Initiating an Ergonomic Analysis

A PROCESS FOR JOBS WITH HIGHLY VARIABLE TASKS

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Abstract

Occupational health nurses play a vital role in addressing ergonomic problems in the workplace. Describing and documenting exposure to ergonomic risk factors is a relatively straightforward process in jobs in which the work is repetitive. In other types of work, the analysis becomes much more challenging because tasks may be repeated infrequently, or at irregular time intervals, or under different environmental and temporal conditions, thereby making it difficult to observe a "representative" sample of the work performed. This article describes a process used to identify highly variable job tasks for ergonomic analyses. The identification of tasks for ergonomic analysis was a two step process involving interviews and a survey of firefighters and paramedics from a consortium of 14 suburban fire departments. The interviews were used to generate a list of frequently performed, physically strenuous job tasks and to capture clear descriptions of those tasks and associated roles. The goals of the survey were to confirm the interview findings across the entire target population and to quantify the frequency and degree of strenuousness of each task. In turn, the quantitative results from the survey were used to prioritize job tasks for simulation. Although this process was used to study firefighters and paramedics, the approach is likely to be suitable for many other types of occupations in which the tasks are highly variable in content and irregular in frequency.

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Describing and documenting exposure to ergonomic risk factors is a relatively straightforward process in jobs in which the work is repetitive. In a manufacturing environment, for example, a set of stereotypic tasks may be repeated anywhere from several times a minute to once every week or two. In any case, the task is repeated in a defined sequence, which in turn lends itself to observation and ergonomic analysis.

In other types of work the analysis becomes much more challenging because tasks may be repeated infrequently, or at irregular time intervals, or under different environmental and temporal conditions, thereby making it difficult to observe a "representative" sample of the work performed. In some cases, the work may be per-

What Does This Mean for Workplace Application?

Describing and documenting exposure to ergonomic risk factors is a relatively straightforward process in jobs in which the work is repetitive. However, in the current work environment, especially in the service sector, it is often difficult to observe a representative sample of the work performed because tasks may be repeated infrequently, at irregular time intervals, or under different conditions. The approach described here can be used by occupational health nurses to address serious musculoskeletal problems in high hazard occupations in which the at risk job tasks are difficult to identify.

formed in environments in which direct observation is not possible.

For instance, in the fire service, emergency rescue tasks are never exactly the same and certainly not repetitive. Situational factors, such as time constraints, condition of the patient, and type of emergency, vary from one incident to another. Fire department resources, including number of personnel and types of equipment, also differ. Therefore, the first challenge in performing ergonomic analyses of jobs such as fire service workers, is to identify what aspects of the work have potential ergonomic concerns and where there is potential for ergonomic intervention. In the fire service there is clearly a need for this type of analysis. Research has shown it is one of the most hazardous occupations in the United States, with musculoskeletal injuries accounting for approximately half of all injuries (International Association of Fire Fighters, 1998; Karter, 1999).

It is increasingly common for firefighters to be cross trained both as firefighters and as paramedics or emergency medical technicians. As with fire suppression tasks, the emergency medical service (EMS) aspect of the firefighter's job poses serious ergonomic risks. In a retrospective study, Hogya (1990) reported high rates of musculoskeletal injury among urban emergency medical technicians and paramedics. Fifty-six percent of the injuries reported in their study were strains and sprains. By far, the largest single category was back injuries (36% of all injuries). Most (62%) were caused by lifting (Hogya, 1990). While this epidemiological approach is informative, by itself, it does not provide direction for potential ergonomic intervention. This requires a better understanding of the types of lifting tasks performed by EMS personnel. While some authors have identified and performed analyses on selected emergency rescue tasks (Doormaal, 1995), there is a need for better specification of the lifting tasks in relation to their relative frequency and physical demands.

This article describes a process used to identify highly variable job tasks for ergonomic analyses. Although this process was used to study cross trained firefighters/paramedics (FFPs), the approach is likely to be suitable for many other types of occupations in which the tasks are highly variable in content and irregular in frequency.

METHODS

Overview of the Process

The identification of tasks for ergonomic analysis was a two step process involving interviews and a survey of FFPs from a consortium of 14 suburban fire departments. The goals of the interviews were to generate a list of frequently performed, physically strenuous job tasks and to capture clear descriptions of those tasks and associated roles. The goals of the survey were to confirm the interview findings across the entire target population of FFPs and to quantify the frequency and degree of strenuousness of each task. In turn, the quantitative results from the survey were used to prioritize the top five tasks for simulation. Ultimately, the simulation allowed for detailed postural and biomechanical analyses (Lavender, 2000a; 2000b).

