure of that task. Therefore, a different approach may need to be considered. A common

sampling practice for noncyclic tasks is to take a number of random samples during the task performance period.

The job sampling approach used in the SHARP Study is based on whether the job is a single-task job or a multiple-task job, and the tasks are cyclic or noncyclic (Figure 44.2). The first step is to determine whether the job is a single-task job or a multiple-task job and, secondly, to determine if each task is cyclic or noncyclic. For a cyclic single-task job, a continuous 15-min job sample is taken for the exposure measurement purpose. For a noncyclic single-task job, three 5-min job samples are taken randomly during the workday. This attempts to obtain good equitable exposure measures for this type of job and capture the fluctuations of the exposure during a workday. The total job sample length for a single task job is 15 min for both cyclic and noncyclic task jobs.

For multiple-task jobs (more than one task is performed during a workday), a different job sampling method is used for both cyclic and noncyclic tasks. A 10-min job sample is taken for each of the cyclic tasks and two 5-min job samples are randomly taken from each of the noncyclic tasks in a multiple-task

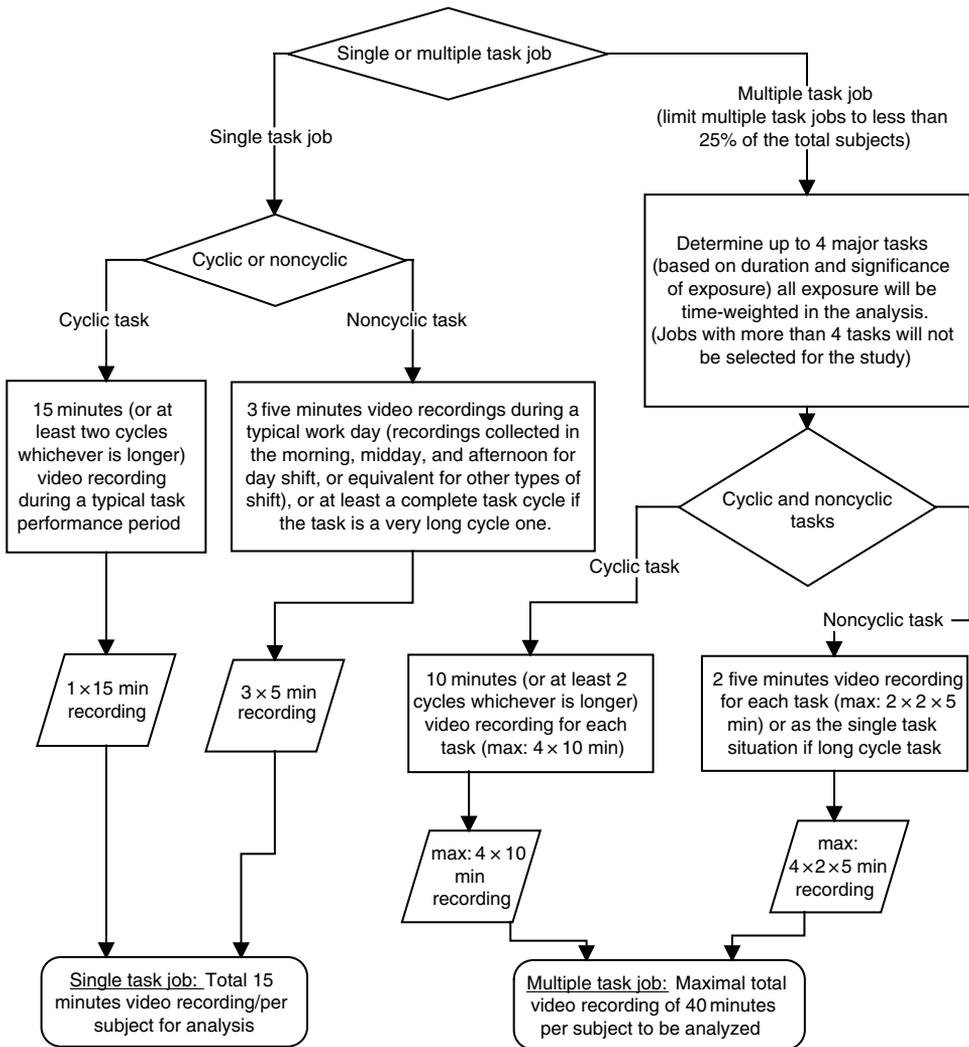


FIGURE 44.2 Job sampling strategies depending on the type of tasks and jobs.

job. Depending on the number of tasks, the total length of the job samples is longer in a multiple-task job than that in a single-task job.

For practical purposes, it may be necessary to limit the number of multiple-task jobs in a large epidemiological study as the amount of time needed for data collection, processing, and analysis is much longer in multiple-task jobs than that in single-task jobs. In many industries where manual activities are dominant, a common practice is to rotate workers between different tasks. Rotations commonly occur at break times. In the SHARP Study, jobs with more than four tasks were excluded.

44.3.2 On-Site Data Collection

After the job sampling strategy is determined, jobs are documented and data are collected on site. Depending on the types of analysis, data collection can be done through interviewing workers, supervisors, and other plant personnel, examining production data logs, performing on-site observations, video filming jobs for further analysis, and collecting direct measurements of relevant parameters. Often a combination of these methods is used. As an example, an on-site data collection form used in the SHARP Study is shown in Figure 44.3.

Before taking any exposure measurements, work hours and days, job change information, and task distribution information (task rotation schedule and number of hours at each task) are obtained from

Field Physical Exposure Data Collection Form

Location: _____; Physical location: _____

Subject ID: _____ Analyst(s): _____ Time: _____

Period ID: _____ Initial job category: _____

Age: _____; Gender: Male Female; Height: _____ in.; Weight: _____ lb

Hand (write): Right Left Both; Hand (work): Right Left Both;

Current job: _____ Shift hours: _____ Work days: _____

Task ID	Task Activity	Duration (h/d)	Expected time(sec)	Cyclic	Note
				Y / N	
				Y / N	
				Y / N	
				Y / N	
				Y / N	

Break times: _____

Power tool information (PT)

Tool ID	Power Tool/Model	Weight	Grip span(s)/Handle Diameter(s)	Note
PT				

On site direct measurement

Task: _____; Task ID: _____

Major object handled

Object	Measure (lb)	Estimated ¹	Sub-task description

Significant force measurement

Force type	Measure (lb)	Est ¹	Not measurable?	Sub-task description
<input type="checkbox"/> push <input type="checkbox"/> pull			<input type="checkbox"/>	
<input type="checkbox"/> push <input type="checkbox"/> pull			<input type="checkbox"/>	
<input type="checkbox"/> push <input type="checkbox"/> pull			<input type="checkbox"/>	
<input type="checkbox"/> push <input type="checkbox"/> pull			<input type="checkbox"/>	

