

## Occupational Ergonomics: Emphasis on Identification or Solutions

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**Abstract:** This paper provides an overview of the major techniques (or tools) for conducting workstation analyses for the purpose of assessing risk for musculoskeletal disorders. No attempt is made to discuss the superiority of one identification tool over another but, rather, to provide information about the relevancy of each in different workstation design scenarios. In addition, the overall process for conducting workstation analyses is discussed with an emphasis on prioritization, solution development, implementation and follow-up strategies. The “trade-off” between extensive evaluations and solution implementation is also discussed.

### 1. Introduction

The role of the occupational ergonomist to identify workstations for evaluation by analyzing available information, recommends a workstation evaluation system that helps to identify the severity of ergonomic related risk factors through the use of ergonomics evaluation models, reviews methods for developing recommendations to reduce the risk factors present in a task or operation, and proposes ways to validate the effectiveness of implemented recommendations. In this paper, the terms solutions, recommendations, abatement methods, and controls are used interchangeably to mean actions that reduce the exposure and/or presence of risk factors.

### 2. Ergonomic Evaluation Process

The problem solving structure with for the ergonomics evaluation process is a presented in graphical form in Figure 1.

#### 2.A. Preliminary Data Analysis

The first step in accurately defining the problem is to take a broad look at information for the department or area to be analyzed. The preliminary analysis should consist of a determination of the workstation, tasks, or operations present, a review of injury records, an analysis of the current discomfort level of the workers, a discussion of important relevant non-ergonomic factors such as hours worked (including overtime), age of workers, years of work experience, and worker turnover. When the information in the preliminary data analysis is as accurate and complete as possible, it is easier to determine the areas of the greatest impact of change. At the end of the preliminary analysis, the evaluator will have enough information to prioritize the order of evaluation for workstations or tasks.

##### 2.A.1. Workstation Flow Diagram

When presented with a group of workstations that should be assessed, it is often helpful to develop a flow diagram. The diagram should be a pictorial representation of the approximate location of workstations in the appropriate order. The flow diagram can include information such as workstation name, key workstation operations or tasks, processing time, material inputs (types and locations of bins or holders), machine process information (including machine time).