Step 1: Interviews

Interviews were conducted with the personnel who actually carried out the EMS tasks to accurately identify the most frequently performed, physically strenuous job tasks performed during EMS activities.

Sample. A purposive sample of FFPs from fire departments chosen to reflect the organizational diversity contained in the consortium was interviewed. The fire departments varied in terms of the age, design, and density of the residential, commercial, and industrial buildings in their service territory. The fire departments also varied in size, economic resources, and staffing schemes (e.g., union versus nonunion, full time versus paid on call).

The interview sample (n = 29) included 1 Black man, 1 Asian man, 3 White women, and 24 White men. Participation in the interviews was voluntary. Many interviewees seemed eager to have an opportunity to describe and demonstrate the nature of their EMS tasks and explain what made them physically challenging.

Procedures. Fire departments were purposively approached one at a time to recruit personnel to be interviewed. A letter was sent to all line duty personnel in the target fire departments who performed EMS tasks. The letter indicated the purpose of the study and the nature of the interview process. The letter explained that a researcher would be calling to speak to personnel about voluntary participation. The calls made to recruit personnel for the interviews included a set of screening questions to ensure the personnel interviewed were individuals who frequently performed EMS activities they considered physically strenuous.

Participants were interviewed one at a time at their firehouse, with interviews lasting up to 1 hour. Audiotapes, videotapes, and photographs were taken during the interviews and later reviewed by all members of the research team. The photographs and videotapes were used to capture detailed task descriptions and demonstrations of postures. When redundancy of information was achieved, the interviewing phase was concluded. This

Figure 1a.

Figures 1a and 1b. Firefighters/paramedics demonstrating work postures during an interview session to identify frequently performed, physically strenuous job tasks.

occurred after the 29th interview. The 29 FFPs were from 8 of the 14 fire departments.

Instrument: The Interview Guide. To test and refine the interview guide, five pilot interviews were conducted with personnel from a fire department resembling the 14 fire departments involved in the full study. Sample questions from the final interview guide include the following:

- Which EMS and rescue tasks are both strenuous and frequently performed? (Suggested criteria for "strenuous" included subsequent fatigue or soreness.)
- What about these tasks makes them physically strenuous?
- Describe and demonstrate the movements and postures associated with each of the roles involved in performing each of these tasks.

End Product of Step 1. Using the hand written notes of the interviewer as well as the photographs, audiotapes, and the videotapes from the interviews, the research team developed the list of tasks for the survey and wrote a scenario to describe each of the top 11 tasks. Figures 1a and 1b are photographs of the FFPs during an interview simulating how a task is performed. The 11 task and role descriptions are shown in Table 1.

Step 2: Job Task Survey

The task survey was conducted to validate that the EMS tasks identified in the interviews were representative of the most frequently performed physically strenuous tasks in the target population of FFPs. Thus, the survey allowed the researchers to quantify the degree to which the EMS tasks identified through the interview process were reported to be physically strenuous and frequently performed among a representative sample of FFPs from the study population.

Sample. All 542 FFPs were invited to participate in the survey process. Twenty four were used in a pilot study of the survey and were excluded from the mailing of the main survey ($n = 518$). A total of 374 usable questionnaires were returned yielding a completion rate of 72%.

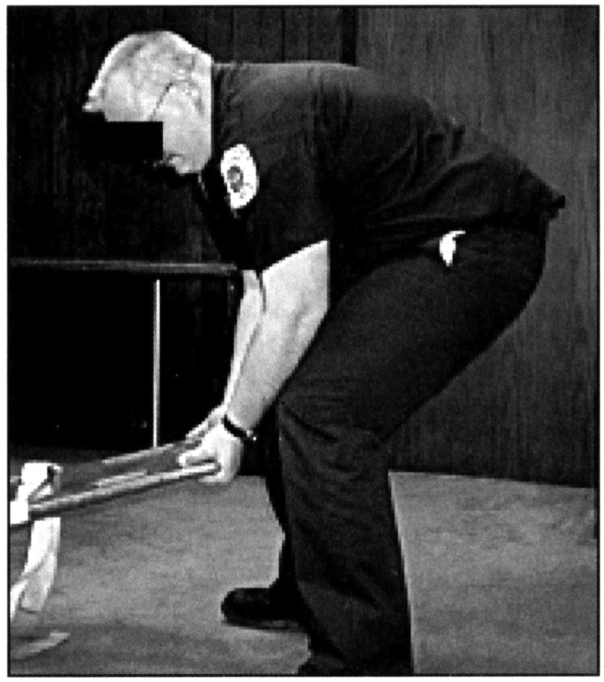

Figure 1b.

