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Participatory Ergonomics in a Red Meat Packing Plant Part II: Case Studies

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APPLIED STUDIES

Three ergonomics-related case studies are presented to demonstrate the problem-solving method used by two participatory ergonomics teams. The problem-solving method was adapted from principles related to quality management (e.g., participation, structure, a scientific approach, and decision by consensus). The first two steps of the problem-solving method were related to identification and evaluation of the problem; the latter three steps were related to solution development, implementation, and evaluation. The problem evaluation process included the collection of background, exposure, and effects data. Solution development following evaluation of the problem started with a brainstorming session, then discussion to select interventions by consensus. The format for presenting the case studies was intended to be concise and visual with the intent of effectively documenting the teams' problem-solving processes.

Keywords: case studies, job analysis, meat packing plants, participatory ergonomics, problem-solving process, Strain Index

During 1992–1993 a red meat packing plant participated in a National Institute for Occupational Safety and Health (NIOSH)-sponsored demonstration project. The methods and results for the entire project were published as part of a NIOSH document.(1) The project had two major components. The first involved working with two ergonomics teams in a slaughtering and processing plant. This article describes the problem-solving process used by these teams and its application to three jobs. A description of each team's activities and feedback from team members is presented elsewhere.(2) The other component involved describing the historical development and implementation of the corporation's ergonomics program and presented information related to evaluating this program's effectiveness across the corporation as a whole as well as in the slaughtering and processing plant mentioned above.(3,4)

In this project both teams were charged with analyzing targeted jobs in their departments; identifying the sources of the problems; and developing, recommending, and implementing appropriate interventions. There is no ideal or consensus method for approaching the evaluation of such problem jobs. The cases presented in this article demonstrate the application of the method used by these two ergonomics teams to accomplish their goals.

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METHODS

This project involved working with two ergonomics teams, one in the Kill Department and another in the Cut Department, at a pork slaughtering and processing plant. The Kill Department ergonomics team consisted of three production workers, a supervisor, an industrial engineer assigned to the Kill Department, the corporate ergonomics coordinator, and the investigators. The Cut Department ergonomics team was similar to the Kill Department's team except that the Cut Department had two production workers instead of three. The manager of industrial engineering, the maintenance engineer, and the most senior industrial engineer of the department also often attended the teams' meetings.

The project started with a meeting at the plant, the purpose of which was to clarify the scope and purpose of the project from all perspectives—the management, the union, and the investigators. This was followed by an 8-hour training session for the ergonomics team members. The training curriculum, delivered by the investigators, included an overview of the demonstration project; the epidemiology, etiology, and development of low-back pain and upper extremity disorders; and an approach to solving ergonomics-related problems, including participatory problem-solving techniques. The audience included production workers, supervisors, maintenance personnel, engineers, and management personnel. There was no specific assessment of training effectiveness.

During 1993 the investigators met with the two teams on five occasions to address the targeted jobs in their departments. Both teams occasionally met on their own. Since the plant was in the midst of a major renovation project, the industrial engineering members of each team often met with the renovation project consulting firm to discuss incorporation and implementation of their teams' recommendations. Since the members of both teams had worked together prior to this project and team dynamics were not considered problematic, little time was required for team-building activities.

The Problem-Solving Process

The problem-solving process applied to the targeted jobs during the demonstration project was developed and recommended by the investigators. It was, to a large extent, adapted from problem-solving principles and processes related to total quality management.[5–8] The major principles underlying the process include participation, structure, a scientific approach, and decision by consensus. The process involved five phases: problem identification, problem evaluation, solution development, solution implementation, and solution evaluation.

Problem Identification

To a large extent, the problem jobs had been identified via the plant's previous ergonomics committee activities, using such tools as the corporation's safety and ergonomics surveys (proprietary).[1,3] The targeted jobs represented those associated with a large number of injuries, one or more particularly severe injuries, or relatively high workers' compensation expenses. In addition, they were problems for which the company had no solutions.