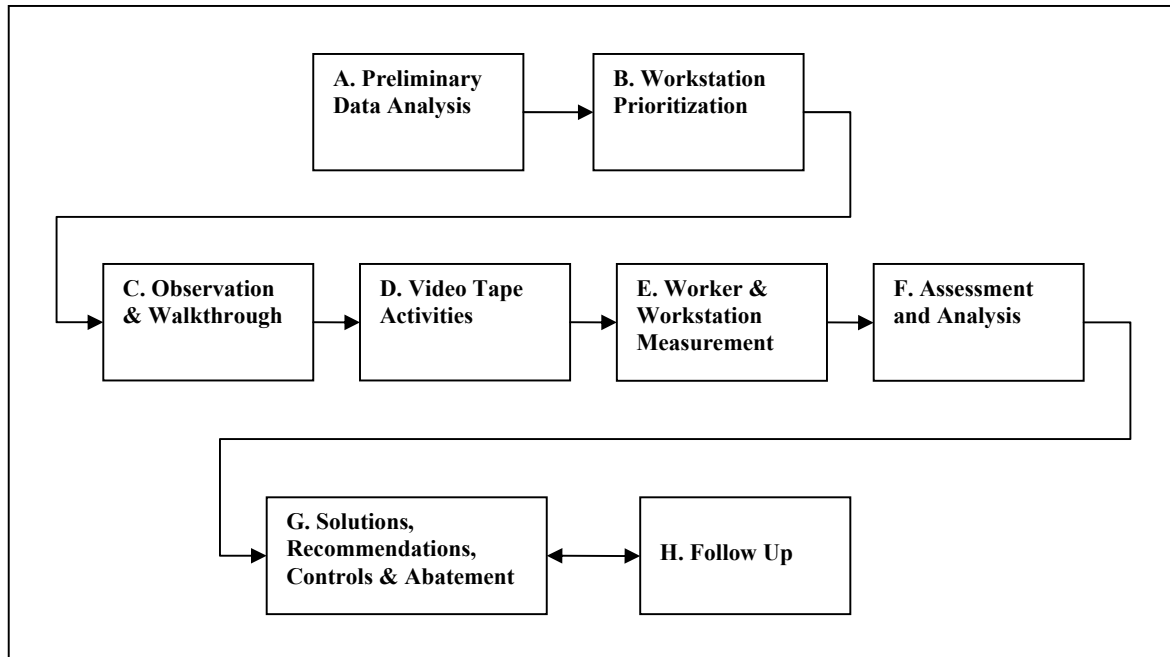


Figure1. Ergonomic Evaluation Process

This workstation flow diagram will assist in showing the relationship between workstations and can be used later to show the impact of changes in layout. Additional information regarding the order of operations within each workstation will be helpful in the detailed analysis discussed later in the chapter. Special attention should be paid to workstations that involve lifting of heavy parts, workstations with short cycle times (less than 30 seconds), and workstations that require a large travel distance.

### 2.A.2. Injury Records Review

After the workstation flow diagram has been completed, an injury records review can assist in determining which workstations may have risk factors that are causing injuries. A thorough injury records review includes all of the injury records for the facility or department for the previous three to five years. The easiest and most common form of injury records are the OSHA 300 logs and injury investigation forms. This will provide a general idea of the types of injuries that have occurred. Many companies have additional information that includes the workstation or operation that was being performed when the injury happened in the injury investigation report that is often completed by the supervisor or safety personnel.

The injuries should be separated and counted by department. Departments with higher injury frequencies may include jobs or tasks that have a number of significant injury risk factors. Additional analysis can be done to determine how many of the injuries within each department occurred at the same workstation or while performing the same task.

### 2.A.3. Pareto Analysis

Pareto analysis can be used in the preliminary analysis as well as during recommendation development. Pareto analysis includes sorting the data by a given criteria (e.g., workstations with injuries, cost of recommendation implementation, number of awkward postures decreased). Conceptually, the ergonomist uses Pareto analyses to concentrate greatest effort on the few jobs that produce most of the concern (such as cost, frequency, severity, etc.).

During the preliminary data analysis, Pareto analysis will identify where the majority of analysis effort should be spent to gain the greatest benefit. Pareto analysis during recommendation development provides the company with specific recommendations that may decrease more than one awkward posture or improve productivity in addition to decreasing injury risk.

#### 2.A.4. Pie Chart

Pie charts are used to show subgroups that make up a whole. All of the data is represented in the shape of a pie. Each subgroup is represented by a slice of the pie. Each slice is sized to appropriately represent the proportion of the subgroup to the whole either by a fraction or by a percentage. During an ergonomic evaluation a pie chart may be used to show the number of injuries attributed to a particular workstation, operation or task as compared to all of the injuries that occurred during a given time period. A pie chart may also be used to depict the percentage of budget that will be used to implement specific recommendations.

#### 2.A.5. Trend Analysis

Trend analysis looks at the pattern created by a specific data set. The data should be collected and depicted in a bar graph with the categories positioned from largest number of occurrences to smallest number of occurrences. Some useful trends to analyze include discomfort or injuries by body part, by task, by shift, by time of the day, by gender, by years of experience, by age, or by worker turnover.

### **2.B. Prioritization of Workstations**

In order to determine where analysis efforts are best invested, the preliminary data discussed above should be used. Several individual or a combination of prioritization schemes may be used to identify the priority of workstation evaluations. One scheme that may be used is the severity of injuries that have occurred at a given workstation. When utilizing this scheme, the workstation with the most severe injury case type (usually days away from work) will be evaluated before a workstation that has not caused an injury or has caused a first aid injury. Along with severity, one may also look at the frequency of workstation injuries. In this case, the workstations that caused the most injuries will be evaluated before other workstations that have caused fewer injuries. Another prioritization scheme that is often used is to determine the number of employees that could be affected by changes to a particular workstation or work area. In this case, the areas or workstations that affect the most people would be analyzed first. Finally, workstations can be prioritized by the estimated cost of controls. In this case, workstations may be ordered in a variety of ways depending on the amount of money available. Most often, a workstation that requires a low to moderate amount of money to significantly decrease the risk factors is evaluated before a workstation that requires a larger amount of money for the same amount of risk decrease. Occasionally, the way budgets are structured requires the analysis of high capital or high cost of control items before the analysis of lower cost of control items.