Procedures. Each participant received a packet containing the questionnaire and a postage paid, preaddressed envelope for returning the questionnaire directly to the university Survey Research Laboratory. The surveys were sent in one bundle by express mail to each fire department. To encourage response, a random drawing was held to award three cash prizes (a $100 grand prize, a $75 second prize, and a $50 third prize). A letter was also sent to the fire chiefs urging them to encourage participation among his FFPs. Approximately 14 days after the initial mailing, a follow up postcard was sent to all the FFPs and a follow up letter to each fire chief. One month after the initial mailing, a second mailing of questionnaires was sent to those FFPs who had not yet responded. The study was approved by the university Institutional Review Board to assure the protection of the participating FFPs.

Survey Instrument. The Questionnaire Review Committee of the university Survey Research Laboratory reviewed the draft questionnaire. A pilot test was conducted with 24 FFPs to evaluate the appropriateness of the instrument and the survey procedures. Of the 24 pilot surveys distributed, 19 were returned, yielding a completion rate of 79%. Because the questionnaire was solidly based on the interview data, no changes to the EMS task list were required. Based on the pilot study data and feedback from the Questionnaire Review Committee, the questionnaire response format was slightly revised and minor changes to the coding procedures were made. The questionnaire was then finalized and printed in an easy to use booklet format.

A sample item from the questionnaire is shown in Table 2. For each task, the FFPs were asked to provide

TABLE 1

The List of Tasks and Roles Used in the Survey

Task	Task Description	Role Description
1	Two FFPs* remove a patient from an automobile on a backboard.	Role 1: At foot of backboard closest to patient. Role 2: At head of backboard, steadying and supporting backboard during transfer.
2	Two FFPs lift a patient from the floor for transfer to a bed or stretcher.	Role 1: FFP lifts patient at torso from behind. Role 2: FFP lifts patient's legs.
3	Two FFPs transfer a patient from a bed to a stretcher using sheets.	Role 1: Kneeling on the bed, FFP lifts patient toward stretcher. Role 2: Standing on the far side of the stretcher, FFP pulls patient onto stretcher.
4	Two FFPs move a patient from a bed on a backboard.	Role 1: FFP stands near the head of the bed, essentially lifting the patient's upper body as the backboard is lifted. Role 2: FFP is near the foot of the bed and lifts the patient's lower body.
5	Two FFPs secure a patient in a confined space to a backboard.	Role 1: FFP shifts patient's upper body onto backboard and secures. Role 2: FFP shifts patient's lower body onto backboard and secures.
6	Two FFPs carry a patient on a backboard down a straight line of steps.	Role 1: FFP in upper position, going forward down the stairs. Role 2: FFP in lower position, going backwards down the stairs.
7	Two FFPs carry a patient on a backboard around a curve in the stairway.	Role 1: FFP in upper position, going forward down the stairs. Role 2: FFP in lower position, going backwards down the stairs.
8	Two FFPs carry a patient in a stair-chair down a straight line of steps.	Role 1: FFP in upper position, going forward down the stairs. Role 2: FFP in lower position, going backwards down the stairs.
9	Four FFPs carry a patient in a stair-chair down a straight line of steps.	Role 1: One of two FFPs holding the upper part of the stair-chair, going forward down the stairs. Role 2: One of two FFPs holding the lower part of the stair-chair, going backwards down the stairs.
10	Two FFPs carry a patient on stretcher down a straight line of steps.	Role 1: FFP in upper position, going forward down the stairs. Role 2: FFP in lower position, going backwards down the stairs.
11	Two FFPs transfer a patient from a stretcher to a hospital gurney using sheets.	Role 1: Standing along side the stretcher, this FFP lifts the patient away from the stretcher and toward the gurney. Role 2: Standing along side the gurney, this FFP lifts and pulls the patient to the gurney.