Problem Evaluation

The problem evaluation process was structured and emphasized a scientific approach to data collection and analysis. Following a structured method was considered important since some people have a tendency to jump immediately to solution brainstorming or even implementation without full understanding of the job and task requirements or a clear definition of the job's problems. In this project the selected method involved the following steps: data collection, data analysis, and assessment of the problem(s). Data elements used to describe the job were grouped into background data, exposure data, and effects data.

Background data included a brief (one sentence) statement of the purpose of the job, a summary of the associated tasks, the weights or sizes of objects lifted or handled, and a description of the job's work organization (number of exposed workers, job rotation, location on the line, etc.).

Exposure data represented descriptors of the forces or movements to which the workers were exposed. One component was a summary of the job's temporal characteristics. This included data on the production rate (pieces per worker per hour), standard times (allowed worker-minutes per piece per worker, job load, and calculated cycle time), observed times (cycle time, duration of exertion per cycle, percentage of time of exertion per cycle, and frequency of exertion), and duration of task(s) per day (hours). Another component was a summary of motion- and exertion-related information. This included a Therblig description of the tasks and an estimation of required intensities of exertion using a five-point scale.[9,10] Associated body postures were qualitatively described. The jobs were also characterized according to their Strain Index (SI) score.[10] The Strain Index is a semiquantitative exposure assessment methodology that, based on preliminary validation, identifies whether jobs place workers at increased risk of developing distal upper extremity disorders (elbow, forearm, wrist, and hand). According to the preliminary validation data, jobs with a Strain Index score below 5 placed workers at minimal to no increased risk of distal upper extremity disorders, while jobs with scores greater than 5 were associated with significantly increased risk of distal upper extremity disorders.[10] SI score ranges of <5, 5–30, 31–60, and >60 were associated with incidence rates of 2, 77, 106, and 130, respectively (defined as the number of distal upper extremity disorders per 100 workers per year).[10]

Effects data represented information that reflected the potential effects of the exposures on the workers. Recordable injuries and illnesses were ascertained by review of the Occupational Safety and Health Administration (OSHA) 200 logs for the years 1988 through 1992 (data prior to 1988 was not available). Disorders were clustered into three categories according to anatomical body part: the distal upper extremity, the shoulder, and the lower back. Days restricted or lost, if any, were noted. Incidence and severity rates for each body part were calculated. The incidence rates were defined as the number of disorders per 100 workers per year. Severity rates were defined as number of days lost or restricted per 100 workers per year. Some of the ergonomics team members had performed some of the target jobs and could offer insights into where they developed soreness or discomfort. Turnover was also used as an indicator of a potential exposure effect and, by consensus of the committee, was considered a useful indicator of problems associated with the job. A third source of effects data was worker feedback. Members of the ergonomics teams interviewed workers who currently or recently performed the targeted jobs. The interviews followed a consistent and structured format by using a worker feedback survey (Appendix). This survey incorporated some background information on the worker's affected body part, perceived problems with the job, and any recommended solutions or changes for the job. Once the data was collected, the teams reviewed and discussed the findings and determined the parts of the job that were of most concern.

Solution Development

Solutions were developed to solve the identified problems. A brainstorming technique was used to ascertain ideas, regardless of feasibility, practicality, or other such concerns. Once a list was completed, the group used informal discussion to modify, delete, and prioritize the listed ideas. Eventually, the group reached consensus on the most desirable and reasonable interventions. No formal process, such as voting, was necessary for either team. One particular solution, reducing line speed, was not economically feasible in this plant.

Solution Implementation

Investigation and implementation of the recommended solutions was primarily the responsibility of the industrial engineer for the area. The engineer initiated and tracked the corporate intervention evaluation form, contacted product manufacturers to obtain equipment, arranged simulations, and coordinated communications with supervision, maintenance, the renovation consulting firm, and others. The engineer reported on the progress of each job at each meeting.

Solution Evaluation

Given the time frame of this project, there was limited opportunity for the investigators to work with the teams to evaluate the proposed interventions. The ergonomics teams, however, plan to reevaluate all of the interventions by repeating the worker feedback survey approximately 3 months postintervention and tracking injuries and illnesses indefinitely. The 3-month time interval was selected to minimize the potential for the Hawthorne effect (i.e., it was believed that any placebo effects related to making any change would have largely dissipated by then).