Significant hand force measurement

Measure ¹ 1 (lb)	Measure ¹ 2 (lb)	Measure ¹ 3 (lb)	RPE	Est ¹	Grip type	Not measurable?	Sub-task description
						<input type="checkbox"/>	
						<input type="checkbox"/>	
						<input type="checkbox"/>	
						<input type="checkbox"/>	

Other significant force measurement

Force type (please describe)	Measurement (lb)	Est ¹	Not measurable?	Sub-task description
			<input type="checkbox"/>	
			<input type="checkbox"/>	

Other estimated and observed measurements

	Task average		Note
	Left	Right	
HAL ²			
Duration of exertion (% of cycle) ³			
Efforts/min ⁴			
Hand/wrist posture ⁵			
Speed of work ⁶			
Duration per day ⁷			

	Check (✓) if yes		Estimated frequency ⁸	Sub-task description
	Left	Right		
Power tool use	<input type="checkbox"/> id: _____	<input type="checkbox"/> id: _____		
Contact stress	<input type="checkbox"/>	<input type="checkbox"/>		
Jerking	<input type="checkbox"/>	<input type="checkbox"/>		
Impact action	<input type="checkbox"/>	<input type="checkbox"/>		

¹. Estimated (Est) intensity of force: 1 (low) to 10 (high)

². HAL

³-handle idle most of the time, no regular exertions ⁴-consistent, conspicuous, long pauses or very slow motions ⁵-slow, steady motions/exertions, frequent brief pauses ⁶-slowly motion/exertion; infrequent pause ⁷-rapid, steady motions/exertions; no regular pauses ⁸-rapid, steady motions/difficulty keeping up or continuous exertion

³. Duration of exertion (% of cycle)

1 - <10%	2 - 10 to 29%	3 - 30 to 49%	4 - 50 to 79%	5 - ≥80
----------	---------------	---------------	---------------	---------

⁴. Efforts/min

1 - <4	2 - 4 to 8	3 - 9 to 14	4 - 15 to 19	5 - ≥20
--------	------------	-------------	--------------	---------

⁵. Hand/wrist posture

1 - very good	2 - good	3 - fair	4 - bad	5 - very bad
---------------	----------	----------	---------	--------------

⁶. Speed of work

1 - very slow	2 - slow	3 - fair	4 - fast	5 - very fast
---------------	----------	----------	----------	---------------

⁷. Duration per day

1 - <1	2 - 1 to 2	3 - 2 to 4	4 - 4 to 8	5 - ≥8
--------	------------	------------	------------	--------

⁸. Estimated frequency: 1-very infrequent, 2-infrequent, 3-average, 4-frequent, 5-very frequent

FIGURE 44.3 Sample of SHARP study's on-site data collection form.

© 2006 by Taylor & Francis Group, LLC

interviewing workers and supervisors. Jobs are then video filmed according to the job sampling strategy discussed previously. Two synchronized cameras are used in order to capture both sides of the body while the worker is performing tasks. The camera crews should be well coordinated so that when the worker moves the cameras should be moved accordingly in order for at least one camera to capture both sides of the body. This will help the off-site data processing in the laboratory.

During the observation period, forces applied in the task are noted and later measured. As it is not feasible to measure all forces that the worker applies in the task, a subjective determination of “significant force” is made. Operationally, when one of the ergonomists considers that the force is obvious and may be of importance to the exposure, the force data will be collected. This is similar to most ergonomics consultations where an ergonomist takes measurements he or she thinks necessary. Conceptually, a “significant force” is defined as a lifting force of ≥ 0.9 kg, a pinch grip force of ≥ 0.9 kg, a power grip force of ≥ 4.4 kg, and a push/pull force of ≥ 4.4 kg. The force value is not known until measured. Therefore, in practice, forces that are lower than the defined levels are sometimes measured. A lifting force is measured by the object weight. This is typically measured by using a force gauge or a weight scale. Object weights can also be obtained from the company. A push/pull force is also measured using a force gauge. For practical purposes, no distinction is made between push and pull forces, though they may have different physiological impacts. Additionally, both lifting weight and push/pull force are also estimated by an ergonomist using a 1 to 10 rating scale. A pinch or power grip hand force is measured using the force matching method (Bao and Silverstein, 2005). This is done by asking a subject to recreate the amount of force he or she uses in the task on a force dynamometer using similar hand/wrist postures. This process is repeated three times, and the median of the three is used in the analysis. Borg ratings by subjects and researchers are also collected for force applications (CR-10, Borg, 1982). Different measurement methods are used for the same exposure parameters in order to study the differences and similarities between the different methods.

Other observed parameters, such as the HAL, and parameters for computing the Strain Index (i.e., duration of exertion, efforts/min, hand/wrist posture, speed of work, and duration per day) are also collected during the on-site data collection period. This allows several event-based exposure estimations to be made.

If the worker uses vibrating tools, the tool information is collected. This is used to crudely estimate vibration exposure to the worker.

It is important to ensure that the data collection process of the on-site analysis does not interfere with the normal performance of the task. Some workers may have the tendency to modify their performance in front of video cameras. This must be discouraged. At the end of the data collection, it is also important to check the completeness of the data and be sure all data are collected properly.

44.3.3 Job Analysis (Significant Force Analysis)

Job analysis is done in the laboratory and is based on the video recording and data collected at the work-site. The purpose of this analysis is to obtain the frequency and duration of significant forces. This can be done by performing time studies on the recorded tasks. A software program called MVTA (multi-video task analysis), developed by the University of Wisconsin (Yen and Radwin, 1995), is used in the SHARP Study. A typical data processing screen is shown in [Figure 44.4](#). The record shows a time line where a certain event (activities of various significant forces) occurred. Significant forces are listed in the right panel. The video window shows the recorded task performance. The analyst can use any video clip from the two synchronized cameras to obtain the best view for the analysis. Time-line marks are inserted at the time when significant forces occur. The analyst may often play the video at normal speed first in order to understand the task activity contents and then play the video in slow motion mode to set the event marks.

After the data processing, a time-study report can be generated. For instance in [Table 44.1](#) it is shown that at recorded cycle #3, the worker lifted an object of 56 lb for a duration of 142 frames (or 4.7 sec) and spent 286 frame time (or 9.5 sec) performing other activities where no significant force was applied.