** FFP = firefighter/paramedic*

ratings for each of two separate jobs ("roles") described as being part of the task. These jobs describe how the FFP is maneuvering the client or piece of equipment. For example, Task 6 is transporting a client on a backboard down a straight line of steps while being in the higher position walking forward (Role 1) or being in the lower position walking backward (Role 2). The FFP was asked to rate each task and role combination in relation to frequency and the degree to which the task role combination was strenuous using the scales shown in Table 2. The questionnaire also asked for age category, years of relevant work experience, and whether or not the FFP was currently experiencing physical pain or had changed work methods because of physical pain.

TABLE 2

Sample Items from the Survey Showing Question Format

Task 4. Two workers move a patient from a bed on a backboard.

This task begins when a patient has been placed on a backboard but the backboard with the patient on it is still lying on the bed. The task consists of lifting the backboard loaded with the patient off the bed for transfer to a stretcher. There are two separate jobs in this task.

Job 1. Worker 1 is standing at the side of the bed near its head. (The physical layout prevents Worker 1 from standing at the head of the bed.) Worker 1 twists and leans in over the bed, grips the head of the backboard, and twists away from the bed, bringing the head of the backboard up and away from the bed.

Job 2. Worker 2 is standing at the foot of the bed in line with the backboard. Worker 2 leans forward, grips the foot of the backboard, lifts it up off the bed, and steps sideways to bring the backboard away from the bed.

1. Out of every 10 emergency calls, on approximately how many calls do you perform Job 1?

   Less than 1 call in every 10........ 1

   1 to 2 calls out of every 10.......... 2

   3 to 4 calls out of every 10.......... 3

   5 to 6 calls out of every 10.......... 4

   7 to 8 calls out of every 10.......... 5

   9 to 10 calls out of every 10........ 6

2. How physically strenuous is Job 1 for you?

   Not at all strenuous..................... 1

   A little strenuous......................... 2

   Somewhat strenuous.................. 3

   Very strenuous............................ 4

For each task-job combination the respondent was asked to answer two questions as shown in this table. The respondent would go on to answer the same two questions for Job 2 of Task 4. The 11 tasks are shown in Table 1.

Analysis. To assure the quality of the data coding, 52% (194) of the returned questionnaires were checked for accuracy by the data reduction coordinator at the Survey Research Laboratory. Only five errors were found, yielding an error rate of only .04%. As an additional quality check, frequencies were run on all the variables after half of the questionnaires had been coded to check for any unusual entries or skip problems. None was found.

For each of the 22 task and role combinations, the ratings for physical strenuousness and frequency were first converted to standard scores (*z* scores). To eliminate the resulting decimals and negative numbers, the *z* scores were then transformed into *T* scores (Munro, 1997) having a mean of 50 and a standard deviation of 10 using the following equations where $_i$ represents each task and role combination numbered from 1 to 22:

- Transformed Frequency_i Score = 50 + 10(frequency z score $_{\text{task and role combination}i}$) = TF_i
- Transformed Strenuousness_i Score = 50 + 10(strenuousness z $_{\text{score task and role combination}i}$) = TS_i

Thus, a task and role combination frequency score or strenuousness score close to the average rating would have a value close to 50. In Figure 2, the resultant distance from the origin (0, 0) to each point representing a task and role combination was computed using the following equation (which defines the hypotenuse of a right angled triangle). This statistical process resulted in equal weighting of the frequency and the strenuousness of a task:

- Resultant $\text{Score}_i = (TF_i^2 + TS_i^2)^{1/2}$

End Product of Step 2. The resultant scores were used to identify the "worst" of the frequently performed strenuous task and role combinations. These became the targets for the simulation phase of the project. (As noted previously, the simulation phase of the study is reported elsewhere [see Lavender, 2000a, 2000b].)

RESULTS

Figure 2 shows a plot of the transformed frequency (TF) versus the transformed strenuousness (TS) scores for each of the 22 task and role combinations sampled in the survey. The most frequently performed strenuous work task (Task 11) identified by the survey is the transferring of clients from the ambulance stretcher to the hospital gurney (see Figure 2). This task is performed