Two of the case studies had trials that involved the use of new or modified tools. The third case study simulated a new work method. The limited information on solution evaluation reported for these case studies is based on observations and worker feedback from these trials and simulation.

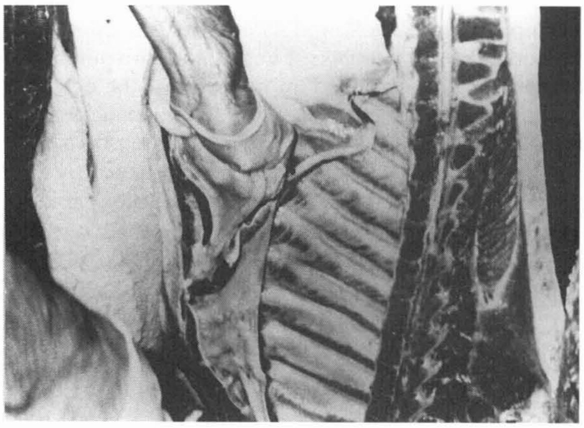

Figure 1. The lower end of the leaf lard is grasped forcefully with a tightly closed fist to tear it loose from the belly. The worker wears a cotton mesh glove to improve the coefficient of friction between the skin of the hand and the leaf lard. Stresses to the fingernails and the back of the distal interphalangeal joints are significant. Most workers have lost parts of fingernails; one had ulcers on the back of the finger joints.

RESULTS

The analyses of three targeted jobs are presented as case studies. In reality, each case study was an illustrated outline that attempted to communicate the team's work concisely. They were intentionally brief and pictorial to accommodate their targeted audience. The format was modified somewhat for presentation in this publication. The case studies are titled according to conventional plant nomenclature: Pulling Leaf Lard, Snatching Guts, and Pulling Ribs.

Pulling Leaf Lard

Background Data

The purpose of this job was to remove leaf lard from the inner aspect of the abdominal cavity because it improves the quality of exposure of the ribs, and the leaf lard is useful for rendering.

There are three tasks associated with this job: (1) pulling leaf lards, (2) trimming bellies with a Whizard knife, and (3) removing the kidneys. In terms of work organization, the three tasks are arranged sequentially. The first worker in the line removes kidneys, the next three pull leaf lards, and the final worker uses the Whizard knife to trim the bellies. There are five workers who advance one workstation every 15 minutes.

Exposure Data

Temporal characteristics for pulling leaf lards was assessed from several perspectives. Production data, based on the line speed, predicted 12.5 seconds per hog (two leaf lards per hog); 18.75 seconds per worker per leaf lard; and nine leaf lards per minute. Formal time and motion analyses, available from the industrial engineers, predicted a standard time of 0.2133 minutes per hog, 88% job load, and 12% recovery. Observations from a videotape revealed that the task cycle time was 6.7 seconds per leaf lard, the duration of hand exertion averaged 3.0 seconds, the duration of exertion per cycle (expressed as a percentage of the task cycle time) was 45%, and the exertions per minute was 18 (two exertions per leaf lard). The duration of the work shift was 9.5 hours, but any one worker spent 5.7 hours pulling leaf lard per day.

A description of the motions and exertions for one task cycle for pulling leaf lards started with the workers grasping the lower end of the leaf lard with one hand (Figure 1). It was necessary to grasp the lead lard forcefully with a tightly closed fist because of the low coefficient of friction (they also wore cotton mesh gloves that often fill with fat). They then supinated the forearm and pulled upward to initiate the tear (Figure 2). Two hands were usually used to regrasp and pull upward to remove the leaf lard (Figure 3). When torn free, the leaf lard was merely dropped into a chute below. Using the SI method, the intensity of the hand exertions was rated Hard, the hand and wrist postures were rated Fair, and the speed of work was rated Fair. The SI score for this task was 27.0, indicating that workers were at increased risk for distal upper extremity disorders (Table I).