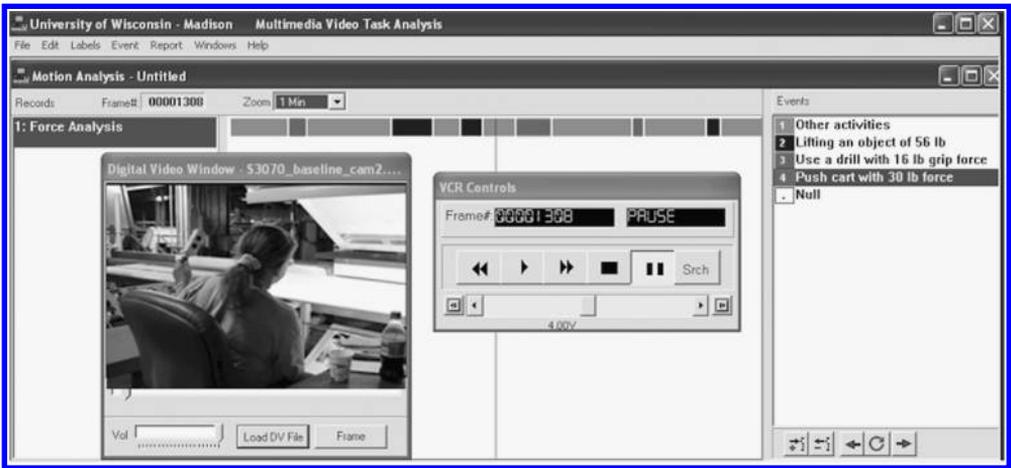


FIGURE 44.4 A typical time study on significant forces.

With the time-study report, a summary statistics report can be produced where average duration, percentage of time, and frequency of the various significant forces can be calculated as follows:

$$\text{Average duration (sec)} = \frac{\sum \text{Duration of individual exertions}}{\text{Total number of exertion cycles}}$$

$$\% \text{ Time} = \frac{\sum \text{Duration of individual exertions}}{\text{Total recording time}} \times 100\%$$

$$\text{Frequency of exertion (times/min)} = \frac{\text{Total number of exertions}}{\text{Total recording time}}$$

When the worker is involved in the use of vibrating tools during task performance, the vibration exposure needs to be quantified. Theoretically, vibration levels should be measured during task performance. However, vibration measurement requires sophisticated instrumentation and enormous resources.

TABLE 44.1 A Typical Time-Study Report of Significant Forces

Time-Study Report				
Event #	Event Elements			
1	Other activities			
2	Lifting an object of 56 lb			
3	Use a drill with 16 lb grip force			
4	Push cart with 30 lb force			
Time Units in Frames				
Cycle	Other Activities	Lifting an object of 56 lb	Use a Drill with 16 lb Grip Force	Push Cart with 30 lb Force
1	270			42
2	198		61	
3	286	142		
...
66	92	75		
67	110			124
68	272		38	
69	212	49		

In the SHARP Study, it is not possible to perform accurate vibration measurements while also collecting a large amount of other physical exposure parameters for each of the subjects. The alternative is to obtain the declared vibration values of the tools that the workers use, and then perform a time study on the video recordings to measure the actual time that the vibration tools are activated. This estimation may not reflect the real vibration exposure of the workers, as other factors such as tool balancing, work surface conditions, and individual work techniques can influence the true vibration level, but it can give an estimation of the vibration exposure.

44.3.4 Posture Analysis, Event Based vs. Time Based

Posture analysis is based on observations of recorded tasks as well. There are two types of posture analyses, “event based” and “time based.” For “event-based” posture analysis the overall postures (the most common posture and the worst posture) for the different body parts when performing a specific task are determined. In “time-based” posture analysis, postures are measured at a particular time for a specific task. There are two types of analyses for the time-based posture analysis: (1) continuous observation and (2) time-sampled observation.

In the continuous observation, the analyst observes the postures of the different body parts continuously, and marks down the changes whenever the body part moves from one predefined angular category to another. This analysis allows the determination of the distribution of the angles of the different body parts and the movement frequency between the different predefined angular categories. However, this type of analysis is very time consuming, particularly when there are several predefined angular categories for each body part. Also, it is very difficult to observe several body parts simultaneously. Therefore, the analyst must play the video several times in order to complete the analyses for the different body parts. In the time-sampled observation of the time-based posture analysis, the analyst observes the postures at a number of preselected times during the task performance, and a distribution of the postures is calculated. Although this method significantly reduces the data processing time, it is not possible to obtain information about repetitive movements of the different body parts in combination with the postures.

In the SHARP Study, both event-based and time-based posture analyses are used. One of the reasons for using both methods is to compare results obtained by the two methods. However, due to the large amount of data processing and analysis in this project, only the time-sampled observation method is used for the time-based posture analysis, rather than the continuous observation approach.

In the event-based posture analysis, predefined postures are used ([Table 44.2](#)). Posture distribution results can then be calculated and used for epidemiological modeling. An illustrative distribution result is shown in [Figure 44.5](#), where job A seems to have more wrist extensions and flexion compared to job B and workers at job B maintain more neutral wrist postures compared to workers at job A. Depending on the need of the epidemiological analysis, some of the predefined angular categories may be consolidated.

Using the event-based posture results, one can also calculate certain indices for the different body parts, such as the RULA scores. To obtain the final RULA score, apart from the posture results, additional information such as forces and muscle use should also be obtained. Details on the computation of RULA scores can be found in relevant articles (McAtamney and Corlett, 1993).

In the time-based posture analysis, postures of the same body regions used in the event-based posture analysis are measured. However, instead of giving overall estimated posture values for an entire task (event), postures are estimated at certain points of time during a task performance. In the SHARP Study, postures are estimated for numerous randomly selected frames during a 15-min task recording (75 frames for a single-task job, 80 frames for a two-task job, 90 frames for a three-task job, and 100 frames for a four-task job). To lower individual analyst variation, the frames are assigned to two analysts for processing.