### **2.C. Observation and Walkthrough**

Observation is the first key to workstation evaluation. Conduct a general walkthrough of the area noting anything that may be of concern. Spend a few minutes observing the worker at the workstation to get an overview of the area and work. The goal of this observational period is to get a general feel for the types of work being conducted, the layout of the workstation, and the risk factors that are present. Pay special attention to the tasks being performed and the body postures and forces associated with completion of the workstation tasks. When there is more than one shift or more than one worker, it is recommended to observe and collect data on a cross section of workers that are representative of the shifts and worker population. At the end of the observation period, a brief interview should be conducted with the worker to discuss the specific order of operations for the workstation being analyzed, the duration of the shift,

breaks, and overtime.

## **2.D. Video Tape Activities**

The next step in evaluation is to videotape the worker. The worker should be taped for at least 3-5 cycles, or 10 minutes, whichever is longer. It is important to get at least 2-3 cycles in each camera view. If the cycle time is short, getting as many as 10-20 cycles is optimal. In addition to documenting the cycle time, photographs or video should be taken of the general work area and layout. This will serve as documentation of the types and sizes of materials handling bins, carts, workstation location, activation lever locations, hand tools, and other key components to successfully completing the operation.

## **2.E. Worker and Workstation Measurement**

Measurements should be taken of both the worker and the workstation. Important worker measurements include standing knuckle height, standing (or seated) elbow height, standing (or seated) eye height, popliteal height (if seated), and thigh height (if seated). When reviewing more than one worker, these measurements should be taken for each affected worker (if available). All measurements of the workstation should be taken including the workstation height, reach distances to objects on workstation, height and reach of activation buttons, and height and reach of product jigs and fixtures. All measurements should reference the floor and worker position as appropriate.

When materials handling is performed as a part of the workstation activities, all relevant materials handling inputs should be collected including starting height, ending height, horizontal distance, distance carried, angle of trunk rotation during the lift, frequency of task, whether the lift is performed with one or two hands, weight of object(s) being lifted, and total duration.

When hand tools are used at the workstation, it should also be documented. Important attributes for hand tools include handle length, handle shape, handle orientation (inline, pistol grip, or other), handle material, handle diameter, approximate activation force (easy, medium, or hard), weight of tool, presence of vibration, and presence of counter balance.

Estimates of force applications such as push force, pinch force, and grip force should be made. When possible, the direct measurement should be taken with a force meter. When this is not possible, the forces applied should be estimated with respect to the maximum effort applied in that particular position (e.g., a pinch force application should be compared to a maximum pinch force). The forces should be classified as low (less than 30% maximum force), medium (30%-50% maximum force), or high (50% - 100% maximum force).

### **2.E.1. Worker and Management Input**

Worker input can be one of the most helpful data collection tools. During the course of data collection, the evaluator should ask the worker to identify the most difficult task, the task that they least like to perform, the task that causes them the most discomfort, and whether they have anything they would change about their work environment. The answers to these questions can provide the evaluator with key clues to the tasks that may have the highest risk factors and ways that they could be easily remedied. A body part discomfort survey can yield more information when trying to identify high risk workstations or tasks. The body part discomfort survey can be used as a general screening tool and a specific workstation evaluation tool.

## **2.F. Assessment and Analysis**

After the observation, video, measurements, and worker data have been recorded, these data should be

analyzed in order to identify the risk factors present using a variety of methods including both traditional industrial engineering and specific ergonomic methodologies.

#### 2.F.1. Video Analysis

Traditional ergonomic video analysis is a method of analyzing a task through video tape so that it may be viewed a number of times at different speeds (frame-by-frame and regular) and classifying the awkward postures and number of repetitive forces. The best method of this type of analysis is to watch the available video more than once, each time concentrating on documenting the number, direction, and extent of the awkward postures. For example, one time through the video the concentration could be on the neck and back. During this viewing, the evaluator will document the frequency of awkward postures per minute or per cycle. This should be done throughout the tape so as to ensure a representative sample. This value can then be converted into a value that represents the number of motions per hour and compared to published standards.

#### 2.F.2. Strain Index

The Strain Index (SI) is a semi-quantitative job analysis methodology that results in a numerical score that correlates with the risk of developing distal upper extremity disorders (mainly hand, wrist, and elbow). The SI is the product of six multipliers including intensity of exertion, duration of exertion, exertions per minute, hand/wrist posture, speed of work, and duration of task per day. An SI score greater than five indicates an increased risk for distal upper extremity disorders (Moore and Garg, 1995).