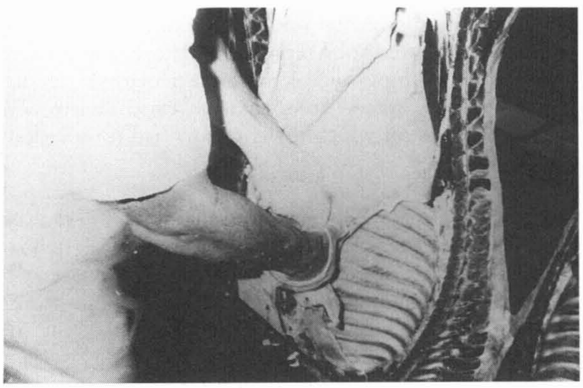

Figure 2. The maneuver used to tear the tissue involves supination of the forearm and an upward pull, combined with a forceful grasp. After the lower end is torn free, the worker grasps again with two hands to pull upward the rest of the way.

Effects Data

Musculoskeletal morbidity, derived from the OSHA 200 log, is summarized in Tables II and III. Morbidity other than in the musculoskeletal system included one worker with dermatitis of the left hand (restricted for 3 days); two workers with strained lower extremities (one was away from work for 147 days; the other 2 days); and seven workers with lacerations or burns, primarily affecting the right hand, that were associated with

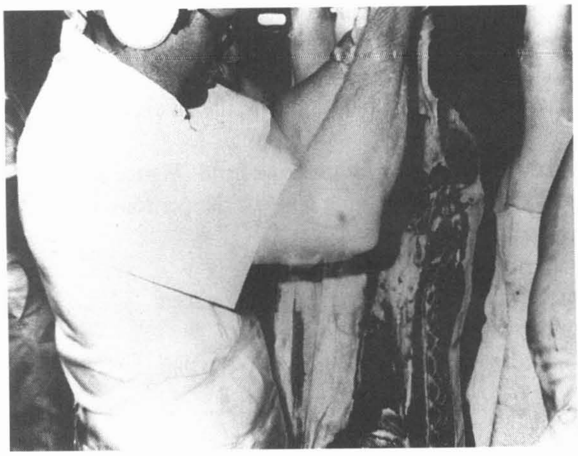

Figure 3. Near completion of the task, the worker's hands are at approximately head height. The shoulders are flexed to almost 90°. The tissue is easier to tear during this phase of the task.

15 restricted days. Evaluation of turnover data revealed that 10 individuals filled these 5 positions in the last 2 years. This represented 100% turnover every year. Worker feedback survey data were available from seven individuals (Tables IV and V).

TABLE I. Strain Index Ratings, Multipliers, and Score for the Pulling Leaf Lard Task

Exposure Factor	Rating	Multiplier
Intensity of exertion	3	6.0
% Exertion per cycle	3	1.5
Exertions per minute	4	2.0
Posture	3	1.5
Speed of work	3	1.0
Duration of task per day	4	1.0
Strain Index Score		27.0

TABLE II. Musculoskeletal Morbidity Related to Pulling Leaf Lard (1988–1992)

Year	Condition	Days Restricted	Days Lost
Distal upper extremity disorders			
1988	Cumulative trauma syndrome (right wrist)	13	18
	Cumulative trauma syndrome and epicondylitis (both wrists and lateral elbows)	8	0
1989	None reported	0	0
1990	Tendonitis (right elbow and wrist)	0	0
1991	Flexor tenosynovitis (both hands)	0	23
1992	Discomfort (left wrist)	0	47
	Discomfort (left hand)	0	0
Low-back disorders			
1988	None reported	0	0
1989	Disc syndrome	0	106
	Lumbago	0	0
1990	None reported	0	0
1991	Strain	4	0
1992	None reported	0	0

None of the workers provided feedback related to recommended improvements.

TABLE III. Average Incidence and Severity Rates for Musculoskeletal Morbidity (1988–1992)

Body Part	Incidence Rate	Severity Rate
Distal upper extremity	24	436
Shoulder	0	0
Lower back	12	440

Note: There were no recorded shoulder conditions during this period. Incidence rates reflect the number of disorders per 100 workers per year. Severity rates reflect the number of days lost or restricted per 100 workers per year.