One of the potential problems with predefined angular categories is that the analyst may be biased by the nature of the job. For instance, when a posture is on the threshold of two predefined angular categories (e.g., posture is approximately 30° while the categories are 0 to 30° and 30 to 60°), the

TABLE 44.2 Predefined Angular Categories for the Different Body Parts

Trunk	Trunk flexion–extension	Trunk lateral flexion	Trunk twisting
	<0° (extension)	0 to 10°	0 to 10°
	0 to 20° (flexion)	10 to 30°	10 to 45°
	20 to 60°	>30°	>45°
	>60°		
Neck	Neck flexion–extension	Neck lateral flexion	Neck twisting
	<0° (extension)	0 to 10°	0 to 10°
	0 to 20° (flexion)	10 to 30°	10 to 45°
	>20°	>30°	>45°
Upper arms	Upper arm flexion–extension	Upper arm abduction–adduction	Upper arm rotation
	<0° (extension)	<0° (adduction)	<0° (outward)
	0 to 20° (flexion)	0 to 30° (abduction)	0 to 15° (inward)
	20 to 45°	30 to 60°	15 to 45°
	45 to 90°	60 to 90°	>45°
	>90°	>90°	
Shoulders and elbows	Shoulder raise	Arm supported	Elbow flexion
	Yes or no	Yes or no	<0° (extension)
			0 to 20° (flexion)
			20 to 60°
			60 to 100°
			>100°
Forearms and wrists	Forearm rotation	Wrist flexion–extension	Wrist ulnar–radial deviation
	–180 to –90° (supination)	<–45° (extension)	<–15° (radial)
	–90 to 0° (supination)	–45 to –15°	–15 to –5°
	0 to 90° (pronation)	–15 to 0°	–5 to 0°
	90 to 180° (pronation)	0 to 15° (flexion)	0 to 10° (ulnar)
	15 to 45°	10 to 20°	
	>45°	>45°	>20°

analyst may assign the worse posture category to the subject when he or she thinks the job is hazardous, or vice versa. To overcome this problem, in the SHARP Study, a continuous angular scale was used during data processing (posture estimate) and then the data were categorized later during the analysis. In order to make the continuous scale for the posture estimate, a special data processing program has been created. One of the data processing screens is shown in Figure 44.6. In this screen the worker is shown from two camera angles (pictures are just for illustrative purpose in the figure and does not represent the actual analysis) at a preselected video frame. The analyst observes the posture and estimates the approximate locations of the body parts by clicking on the posture diagrams. The continuous angle data are automatically entered into a database.

From the raw posture data, posture distributions can be computed based on pre-defined angle categories (e.g., Job A: 15% of time wrist posture is >45° extended, 67% of time wrist posture is

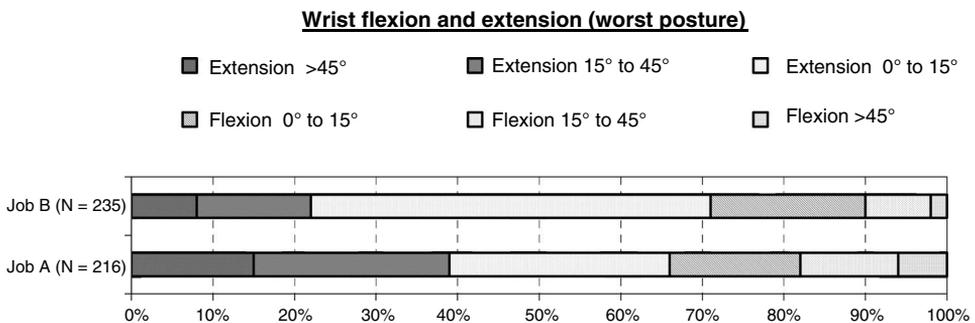


FIGURE 44.5 Distribution results of event-based posture analysis (*n* — number of subjects).

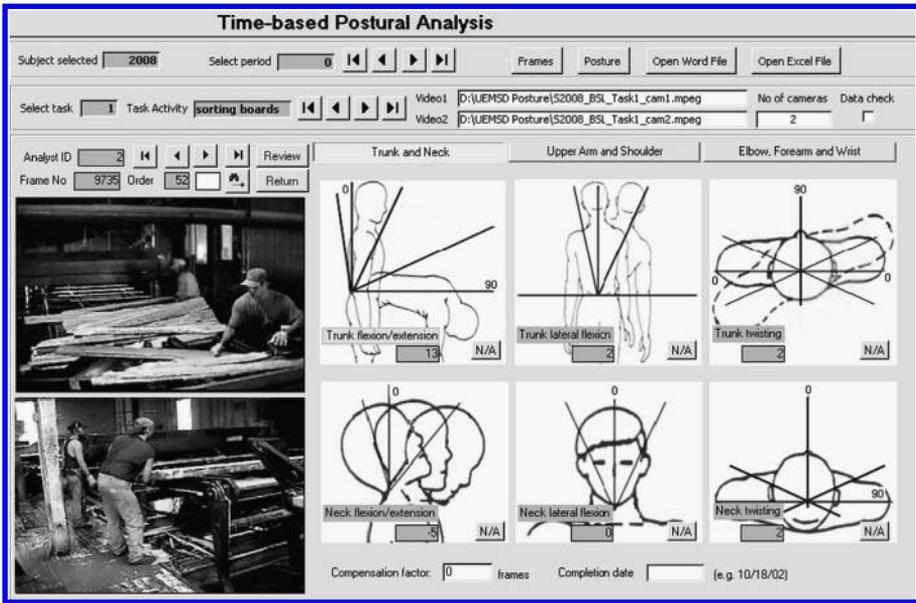


FIGURE 44.6 Time-based posture analysis using continuous angular scales (data do not represent the actual angle measurements).

between 45° extension and 15° flexion, and 18% of time wrist posture is >15° flexion; Job B: 8% of time wrist posture is >45° extended, 82% of time wrist posture is between 45° extension and 15° flexion, and 10% of time wrist posture is >15° flexion). Depending on the epidemiological analysis needs, alternatively, the descriptive statistics for individual subjects such as mean, median, 95% percentile of the postures can also be calculated.

44.3.5 Repetitive Exertion Analysis

In the SHARP Study, hand exertion is defined as any physical effort of the hand when performing a task activity. This is different from the significant force applications, which may not include all hand exertions. This analysis is another way to capture exposure on hand activities. The purpose of this analysis is to calculate the frequency of exertion (or cycle time of exertion), duration of exertion, and exertion duty cycles (% exertion). In the SHARP Study, this analysis is done using the MVTA time-study program (Yen and Radwin, 1995). In this analysis, completed in the laboratory, each hand is analyzed separately. Videotapes may be played at normal speed in order for the analysts to understand the contents of the task activities and played in slow motion mode in order for the analyst to capture the exertions. To reduce processing time, particularly when the tasks are of a very repetitive nature, the analysis is done on five to six randomly selected 1-min intervals of the recorded task instead of the whole video recording.

