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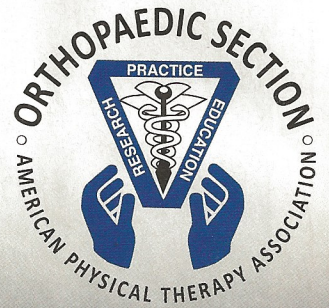
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Ergonomic Exposure Assessment Methods for Identifying Musculoskeletal Disorder Risk in the Workplace: An Example from the Grocery Industry

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ABSTRACT

Background and Purpose: Work-related musculoskeletal disorders (WRMSDs) are common in industry. Physical risk factors are associated with WRMSDs, and ergonomics programs are effective in reducing exposure to these factors. The purpose of this paper is to describe the exposure assessment methods used in an ongoing ergonomics study of the grocery industry and provide practical suggestions for physical therapists who wish to function as ergonomic consultants to industry. Four ergonomic exposure assessment methods used in the grocery ergonomics study are described. **Clinical Relevance:** The ergonomic exposure assessment methods described in this paper may be used by physical therapists to evaluate risk factors associated with WRMSDs. Exposure assessment methods are readily available through online resources and may be used by clinicians to perform ergonomic consultation.

Key Words: occupational, participatory ergonomics, grocery, exposure assessment methods

INTRODUCTION

Work-related musculoskeletal disorders (WRMSDs) are prevalent throughout all sectors of the workforce and hinder the ability of workers to perform job-related tasks.¹⁻³ The economic impact that WRMSDs have on industry is large; WRMSDs account for the highest percentage of compensation and disability cases among workers.⁴ Additionally, WRMSDs result in lost productive time due to days away from work.⁵ In 2010, the Bureau of Labor Statistics estimated that 40% of all nonfatal occupational injuries and illnesses that resulted in days away from work were due to sprains, strains, or tears.⁶

The grocery industry is no exception. For example, the incidence rate of sprains and strains among grocery workers was 65.7 per 10,000 full time workers compared to 48.3 for the retail industry in general.⁷

It is well established that exposure to physical risk factors is associated with WRMSDs.^{4,8} Common risk factors found in grocery stores include forceful and repetitive exertions of the hand, heavy lifting, and awkward or sustained postures.⁹⁻¹² Specific examples include repetitive scanning of items by cashiers, lifting heavy boxes by meat cutters, and frequent trunk forward bending by bakers.

The risk of musculoskeletal injury inherent in a particular work task can be estimated by assessing exposure to risk factors in that task. Many exposure assessment methods are available for physical therapists to use in any industry where they provide ergonomic consultative services. The purpose of this paper is to describe the exposure assessment methods used in a study of participatory ergonomics in the grocery industry.

PROJECT DESIGN

The primary goal of the ongoing ergonomics study is to evaluate the effectiveness of a participatory ergonomics (PE) program for the grocery industry. Participatory ergonomics is a process where management and employees receive education in ergonomics and WRMSD risk management. They can then work together to identify risk factors, brainstorm to come up with solutions to mitigate the factors, and implement these changes to reduce the risk of WRMSDs.^{13,14} To date, no studies have examined the effectiveness of participatory ergonomics programs within grocery stores.

The project methods were based on the

"Ergonomics Process" consisting of 5 steps: (1) identification, (2) analysis, (3) solution development, (4) solution implementation, and (5) re-evaluation.^{14,15} In the initial phase of the study, we administered Step 1 of the Ergonomics Process and surveyed grocery workers about musculoskeletal symptoms they felt were work-related using the Modified Nordic Survey.¹⁶ Additionally, we identified physical risk factors in the grocery store and analyzed them (Step 2) using the ergonomic exposure assessment methods described below.

After implementing these baseline steps, we implemented an ergonomic training intervention for the store's safety committee members. This 6-hour training emphasized committee implementation of the Ergonomics Process into current systems using a problem-solving approach. Topics of the training included the goals of ergonomics; common work-related MSDs among grocery workers; modifiable work factors; workplace risk factors; basic methods of ergonomic exposure assessment; ergonomic job analysis of grocery tasks; ergonomic process implementation; hierarchy of controls (ergonomic solutions); and the development, implementation, and evaluation of solutions. The training was customized for the participating grocery stores by using video clips of their workers performing tasks. A PowerPoint version of this training will be available at the Washington State Department of Labor & Industries Web site at the conclusion of the study.