#### 2.F.3. Rapid Upper Limb Assessment (RULA)

Rapid upper limb assessment (RULA) was developed to generally assess the loads sustained by the musculoskeletal system due to work posture, muscle use and force exerted and to calculate the exposure to risk factors associated with upper extremity MSDs (McAtamney and Corlett, 1993). It is a good tool to use when trying to identify or prioritize a number of tasks for further investigation. RULA creates a grand score that represents the musculoskeletal loading. A score of 5 or 6 requires prompt investigation and change, and a score of 7 requires immediate investigation and change (Massaccesi et al., 2003).

#### 2.F.3. Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) was developed to generally assess whole body loads. Like its counterpart, RULA, REBA is appropriate for prioritizing a series of tasks for further evaluation. REBA uses scores A and B to determine a Score C, and Score C is used to determine the final REBA score. Score A includes postures for the neck, trunk, and legs and is augmented by a load/force score. Score B includes postures for the upper arms, lower arms, and wrists and is augmented by a coupling score. Scores A and B are combined to determine Score C. Score C is augmented with an Activity Score to identify the REBA score. A REBA score of 1-3 is considered acceptable, scores of 4-7 indicate a medium risk with necessary action. A score of 8-10 indicates high risk with action soon, and a score of 11-15 indicates very high risk with immediate action (Hignett and McAtamney, 2000).

#### 2.F.4. Ovako Working Posture Analyzing System (OWAS)

The Ovako Working Posture Analyzing System (OWAS) consists of two parts. The first part contains an observational technique for evaluating working postures. The second part contains a set of criteria for redesign of working methods and places (Karhu et al., 1977). The method was created by collecting information on all possible working postures and then standardizing them with regard to trunk, arm, and legs

#### 2.F.5. Lumbar Motion Monitoring (LMM)

Lumbar Motion Monitoring (LMM) assesses the instantaneous position of the lumbar spine in three dimensions. The LMM is an exoskeleton of the spine that is attached to the subject at the thorax and the pelvis with a semi-rigid material. The LMM replicates the motion of the T section in the Lumbar spine

created by the spinous processes and the transverse processes in the posterior aspect of each spinal vertebrae. The exoskeleton is worn on the back, moves along with the subject, and is connected to potentiometers via wires. As the exoskeleton moves the wires change voltage within the potentiometers documenting forwards, backwards, lateral, or twisting motion. These voltage changes can then be analyzed to determine position, velocity, or acceleration of the trunk (Marras et al., 1992).

#### 2.F.6. Michigan 3D Static Strength Prediction Program (3DSSPP)

The Michigan 3D static strength prediction program (3DSSPP) was developed to assist in the analysis of biomechanical forces during manual handling activities. 3D SSPP software predicts static strength requirements for tasks such as lifts, presses, pushes, and pulls. The program provides an approximate job simulation that includes posture data, force parameters and male/ female anthropometry. Output includes the percentage of men and women who have the strength to perform the described job, spinal compression forces, and data comparisons to NIOSH guidelines. The user can analyze torso twists and bends and make complex hand force entries. Analysis is aided by an automatic posture generation feature and three dimensional human graphic illustrations (Chaffin et al., 2006).

#### 2.F.7. NIOSH Lifting Equation

The National Institute for Occupational Safety and Health (NIOSH) initially developed a lifting guideline in 1981 (NIOSH, 1981) that was later updated in 1991 (Putz-Anderson and Waters, 1991). The NIOSH guideline remains unique in that it is based upon a more comprehensive set of criteria and task factors than other models. According to NIOSH (1997) “The review provided evidence for a positive relationship between back disorder and heavy physical work, although risk estimates were more moderate than for lifting/forceful movements, awkward postures, and WBV. This was perhaps due to subjective and imprecise characterization of exposures. Evidence for dose-response was equivocal for this risk factor.”

#### 2.F.8. Psychophysical Models

Psychophysical data has been used to develop the NIOSH lifting guide as well as the Liberty Mutual models for manual material handling tasks. In both of these cases, the data were generated using whole body exertion. It has been widely used in establishing acceptable weights of lift (e.g., Mital, A., Nicholson, A.S., Ayoub, M.M., 1997, Snook, S.H. and Ciriello, V.M., 1991). Still other design data have been generated for other body segments, particularly the upper-extremities in studies conducted at Wichita State University (Fernandez et al., 1995).