A typical repetitive exertion MVTA analysis window is shown in Figure 44.7. The left and right hands are analyzed separately. From this analysis, a raw data report, containing durations of individual exertion and nonexertion events, can be generated. The raw data report can be used to calculate the following:

$$\text{Average duration of exertion (sec)} = \frac{\sum \text{Duration of individual exertion}}{\text{Number of exertion cycles}}$$

$$\text{Average cycle time (sec)} = \frac{\text{Total recording time}}{\text{Number of exertion cycles}}$$



FIGURE 44.7 A typical repetitive exertion analysis screen in MVTA.

or

$$\text{Average frequency of exertion (times/ min)} = \frac{\text{Number of exertion cycles}}{\text{Total recording time}}$$

Average duty cycle (%)

$$= \frac{\sum \left[\frac{\text{Individual exertion}}{\text{Individual exertion} + \text{individual nonexertion}} \right]}{\text{Number of exertion cycles}} \times 100\%$$

44.3.6 Repetitive Movement Analysis

Repetitive movement analysis quantifies the frequency of movements of a specific joint. In the SHARP Study, shoulder movements are quantified through a time study of the recorded tasks using the MVTA program (Yen and Radwin, 1995). Two events are defined to distinguish the directions of the shoulder (the upper arm) movements. A complete movement cycle is defined as movement of the upper arm from one direction to another. Again the left and right shoulders are analyzed separately. Average frequency of the shoulder movement can then be computed based on the raw data report generated by the MVTA program:

$$\text{Average frequency (times/ min)} = \frac{\text{Number of movement cycles}}{\text{Total recording time}}$$

44.3.7 Work Organization Measurement

The SHARP Study is associated with the NIOSH Research Consortium on Work-related Musculoskeletal Disorders, along with other U.S. research groups. One of the first collaborative efforts of the consortium was to develop an observational assessment tool for work organization characteristics adapting elements from AET (Rohmert and Landau, 1983), EWA (Ahonen et al., 1996), and VERA (Volpert et al., 1989). SHARP has been using this checklist (Figure 44.8) at the departmental level during baseline exposure

assessment. Prior to specific physical job demand parameter observations, supervisors and workers are queried about the number and type of tasks and their usual duration, rotation patterns, and upset conditions. The ergonomist observes the department that the worker is in for environmental factors, demographic segregation, work method, social content, pacing, positioning, preparation for action, flexibility, attentiveness demands (adapted from EWA; Ahonen et al., 1996), responsibility for the safety of

Organization of Work Observational Rating Sheet				
Worksite _____		Department _____		Job _____
Date ____ / ____ / ____		Analyst _____		
Gender mix overall job:		<input type="checkbox"/> Male ⁰	<input type="checkbox"/> Female ¹	<input type="checkbox"/> Mixed ²
Gender segregation by sub-task?		<input type="checkbox"/> No ⁰ <input type="checkbox"/> Yes ¹ → <i>Specify</i>		
Other demographic segregation?		<input type="checkbox"/> No ⁰ <input type="checkbox"/> Yes ¹ → <i>Specify</i>		
Ambient Environment				
Temperature: _____				
Humidity: _____				
Illumination: <input type="checkbox"/> Adequate <input type="checkbox"/> Too Bright <input type="checkbox"/> Too low for task				
Noise: <input type="checkbox"/> Normal talk <input type="checkbox"/> Yell <input type="checkbox"/> Hearing protection				
Housekeeping:	<input type="checkbox"/> Very Good	<input type="checkbox"/> Good	<input type="checkbox"/> Bad	<input type="checkbox"/> Very Bad
	well controlled storage and cleanliness	neat and orderly; some clutter but generally contained	housekeeping is fair; some clutter on pedestrian traffic routes	dirty and poor storage of materials
Task-Level Work Organization				
Labor Content:	a) <input type="checkbox"/> Direct production / service delivery ¹ <input type="checkbox"/> Indirect production / service delivery ² b) <input type="checkbox"/> Non-skilled ¹ <input type="checkbox"/> Semi-skilled ² <input type="checkbox"/> Skilled manual ³ <input type="checkbox"/> Skilled trade ⁴ <input type="checkbox"/> Professional ⁵			
Job Type:	<input type="checkbox"/> Temporary Workers ¹ <input type="checkbox"/> Hourly, Full-time Workers ² <input type="checkbox"/> Salaried, Full-time Workers ³			
Work Method:	<input type="checkbox"/> Assembly Line ¹ <input type="checkbox"/> Work Cells ² <input type="checkbox"/> Desk Work ³			
Posture Type:	<input type="checkbox"/> Primarily dynamic posture ¹ <input type="checkbox"/> Primarily static postures ² <input type="checkbox"/> Combination of dynamic and static postures ³			
Social Content:	<input type="checkbox"/> Individual ¹ <input type="checkbox"/> Work team, minimal coordination ² <input type="checkbox"/> Work team, mod. coordination ³ <input type="checkbox"/> Work team, high coordination (<i>planning, decision making</i>) ⁴			
Positioning:	<input type="checkbox"/> Single-task, single activity ¹ (e.g. 1 station, only insert screws) <input type="checkbox"/> Single-task, multiple activities ³ (e.g. 1 station, operates multiple machines) <input type="checkbox"/> Multiple tasks ² (e.g., rotate through stations, perform different tasks throughout day)			
Pacing:	<input type="checkbox"/> Self ¹ <input type="checkbox"/> Social/Peer ² <input type="checkbox"/> Machine ³ <input type="checkbox"/> Line ⁴ <input type="checkbox"/> Piece rate ⁵ <input type="checkbox"/> Quota ⁶			
Pacing Control:	<input type="checkbox"/> None ¹ <input type="checkbox"/> Manual over-ride ² <input type="checkbox"/> Event triggered ³ <input type="checkbox"/> Work ahead (e.g., up-line) ⁴ <input type="checkbox"/> Inventory "buffer" ⁵ <input type="checkbox"/> Material staging (e.g., sub-assembly) ⁶ <input type="checkbox"/> Regular informal breaks (e.g., relief staff coverage) ⁷			
Prep for Action:	<input type="checkbox"/> None ¹ <input type="checkbox"/> Maintain "working posture" between work "events" ² <input type="checkbox"/> Part handling ³ <input type="checkbox"/> Maintain grasp of tool/other between work "events" ⁴			

FIGURE 44.8 A sample of work organization checklist used in the SHARP study.