ERGONOMIC EXPOSURE ASSESSMENT

As mentioned, Step 2 of the Ergonomics Process is analysis of the worksite, also called "exposure assessment." There are 3 types of

exposure assessment methods commonly used by ergonomic consultants: self-report, observational, and direct measurement.¹⁷ Self-report methods require the worker to estimate exposure to risk factors, such as rating perceived exertion (RPE) with the Borg scale.¹⁸ These methods have the potential for bias since the respondent can over- or under-report workplace exposure. In contrast, exposure can be directly measured with instrumentation, such as surface electromyography for estimating forceful exertions or electrogoniometry for measuring awkward wrist postures. Although more accurate than self-report, direct measurement is costly and limited to assessing a minimum number of anatomical sites.

Observational exposure assessment methods are a compromise between the simplicity and ease of use of self-report methods, and the precision of direct exposure assessment.¹⁹ Observational analysis methods are being used in the current study to allow for simple, noninvasive, and efficient exposure assessment while grocery workers perform work tasks in their natural work environment.

Tasks were selected for observational analysis based on worker reports of fatigue while performing tasks, and/or observation of potentially hazardous tasks during the investigators' initial store walk-through. Particular tasks were measured and included stocking of large items by the freight crew, bread making, meat cutting, stocking milk, and cashiering, among others. Each task was filmed for 10 to 30 minutes depending on the assessment method used for the task. To ensure accurate representation of the task, two video cameras were placed on tripods at approximately 90° angles to each other. For tasks requiring manual material handling, a tape measure and scale were used to measure distances and weights, respectively. When possible, investigators were not present in the work area during filming in an attempt to minimize the Hawthorne Effect,²⁰ ie, workers modify how they do a task if observed.

After data was collected, exposure to physical risk factors was assessed in the Biomechanics and Ergonomics Laboratory at Eastern Washington University using 4 methods: Rodgers Muscle Fatigue Analysis, Hand Activity Level, Ovako Working Posture Analyzing System, and Utah Back Compressive Force Scale. These methods were selected because they efficiently and accurately assess exposure. Additionally,

these methods are easy to learn for those without formal training in ergonomics, ie, safety committee members. Finally, the techniques are versatile and can be used by physical therapists to assess exposure at virtually any worksite.

Rodgers Muscle Fatigue Analysis

The Rodgers Muscle Fatigue Analysis is being used in the current study to prioritize grocery work tasks in terms of their ability to cause musculoskeletal fatigue.²¹ The primary construct of the Rodgers Analysis is that musculoskeletal fatigue could lead to a WRMSD. This method assesses the 3 variables associated with any physical risk factor: effort level, frequency, and duration. Effort level estimates worker exertion based on body posture, load lifted, and/or force exerted. Effort frequency is assigned by recording the number of times the worker performs the exertion per minute. Duration measures the length of time for a single exertion in seconds. The combination of effort level, frequency, and duration determine the risk of fatigue, ie, injury potential, for the task being assessed. Specific anatomical regions, for example, the neck, shoulders, or back, are assessed separately.

The outcome of the Rodgers Muscle Fatigue Analysis is a 'priority for change' score, categorized as low, moderate, high, or very high. The physical therapist can use this score to prioritize which tasks to modify first, as well as which variable (effort, duration, and/or frequency) should be modified to reduce the risk of injury. In an example from the study, the task of stocking milk (Figure 1) earned a high priority for change score of 313 at the shoulder. This score indicated the worker was "exerting forces or holding weight with arms away from body or overhead" for less than 6 seconds at a time but repeating this effort 5 to 15 times per minute.

Since effort contributed the most to potential musculoskeletal fatigue in the previous example, potential ergonomic solutions could include lowering milk shelves to below shoulder height and incorporating shelf sliders so the milk could roll into position rather than being pushed forward by the worker. The frequency score could be reduced by lifting milk containers with alternate hands or interspersing the stocking task with other tasks. In participatory ergonomics programs, the safety committee is often charged with developing potential solutions for reducing exposure to risk factors (Step 3

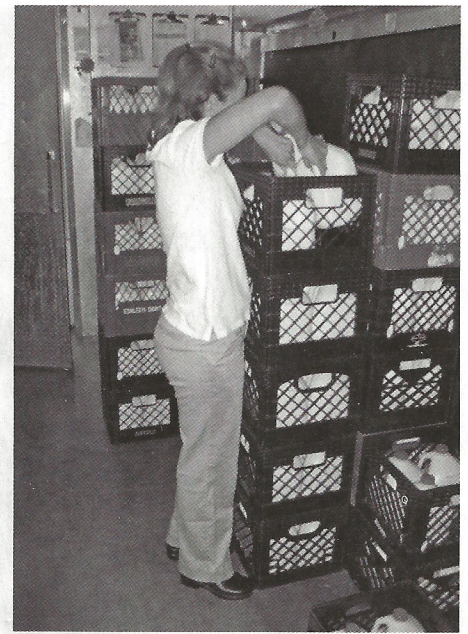


Figure 1. Example of task assessed with the Rodgers Muscle Fatigue Analysis. Primary physical risk factors of stocking milk are repetitive exertions and awkward shoulder postures.

of the Ergonomics Process), although outside experts such as physical therapists may assist with this step.