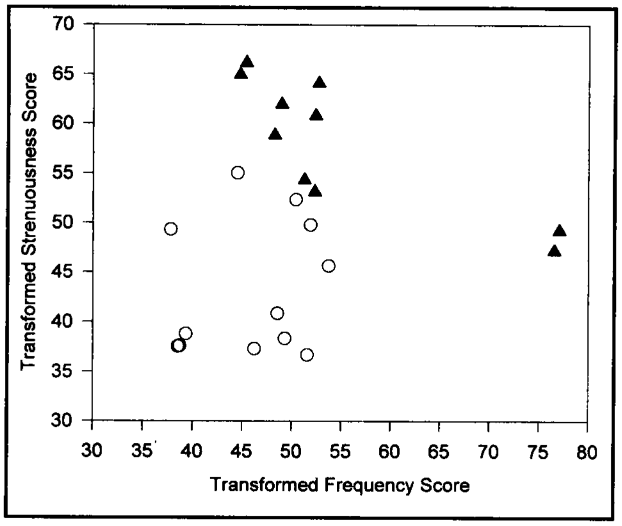

Figure 2. The strenuousness versus frequency of surveyed task and role combinations. Shaded triangles represent the 10 task and role combinations with the highest resultant scores. The task and role labels for each point are defined in Table 1.

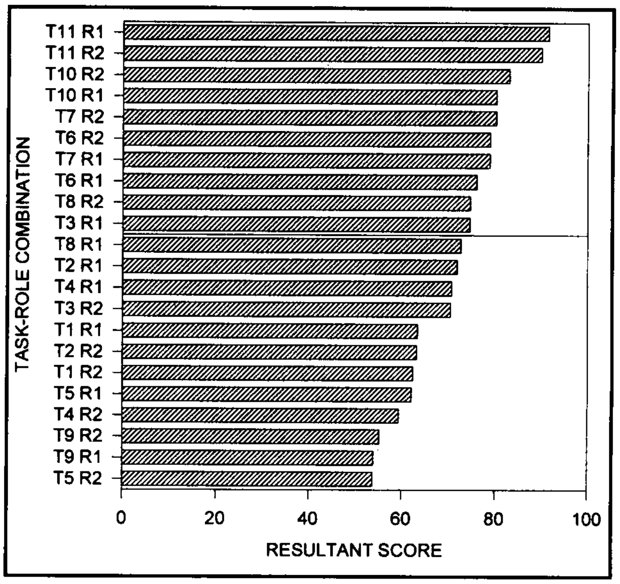

Figure 3. The resultant score for each of the 22 task and role combinations. The horizontal line between T3R1 (Task 3, Role 1) and T8R1 (Task 8, Role 1) indicates the initial cut off for identifying the top 10 task and role combinations for simulation. The task and role labels are defined in Table 1.

with one individual on each side of the two adjacent horizontal surfaces and is performed on nearly all EMS runs as the client arrives at the hospital. The most strenuous task (Task 7) frequently performed by FFPs is negotiating a corner while carrying a client down the stairs on a backboard. Figure 2 also illustrates the trade off between frequency and the strenuousness of the task and role combinations sampled. The shaded triangles in Figure 2 represent the 10 task and role combinations with the highest resultant score. Thus, in addition to the two tasks just described, two additional tasks (Tasks 6 and 10), carrying a client down a line of steps using either the stretcher or the backboard, had high resultant scores regardless of the FFP's role. The FFPs also indicated two more specific roles within the sampled tasks that filled out this top group of 10 task and role combinations. These included carrying a stair chair in the lower position (Task 8, Role 2), and kneeling on the bed during a transfer to a stretcher (Task 3, Role 1).

As expected, Task 9, which involved the use of four FFPs to transfer a client on a stair chair, was considered much less strenuous than performing the task with two people. Moreover, the respondents indicated it did not happen frequently even though this variant of the task was mentioned during the interview process. It is also interesting to note that while every FFP seemed to have a story about rescuing a person from a confined area, the survey confirmed this task was relatively infrequent. More frequently the FFPs extract victims from automobiles. However, relatively speaking, this task (Task 1) was not considered strenuous by the survey respondents.

Figure 3 shows the sequence of task and role combinations sorted by their resultant score. Figure 3 emphasizes even though the transfer from stretcher to gurney is slightly below average with respect to the strenuousness score, its normalized frequency score resulted in it having the greatest resultant score. The horizontal line between Task 3, Role 1 and Task 8, Role 1 was used to indicate the top 10 task and role combinations targeted during the simulation phase of the project.

DISCUSSION

In jobs in which task demands are highly variable, often affected by a host of environmental and situational factors, a methodology is required allowing identification of tasks that will most likely result in work related musculoskeletal disorders. In addition to the fire service, examples of such industries include home health care, some of the skilled trades, construction, agriculture, and home delivery of large appliances and furniture. In such industries, even though high rates of musculoskeletal injury are observed, it is difficult to pinpoint the at risk tasks.