Job Rotation:	<input type="checkbox"/> No ⁰ <input type="checkbox"/> Yes ¹ → <input type="checkbox"/> Hourly ¹ <input type="checkbox"/> Other ² (specify) _____ → Number of jobs in rotation schedule: _____ (# jobs) → Use of different muscle groups? <input type="checkbox"/> No ⁰ <input type="checkbox"/> Some ¹ <input type="checkbox"/> Mostly ²
Recent Dept Changes:	<input type="checkbox"/> None ¹ <input type="checkbox"/> Work methods, all new duties ² <input type="checkbox"/> Job enlargement ³ (i.e. vertical job additions) <input type="checkbox"/> Job Rotation ⁴ (i.e. horizontal job additions)
Work Group	
	Comments
Flexible work hours	<input type="checkbox"/> Yes <input type="checkbox"/> Somewhat <input type="checkbox"/> No
Flexible work arrangements	<input type="checkbox"/> Yes <input type="checkbox"/> Somewhat <input type="checkbox"/> No
Formal break schedule	<input type="checkbox"/> Yes <input type="checkbox"/> Somewhat <input type="checkbox"/> No
Informal break possibilities	<input type="checkbox"/> Yes <input type="checkbox"/> Somewhat <input type="checkbox"/> No
Extended work hours	<input type="checkbox"/> 8 hr <input type="checkbox"/> 10 hr <input type="checkbox"/> 12 hr <input type="checkbox"/> Other
Shift work	<input type="checkbox"/> Yes <input type="checkbox"/> Somewhat <input type="checkbox"/> No

Attentiveness Demands (adapted from EWA)					
<input type="checkbox"/> ¹ Superficial	<input type="checkbox"/> ² Average	<input type="checkbox"/> ³ Somewhat High	<input type="checkbox"/> ⁴ Very High		
handling materials that are not delicate, stamping papers	positioning parts, passive monitoring	proof reading, inspection, active monitoring with some consequence	use of adjusting and measuring instruments; drawing maps; active monitoring with critical consequence		
Responsibility for Safety of Others					
<input type="checkbox"/> ¹ Does not apply	<input type="checkbox"/> ² Very Limited	<input type="checkbox"/> ³ Limited	<input type="checkbox"/> ⁴ Average	<input type="checkbox"/> ⁵ Significant	<input type="checkbox"/> ⁶ Very Significant
	worker bears little responsibility for safety of others	worker responsible for safety of others within narrow limits (e.g., proper operation of punch press, lathe)	Worker must maintain vigilance to ensure others are not injured by his/her actions (e.g., operating a crane, auto)	Continual care to ensure safety of others (e.g., handling explosives)	Safety of other depends mainly on the corrective actions of worker (e.g., pilot, surgeon)
Job Content *					
Rating	AET (Landau & Rohmert)	Ergonomic Workplace Analysis	Action Regulation		
<input type="checkbox"/> ¹ Very minor structural restraints	Worker determines the organization of work, e.g., freelance artist	Work method is in no way restricted to the requirements of a machine, process or the production method or pace.	Establish new working processes - the goal of the actions is not determined in advance.		
<input type="checkbox"/> ² Little structural restraint	Personal freedom of action to organize work to meet general requirements of the job, e.g., sales representative or a scientist		Coordinating several working processes - planning of several sub-goals is needed and their coordination needs to be considered.		
<input type="checkbox"/> ³ Average structural restraints	e.g., activities of teachers, administrative workers	Work method is occasionally restricted; demands concentration on the task for a certain time.	Sub-goal planning - a rough planning of sequence is needed and each activity needs its own planning with the sequent activity depending upon the result of the first.		
<input type="checkbox"/> ⁴ Strong structural restraints	Performs a largely predetermined sequence of tasks		Action planning - a sequence of work steps needs to be planned and different circumstances need to be considered.		
<input type="checkbox"/> ⁵ Very strong structural restraints	The sequence of tasks is precisely determined, e.g., parts assembly.	Work method is completely restricted by a machine, process or work group.	Sensory motoric - no conscious planning is needed and occasionally different tools might be used.		

FIGURE 44.8 Continued.

others, and job content. During subsequent visits, changes to the work organization are documented using the checklist.

The annual worker questionnaire interview inquires about duration on the current job, shift, hours and days of work, overtime schedules, the number of days off in the last week and month, changes in the previous 4 months in tools/equipment, parts made, workstation/area, tasks, rotation pattern, pace. Changes in these parameters are queried every 4 months. Annual self-administered questionnaires include questions about job demands, decision latitude, social support, job satisfaction, job security, and motivation.

It should be noted that there is high correlation between this observational assessment of work organization and worker assessment of psychosocial demands. There is also high correlation between job content identified on this checklist and HAL.

44.4 Summary

The SHARP Study uses a variety of exposure assessment approaches at the individual level and the more global level, incorporating worker estimates (force matching, job content, psychosocial demands, social support, work scheduling), direct measurement (significant push/pull, lifting, pinch and grip forces), observational methods of physical demands (upper extremity postures and motions in terms of amplitude, frequency, and duration), and departmental-level measures of work organization. These data collection methods allow us to input variables into existing event-based and time-based exposure assessment methods (RULA, REBA, HAL, Strain Index) as well as to add precision to estimates of risk based on more quantitative time-based methods. It is hoped that these detailed exposure assessment methods used by ourselves and others in prospective studies will ultimately lead to more efficient and easy-to-use exposure assessment methods for practitioners.

References

- ACGIH (2001) Hand activity level. In *TLVs and BEIs — Threshold Limit Values for Chemical Substances and Physical Agents*. Cincinnati, OH: ACGIH.
- Ahonen, A., Launis, M., and Kuorinka, T. (1996) *Ergonomic Workplace Analysis*. Helsinki, Finland: Finnish Institute of Occupational Health.
- Armstrong, T. J. and Chaffin, D. B. (1979) Carpal tunnel syndrome and selected personal attributes, *J Occup Med* 21 (7): 481–486.
- Armstrong, T. J., Dunnigan, J., Ulin, S., and Foulke, J. (1993) Evaluation of a biaxial flexible wire electrogoniometer for measurement of wrist posture. Paper presented at the 24th Congress of the International Commission on Occupational Health.
- Armstrong, T. J., Foulke, J. A., Joseph, B. S., and Goldstein, S. A. (1982) Investigation of cumulative trauma disorders in a poultry processing plant, *Am Ind Hyg Assoc J* 43 (2): 103–116.
- Bao, S. and Silverstein, B. (2005) Estimation of hand force in ergonomic job evaluations, *Ergonomics* 48: 288–301.
- Baty, D., Buckle, P. N., and Stubbs, D. A. (1986) Posture recording by direct observation, questionnaire assessment and instrumentation: a comparison based on a recent field study. In *The Ergonomics of Working Postures*. Edited by N. Corlett and J. Wilson. London: Taylor & Francis.
- Belkic, K., Savic, C., Theorell, T., and Cizinsky, S. (1995) *Work Stressors and Cardiovascular Risk: Assessment for Clinical Practice. Part I*. Stockholm (Sweden): Stress Research Reports, National Institute for Psychosocial Factors and Health. Section for Stress Research, Karolinska Institute, WHO Psychosocial Center.
- Bernard, B. P., Sauter, S. L., Fine, L. J., Petersen, M., and Hales, T. R. (1994) Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees, *Scand J Work Environ Health* 20: 417–426.
- Blanc, P., Faucett, J., Kennedy, J. J., Cisternas, M., and Yelin, E. (1996) Self-reported carpal tunnel syndrome: predictors of work disability from the National Health Interview Survey Occupational Health Supplement, *Am J Ind Med* 30 (3): 362–368.
- Borg, G., Ljunggren, G., and Ceci, R. (1985) The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer, *Eur J Appl Physiol* 54: 343–349.
- Borg, G. A. V. (1982) Psychophysical bases of perceived exertion, *Med Sci Sports Exer* 14 (5): 377–381.
- Buchholz, B. and Wellman, H. (1997) Practical operation of a biaxial goniometer at the wrist joint, *Hum Factors* 39: 119–129.
- Burdorf, A. and Laan, J. (1991) Comparison of methods for the assessment of postural load on the back, *Scand J Work Environ Health* 17: 425–429.