Hand Activity Level

Certain tasks in the grocery industry, such as cashiering and meat cutting, are considered highly repetitive for the hand. To assess this risk factor, the Hand Activity Level (HAL) measure was used.²² The HAL is a 0 to 10 point scale that estimates both hand "pauses" or rest periods and hand "busyness" or speed of hand movement. Higher HAL ratings are associated with WRMSDs of the distal upper extremity, such as carpal tunnel syndrome.²³ This assessment method has been used in a variety of industries including automotive, manufacturing, and health care.²⁴⁻²⁸ Additionally, the HAL is one of only 3 ergonomic exposure assessment methods that has a Threshold Limit Value (TLV),²⁹ the level of exposure that minimizes potential for musculoskeletal injury. In the current study, the mean HAL score for meat cutting (Figure 2) was 8 for some workers, which is considered high repetition.

Ovako Working Posture Analyzing System

To assess awkward postures during grocery tasks, the Ovako Working Posture Ana-



Figure 2. Meat cutting assessed with the Hand Activity Level.

Table 1. Description of the OWAS Scoring Method

Anatomical Region	Description	OWAS Score*
Back	Straight	1
	Bent forward	2
	Twisted or bent sideways	3
	Bent and twisted	4
Shoulders/Arms	Both arms below shoulder level	1
	One arm at or above shoulder level	2
	Both arms at or above shoulder level	3
Legs	Sitting	1
	Standing with both legs straight	2
	Standing with one leg straight	3
	Standing or squatting with both knees bent	4
	Standing or squatting with one knee bent	5
	Kneeling on one or both knees	6
	Walking or moving	7
Load Weight	< 10 kg	1
	10 -20 kg	2
	> 20 kg	3

*Higher OWAS scores do not necessarily indicate higher exposure.

lyzing System (OWAS) was used.^{30,31} This "work sampling" method requires the physical therapist to make numerous observations of low back, shoulder, and lower extremity posture, and enter a number related to each posture category (Table 1) into a computer program (WinOWAS, Tampere University of Technology, Finland). The load handled by the worker is similarly entered. Samples are taken at a repeated time interval for a set

duration; in the current study, samples were taken every 15 seconds for 30 minutes. The OWAS method can be used in real time by using a laptop computer or by watching a video recording of the task.

When all samples are collected, the computer program calculates the percentage of time the worker spends in each posture category. The task is then placed into an "action category" (AC), reflecting the risk level for

developing WRMSDs. The first action category, AC 1, is considered a normal posture, while ACs 2 through 4 are classified as harmful postures. The OWAS method is especially beneficial for analyzing tasks without a set work cycle, such as the freight tasks in the current study. Grocery freight workers spend hours unloading boxes off pallets, stacking items onto low and high grocery store shelves, and moving heavy pallet jacks down aisles in order to stock items. As a result of this repetitive manual material handling, OWAS placed freight tasks into one of the harmful AC categories.

Utah Back Compressive Force Scale

The Utah Back Compressive Force Scale (UBCF) is being employed in the current study to estimate spinal compression at the L5-S1 joint.³² When using this tool, the physical therapist weighs the object to be lifted with a scale, measures the horizontal distance from the object to the L5-S1 motion segment with a tape measure in real time, and estimates the worker's maximal lumbar flexion angle during the task. These values and the worker's body weight are used to estimate the compressive force on the spine. If the compressive force of the task is greater than a benchmark of 3.4 kN (770 lb), the task is considered hazardous and could lead to injury.³³ Due to the approximation method of the UBCF Scale and the potential for measurement error, a slightly lower benchmark of 700 lb is suggested for the force limit.

We are using the UBCF to estimate spinal compressive forces while stocking 16 kg dog food bags (Figure 3, Table 2). As indicated in Table 2, the estimated compressive force of 1,136 lb was well over the acceptable 700 lb value. The load and moment contributed the most to the compression. Therefore, these variables should be considered for change first when modifying the task. Potential solutions include using a lift team when handling heavier objects, use of pallet jacks with a scissors lift to maintain lifting between knee and waist height (Figure 4), or modifying the height of the store shelves.