### **2.G. Solutions, Recommendations, Controls, and Abatement**

After the risk factors have been identified and prioritized, controls or recommendations should be developed to reduce each risk. Controls may be classified in one of three categories: engineering, administrative, or personal protective equipment. In all situations, engineering changes should be the preferred method of change. Engineering changes are superior to administrative changes and personal protective equipment because engineering modifications permanently change the workstation or process to reduce or eliminate the presence of the hazard. Some examples of engineering controls include workstation design and redesign, hand tool selection and implementation, workstation layout, and process redesign.

Administrative changes work to reduce exposure to the hazard through the development of rules, policies and regulations (however, the presence of the hazard remains). Some examples of administrative changes include worker training, worker selection, task sequencing, and modifications to the work pace or frequency.

Personal protective equipment (PPE) are aids that reduce the exposure through creating a barrier. Some

examples of PPE include gloves, safety boots, hearing protection, and safety goggles. It should be noted that wrist splints and back belts are not effective PPE and should be worn only in cases where they have been recommended by a qualified medical professional for rehabilitation purposes.

Besides type of control (as mentioned earlier), controls can be classified as short term, long term, or ideal. Short term controls are lower in cost and can be implemented rather quickly. One example is to use a phonebook as a monitor riser until an appropriately designed riser can be purchased. Long term controls tend to be higher in cost and may take a longer time to implement. Ideal controls are the modifications that should be made if cost and time were not constraining factors.

#### 2.G.1. Implementation of Controls

After the controls have been recommended, there may be some decision processes to determine the order in which controls are implemented. Often this includes a cost benefit analysis to determine what controls will provide the largest decrease in risk for the dollars that are being spent. When the modifications are implemented, it is important that all of the workers receive training on the proper use of the new equipment, handtools, or processes. Without this training, workers may experience increased risk instead of decreased risk.

#### **2.H. Follow Up**

Follow-up evaluations should be conducted to ensure the effectiveness of any modifications. The goal of the follow-up is to ensure that additional risks have not been inadvertently created and to document the decreases in risks as compared to the previous evaluation. The process for the follow-up evaluation will be a somewhat abbreviated version of the initial evaluation process outlined in this chapter. It should include additional preliminary data collection (e.g., additional injuries or other significant events), videotaping, recording of measurements, analysis of data, and identification of risks. These quantified risks can be compared to those of the original evaluation and improvements in risk factors, productivity, and quality can be noted.

### **3. Discussion**

The proliferation of tools used in the risk assessment of workstations is due in part upon the virtually limitless iterations of design configurations, materials, and many other work parameters that are seen in modern business and industry. No single tool is equally useful across a wide range of workstations. It is up to the ergonomic analyst to determine the most appropriate technique under the given circumstances they encounter.

There are certainly instances when the analyst understands through observational evidence or other compelling data from initial assessment that risk for injury is present. Examples may come from a worker exposed to regular lifting of heavy items, or regular motions requiring substantial postural deviations, or very frequent motions in repetitive tasks, or other task profiles in which the ergonomic analyst's experience will dictate that risk assessment, by any technique, will result in a high level. In such situations, the analyst should weigh the cost to further document risk and the identification of specific agents, against the time reduced to determine feasible solutions. When the risk of injury is clearly evident, development of solutions should be pursued as soon as feasibly possible.

The advantages of early development of solutions in the Ergonomic Evaluation Process could include higher productivity, lower severity and cost of injury, increased work quality, lower absenteeism, lower worker turnover, lower lost work time, and increased morale. Other benefits are sometimes more difficult to measure, for example, when workers see a relatively quick turn-around in terms of assessment, followed shortly by workstation modification, workers will be more receptive to the solutions being

proposed. This can lead to even more dramatic and positive impacts resulting from the solutions implemented.

#### 4. Concluding Remarks

This paper provides an overview of the process by which ergonomic evaluation is conducted as well as provided a summary of major evaluation techniques (or tools) by which an ergonomic expert may utilize in the assessment of musculoskeletal risk due to poor workstation design. Each technique has its strengths and weaknesses and it is incumbent upon the ergonomic analyst to understand these differences and where each may be best utilized. We have also implored the expert to not succumb to the temptation to over-analyze certain situations wherein the risk factor(s) is/are readily apparent. It is our contention that engineering and/or administrative improvements in workstation design should not be delayed for the sake of a slightly higher degree of confidence in the risk assessment. This may be even more imperative during difficult economic conditions wherein workers may already be emotionally (perhaps physically) stressed due to changing work conditions.

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