- Corlett, E. N., Madeley, S. J., and Manenica, I. (1979) Posture targetting: a technique for recording working postures, *Ergonomics* 22 (3): 357–366.
- Fallentin, N., Juul-Kristensen, B., Mikkelsen, S., Andersen, J. H., Bonde, J. P., Frost, P., and Endahl, L. (2001) Physical exposure assessment in monotonous repetitive work — the PRIM study, *Scand J Work Environ Health* 27 (1): 21–29.
- Fransson, C., Gloria, R., Kilbom, Å., Karlqvist, L., Nygård, C-H., Wiktorin, C., Winkel, J., and the Stockholm MUSIC I Study Group. (1991) Presentation and evaluation of a portable ergonomic observation method (PEO). In *11th Congress International Ergonomics Association: Designing for Everyone*. Edited by Y. Quéinnec and Daniellou. London: Taylor & Francis.
- Fransson-Hall, C., Bystrom, S., and Kilbom, A. (1996) Characteristics of forearm-hand exposure in relation to symptoms among automobile assembly line workers, *Am J Ind Med* 29 (1): 15–22.
- Freivalds, A. and Eklund, J. (1993) Reaction torques and operator stress while using powered nutrunners, *Appl Ergon* 24 (3): 158–164.
- Frost, P. and Andersen, J. H. (1999) Shoulder impingement syndrome in relation to shoulder intensive work, *Occup Environ Med* 56 (7): 494–498.
- Helliwell, P. S., Mumford, D. B., Smeathers, J. E., and Wright, V. (1992) Work related upper limb disorder: the relationship between pain, cumulative load, disability, and psychological factors, *Ann Rheum Dis* 51: 1325–1329.
- Hignett, S. and McAtamney, L. (2000) Rapid entire body assessment (REBA), *Appl Ergon* 31: 201–205.
- Holmstrom, E. B., Lindell, J., and Mortiz, U. (1992) Low back and neck/shoulder pain in construction workers: occupational workload and psychosocial risk factors Part 1: relationship to low back pain, *Spine* 17 (6): 663–671.
- Holzman-Voigt, P. (1979) ARBAN: a method for ergonomic analysis of work sites, *Arh Hig Rada Toksikol* 30: 82–86.
- Holzmann, P. (1982) ARBAN — a new method for analysis of ergonomic effort, *Appl Ergon* 13 (2): 82–86.
- Hägg, G. M., Oster, J., and Bystrom, S. (1997) Forearm muscular load and wrist angle among automobile assembly line workers in relation to symptoms, *Appl Ergon* 28 (1): 41–47.
- Karhu, O., Härkönen, R., Sorvali, P., and Vespsäläijnen, P. (1981) Observing working postures in industry: examples of OWAS application, *Appl Ergon* 12: 13–17.
- Karhu, O., Kansi, P., and Kuorinka, I. (1977) Correcting working postures in industry: a practical method for analysis, *Appl Ergon* 8 (4): 199–201.
- Kasl, S. V. (1992) Surveillance of psychological disorders in the workplace panel. In *Work and Well-being: An Agenda for the 1990s*. Edited by G. P. Keita, and S. L. Sauter. Washington, DC: American Psychological Association, pp. 73–95.
- Kemmlert, K. and Kilbom, Å. (1986) *Method for the Identification of Musculo-skeletal Stress Factors which may Have Injurious Effects — PLIBEL*. Solna, Sweden: National Board of Occupational Safety and Health, Research Department, Work Physiology Unit.
- Kerr, M. S., Frank, J. W., Shannon, H. S., Norman, R. W., Wells, R. P., Neumann, W. P., and Bombardier, C. (2001) Biomechanical and psychosocial risk factors for low back pain at work, *Am J Public Health* 91 (7): 1069–1075.
- Keyserling, W. M. (1986) Postural analysis of the trunk and shoulders in simulated real time, *Ergonomics* 29: 569–583.
- Kilbom, Å., Persson, J., and Jonsson, B. (1986) Risk factors for work-related disorders of the neck and shoulder with special emphasis on working postures and movements. Edited by N. Corlett, J. Wilson, and I. Manenica. London: Taylor & Francis.
- Kingdon, K. and Wells, R. (2000) Accuracy of force matching using a hand dynamometer, Unpublished work from University of Waterloo, Ontario, Canada.
- Latko, W. (1997) Development and evaluation of an observational method for quantifying exposure to hand activity and other physical stressors in manual work, Ph.D. Dissertation, The University of Michigan.