DISCUSSION

After task identification and exposure assessment, the next few steps in the Ergonomics Process are solution development and implementation, followed by re-evaluation of the newly designed tasks. Thus, the Ergonomics Process works in a circular fashion, allowing for continued ergonomic



Figure 3. Stocking dog food assessed with the Utah Back Compressive Force Scale. Since the physical risk factors are heavy lifting and awkward back postures, the Rodgers Muscle Fatigue Analysis and OWAS could also be used.

Table 2. UBCF Scale Results for Lifting Dog Food Task*

Measure	Value
Body weight (lb)	175
Load (eg, weight of dog food bag; lb)	44
Horizontal distance from hands to L5-S1 joint (in)	23
Back posture angle from vertical (degrees)	90
Contributing Factors*	
A. Back posture	525
B. Load moment with dog food bag lift	506
C. Compression from dog food bag and upper body weight	105
Estimated compressive force (A+B+C; lb)	1,136
* Equations for contributing factors are as follows: $A=3 \text{ (Body weight)} \times [\sin \text{ (Back posture angle from vertical)}]$ $B=0.5 \text{ (Load)} \times \text{(Horizontal distance from hands to L5-S1)}$ $C=0.8 \text{ [(Body weight)/2 + Load]}$	

improvement in the workplace.³⁴

In the current ergonomics study, grocery workers have been eager to develop ergonomic solutions. For example, a worker from the meat department recognized that grinding meat into hamburger was stressful on his back. The position of the grinder required him to stand in a forward flexed static posture for long periods of time (Figure 5). Since raising the height of the grinder was not possible, his simple solution was to sit on a milk crate while grinding the meat. Inexpensive solutions such as this are common for many ergonomic interven-

tions.^{14,35} Regardless, successful participatory ergonomics programs involve both workers and management in solution development. The ergonomic consultant guides the process but is not the primary individual recommending solutions.

In the current study, multiple assessment methods were used to analyze one task if that task demonstrated several physical risk factors. For example, cashiers are not only exposed to highly repetitive actions of the hand but also experience static postures of the neck. Therefore, the HAL and Rodgers Muscle Fatigue Analysis were used. It is at

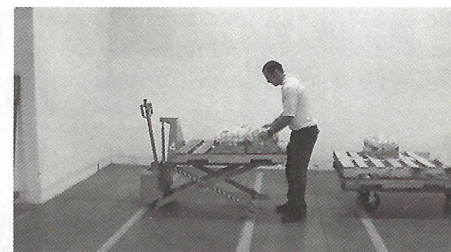


Figure 4. Scissors lifts pallet jacks are an example of an ergonomic solution that could maintain lifting between knee and waist height.

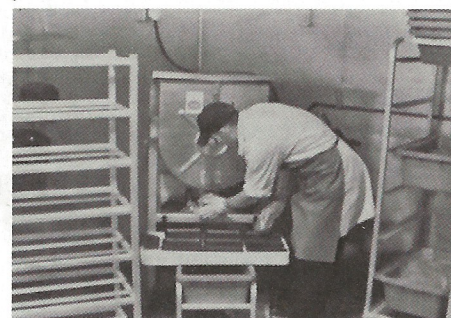


Figure 5. Grinding hamburger in a prolonged trunk flexion posture.

the discretion of the physical therapist to determine which assessment methods are appropriate for analyzing a task.

Physical therapists must have an adequate understanding of exposure assessment methods to function as independent ergonomic consultants. The Web site for the American Physical Therapy Association's Occupational Health Guidelines³⁶ and the *Guide to Physical Therapist Practice*³⁷ are useful resources to begin exploring the role of ergonomics in physical therapy. Continuing education courses, either online or in-person, are another way to learn about occupational health topics. Also, visiting a patient's worksite is an excellent way to gain experience in ergonomics. Finally, online resources are available describing various exposure assessment methods. A comprehensive site of these methods has been compiled by Dr. Thomas Bernard, Department of Occupational and Environmental Health, University of South Florida.³⁸ This Web site contains a description and instructions for each exposure assessment method, helpful for physical therapists deciding which exposure assessment to use when analyzing a certain task.

Physical therapists are trained to be experts in movement science and musculoskeletal injuries. As ergonomic consultants,

physical therapists can expand their role in health care and help minimize the tremendous economic impact that WRMSDs have across all sectors of industry.

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- ## ERGONOMIC EXPOSURE ASSESSMENT METHODS FOR IDENTIFYING MUSCULOSKELETAL DISORDER RISK IN THE WORKPLACE: AN EXAMPLE FROM THE GROCERY INDUSTRY
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