One can conceive of overly strenuous tasks, when performed even once, may exceed the strength capacities of a worker, and hence, lead to an overexertion type injury (Chaffin, 1987). At the other end of the spectrum are the nonstrenuous but frequently performed tasks, where it is not the one time performance that is responsible for tissue degeneration, but the cumulative repetitive performance that results in injury. In many jobs it is the combination of the force requirements and the frequency that drives the risk of injury (Marras, 1993; Waters, 1993). In jobs comprised of tasks with variable frequencies and force requirements, (e.g., FFPs), the challenge for the occupational health nurse or ergonomics team is to identify the tasks occurring with enough frequency that ergonomic analysis and intervention is warranted.

The utility of the approach becomes more relevant as jobs within the American economy shift from manufacturing to the service sector. With this change many of the stereotypic and repetitive jobs that so easily lend themselves to ergonomic analysis are disappearing. This is not to say the new service sector jobs are not physically demanding, only the simple methodologies previously developed for evaluating job demands are not as readily applicable. In the past, an ergonomic evaluation of an assembly line job could be completed relatively quickly, in large part because the pertinent tasks could easily be identified. Moreover, in manufacturing operations the tasks within the job may be repeated anywhere from once every few seconds to several times per hour. With the shift toward service sector jobs, workers may be performing a much larger number of more variable tasks rather than performing a repetitive task for an entire shift. Each of these tasks can be characterized in terms of both frequency and its degree of strenuousness.

By using a resultant score, similar to the one proposed here, the tasks most in need of ergonomic evaluation can be identified. The advantage of a resultant score is it allows one to combine the effects of both frequency and strenuousness in a way that sharpens the focus on the interaction of these two quantities. Simply summing the transformed frequency and strenuousness scores may overemphasize one dimension, such as lifting too heavy a weight once can cause a permanent disability. While such an infrequent event may represent a safety hazard, it most likely is not a priority for ergonomic intervention. The focus for cost effective intervention needs to be on tasks sufficiently strenuous and frequent enough on a population basis to warrant the resource expenditure.

In some types of occupations, the challenge in performing an ergonomic analysis, beyond task identification, is scheduling an observation period. The proposed methodology, by allowing one to identify a priori the most pertinent tasks for ergonomic analysis, enables the occupational health nurse or ergonomics team to schedule observation periods so the tasks most likely leading to work related musculoskeletal disorders will be included in the analysis. In extreme cases, as with the FFPs sampled here, or with other types of on call personnel, onsite collection of ergonomic data may not be feasible. Thus, this analysis allows the appropriate work tasks to be simulated. This is particularly important where the evaluator and organization have limited resources to address the ergonomic issues.

While completing the interview and survey steps of the ergonomic assessment process outlined here are critical, the rigor of the interviews and surveys can be adjusted based on the available company resources. The logic of this process remains, although the accuracy of the final results will be influenced by these adjustments. The example of the process provided in this article used very rigorous methods. Depending on the level of expertise, time availability, and financial support, the occupational health nurse may conduct fewer interviews or select a small but representative sample of workers for the surveys.

OCCUPATIONAL HEALTH NURSING RESEARCH AND PRACTICE RELEVANCE

Occupational health nurses play a vital role in addressing ergonomic problems in the workplace as they assess worker risk; conduct ergonomic surveillance programs; and design, implement, and evaluate ergonomic interventions (Martin, 1999; Stoy, 1999; Zabel, 1997). This article presented an example of how an occupational health nurse researcher mobilized an ergonomics team to address a serious musculoskeletal problem in a high hazard occupation in which the at risk job tasks are difficult to identify.

The importance for the occupational health nurse to include the worker as a team member cannot be overemphasized (Steinbrecher, 1999). In the ergonomic assessment described here, a sample of FFPs participated in the interviews, the results of which formed the basis of the survey completed by the target population of FFPs. The FFPs served as team members for the simulation phase of the study (Lavender, 2000a; 2000b). The FFPs actively participated in all phases of the study, some of them sharing how pleased they were to see their ergonomic issues seriously considered.

This research was partially supported by the National Institute for Occupational Safety and Health (NIOSH) (grant R03 OH03123-01A1, K. Conrad, Principal Investigator). The content is solely the responsibility of the authors and does not necessarily represent the official views of NIOSH.

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