- Latko, W. A., Armstrong, R. J., Foulke, J. A., Herrin, G. D., Ranbourn, R. A., and Ulin, S. S. (1997) Development and evaluation of an observation method for assessing repetition in hand tasks, *Am Ind Hyg Assoc J* 58 (4): 278–285.
- Lloyd, A., Gandevia, S., and Hales, J. (1991) Muscle performance, voluntary activation, twitch properties and perceived effort in normal subjects and patients with the chronic fatigue syndrome, *Brain* 114: 85–98.
- Lueder, R. (1996) A proposed RULA for computer users. Proceedings of the Ergonomics Summer Workshop, August 8–9, UC Berkeley Center for Occupational and Environmental Health.
- Marras, W. S. and Schoenmarklin, R. W. (1993) Wrist motions in industry, *Ergonomics* 36: 341–351.
- McAtamney, L. and Corlett, E. N. (1993) RULA: a survey method for the investigation of work-related upper limb disorders, *Appl Ergon* 24: 91–99.
- Moore, J. S. and Garg, A. (1995) The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. *Am Ind Hyg Assoc J* 56: 443–458.
- Moore, A., Wells, R., and Ranney, D. (1991) Quantifying exposure in occupational manual task with cumulative trauma disorder potential, *Ergonomics* 34 (12): 1433–1453.
- MOW International Research Team (1987) *The Meaning of Working*. London: Academic Press.
- Nathan, P. A., Keniston, R. C., Meadows, K. D., and Lockwood, R. S. (1993) Validation of occupational hand use categories, *J Occup Med* 35: 1034–1042.
- National Institute for Occupational Safety and Health (NIOSH) (1992) *Selected Topics in Surface Electromyography for Use in the Occupational Setting: Expert Perspectives*. DHHS (NIOSH) Publication No. 91–100.
- National Institute for Occupational Safety and Health (NIOSH) (1997) *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back*. DHHS (NIOSH).
- National Institute for Occupational Safety and Health (NIOSH) (1994) *Revised NIOSH Lifting Equation*. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.
- Niebel, B. W. (1988) *Motion and Time Study*, 8th edn. Homewood, IL: Irwin.
- Nordstrom, D. L., Vierkant, R. A., DeStefano, F., and Layde, P. M. (1997) Risk factors for carpal tunnel syndrome in a general population, *Occup Environ Med* 54: 734–740.
- Panel on Musculoskeletal Disorders and the Workplace; Commission on Behavioral and Social Sciences and Education; National Research Council, and Institute of Medicine (2001) *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*. Washington, DC: National Academy Press.
- Persson, J. and Kilbom, Å. (1983) VIRA — en enkel videofilmteknik för registrering och analys av arbetsställningar och rörelser, Vol. 10, 23 pp.
- Pope, D. P., Silman, A. J., Cherry, N. M., Pritchard, C., and Macfarlane, G. J. (1998) Validity of self-completed questionnaire measuring the physical demands of work, *Scand J Work Environ Health* 24 (5): 376–385.
- Punnett, L. (1998) Ergonomic stressors and upper extremity disorders in vehicle manufacturing: cross sectional exposure–response trends, *Occup Environ Med* 55: 414–420.
- Punnett, L., Fine, L. J., Keyserling, W. M., Herrin, G. D., and Chaffin, D. B. (2000) Shoulder disorders and postural stress in automobile assembly work, *Scand J Work Environ Heal* 26 (4): 283–291.
- Radwin, R. G., Lin, M. L., and Yen, T. Y. (1993) Exposure assessment of biomechanical stress in repetitive manual work using spectral analysis. In Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, pp. 669–693.
- Roberts, R. (1997) Calibration procedure for the Penny and Giles Z110 torsionmeter. University of Massachusetts Lowell, unpublished master's project.
- Rohmert, W. and Landau, K. (1983) *A New Technique for Job Analysis*. London: Taylor & Francis.
- Roquelaure, Y., Mechali, S., Dano, C., Fanello, S., Benetti, F., Bureau, D., Mariel, J., Martin, Y.-H., Derriennic, F., and Penneau-Fontbonne, D. (1997) Occupational and personal risk factors for carpal tunnel syndrome in industrial workers, *Scand J Work Environ Health* 23: 364–369.

- Sauter, S. L. and Swanson, N. G. (1996) An ecological model of musculoskeletal disorders in office work. In *Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work*. Edited by S. D. Moon and S. L. Sauter. London: Taylor & Francis.
- SHARP (1999) Ergonomics evaluation report on a trimmer operator's job. Technical Report 22-4-1999. Washington State Department of Labor and Industries, Olympia, WA.
- Silverstein, B., Fine, L. J., and Armstrong, T. J. (1987) Occupational factors and carpal tunnel syndrome, *Am J Ind Med* 11: 343–358.
- Smutz, P., Serina, E., and Rempel, D. (1994) A system for evaluating the effect of keyboard design on force, posture, comfort, and productivity, *Ergonomics* 37 (10): 1649–1660.
- Snook, S. H. (1978) The design of manual handling tasks, *Ergonomics* 21 (12): 963–985.
- Snook, S. H., Vaillancourt, D. R., Ciriello, V. M., and Webster, B. S. (1995) Psychophysical studies of repetitive wrist flexion and extension, *Ergonomics* 38 (7): 1488–1507.
- Spielholz, P., Silverstein, B. A., and Stuart, M. (1999) Reproducibility of a self-report questionnaire for upper extremity musculoskeletal disorder risk factors, *Appl Ergon* 30: 429–433.
- Stetson, D. S., Keyserling, W. M., Silverstein, B. A., and Leonard, J. A. (1991) Observational analysis of the hand and wrist: a pilot study, *Appl Occup Environ Hyg* 6 (11): 927–937.
- Stetson, D. S., Silverstein, B. A., Keyserling, W. M., Wolfe, R. A., and Albers, J. W. (1993) Median sensory distal amplitude and latency: comparisons between nonexposed managerial/professional employees and industrial workers, *Am J Ind Med* 24: 175–189.
- Toomingas, A., Theorell, T., Michelsen, H., Nordemar, R., and Stockholm MUSIC I Study Group. (1997) Associations between self-rated psychosocial work conditions and musculoskeletal symptoms and signs, *Scand J Work Environ Health* 23: 130–139.
- Veiersted, K. B. and Westgaard, R. H. (1993) Development of trapezius myalgia among female workers performing light manual work, *Scand J Work Environ Health* 19: 277–283.
- Viikari-Juntura, E., Martikainen, R., Luukkonen, R., Mutanen, P., Takala, E., and Riihimaki, H. (2000) A longitudinal study of work-related and individual risk factors of radiating neck pain. People and Work Research Report, Helsinki, Finland.
- Viikari-Juntura, E., Rauas, S., Marikainen, R., Kuosma, E., Riihimaki, H., Takala, E., and Saarenmaa, K. (1996) Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders, *Scand J Work Environ Health* 22: 251–259.
- Volpert, W., Kötter, W., Gohde, H.-E., and Weber, W. G. (1989) Psychological evaluation and design of work tasks: two examples, *Ergonomics* 32 (7): 881–890.
- Wiktorin, C., Karlqvist, L., Winkel, J., and Stockholm MUSIC I Study Group, (1993) Validity of self-reported exposures to work postures and manual materials handling, *Scand J Work Environ Health* 19: 208–214.
- Wiktorin, C., Selin, K., Ekenvall, L., Kilbom, A., and Afredsson, L. (1996) Evaluation of perceived and self-reported manual forces exerted in occupational materials handling, *Appl Ergon* 27 (4): 231–239.
- Winkel, J. and Gard, G. (1988) An EMG-study of work methods and equipment in crane coupling as a basis for job redesign, *Appl Ergon* 19 (3): 178–184.
- Winkel, J. and Mathiassen, S. E. (1994) Assessment of physical work load in epidemiologic studies: concepts, issues and operational considerations, *Ergonomics* 37: 979–988.
- Yen, T. Y. and Radwin, R. G. (1995) A video-based system for acquiring biomechanical data synchronized wit arbitrary events and activities, *IEEE Transactions on Biomedical Engineering* 42 (9): 944–948.