The Team's Assessment

Based on this data, the team concluded that (1) it was difficult to grasp the leaf lard because of its size, consistency, and slipperiness; (2) the tight and forceful grasp created high compression and shear forces on fingers and fingernails when grasping; and (3) pulling up the leaf lard stressed the hands, wrists, and low back.

TABLE IV. Tabulated Responses for Affected Body Parts from the Worker Feedback Surveys

Body Part	Right	Left	Bilateral	Total
Neck	—	—	—	2
Shoulders	1	1	3	5
Elbows	1	0	0	1
Forearms	0	1	4	5
Wrists	2	0	2	4
Hands	0	0	6	6
Upper back	—	—	—	0
Lower back	—	—	—	5

Solution Development

The solution brainstorming session identified several possible solutions, including the following.

- Use of an automatic leaf lard puller (a recognized product)
- Use of a leaf lard starter and/or roller (a recognized product)
- Use of a vacuum with a cutting nozzle
- Cutting the lower end of the leaf lard with a knife, then pulling manually
- Starting at the top of the leaf lard, then pulling down
- Cutting the leaf lard in the middle, then pulling the halves out
- Injecting air behind the leaf lard to loosen it, then pulling it out
- Freezing the leaf lard, then breaking it out
- Use of a hand-held skinner to remove the leaf lard

TABLE V. Tabulated Responses for Perceived Problems from the Worker Feedback Surveys

Employee Responses	Total
Gripping the leaf lard	5
Breaking the leaf lard free	2
Pulling the leaf lard	1
Tearing the leaf lard	1
Rolling the leaf lard	1

APPLIED STUDIES

The team felt that only the first two options were likely to be effective and feasible. The industrial engineers were familiar with both pieces of equipment. The automated leaf lard puller was considered a less favorable alternative for this plant because of its size and cost plus concern about efficiency and quality. The leaf lard starter was a powered hand tool combined with a hoist. The tool and its hoses were suspended by the chain component of the hoist, thus eliminating the need for the worker to support the weight of the tool. The tool handle allowed for power grasp with one hand. The worker placed the tool at the bottom edge of the leaf lard in a position for its jaws to close on the tissue. Activation of the tool's trigger closed the jaws and initiated upward movement of the entire tool on the hoist, thus eliminating lifting forces to tear out the leaf lard. The worker's hand passively followed the motion of the tool. The hoist's upward movement stopped at a specified height, approximately shoulder height for most workers, where the leaf lard would be torn free. The jaws then opened and the leaf lard dropped into the chute below.

The plant had previously tried a single leaf lard starter to tear loose the leaf lard for each side of the hog. This did not work well because the tool's cycle time could not keep up with the line speed. The team recommended trying two units—one for right sides and one for left sides.

Solution Implementation

Two leaf lard starter units were obtained for trial in August 1993. A cylinder malfunction delayed the trial until September 1993. Both units were scheduled for final installation by the end of the 1993.

Solution Evaluation

Solution evaluation was limited to the trial in September 1993. Worker feedback and acceptance of the leaf lard starters were favorable. There were no evident adverse impacts on quality or productivity. The solution appeared to reduce biomechanical stresses on the workers. For the low back and shoulders, the hoist eliminated the upward pull by the workers. For the distal upper extremity, the intensity of effort to operate the leaf lard starter was light (rating = 1). Given the relatively slower speed of the hoist compared with the workers' pulling motions, the percentage exertion per cycle increased to the 50–74% range (rating = 4). Since the hand exerted effort on the tool only once per leaf lard, the exertions per minute decreased to 9 (rating = 3). Hand/wrist posture improved to good because of a more favorable power grip (rating = 2). Speed of work stayed fair (rating = 3). The duration per day stayed in the 4–8 hours range (rating = 4). The SI score for the revised work method was 3.0—a score not considered to place workers at increased risk of developing a distal upper extremity disorder. Follow-up morbidity data was not available.

Snatching Guts

Background Data

The purpose of this job was to remove the internal organs (viscera) from the hog's body cavities. There was one task: remove the viscera, then set them on the aside conveyor. In terms of work organization, three workers performed this job without rotation.

Exposure Data

In terms of temporal characteristics, production data revealed a rate of 742 hogs per hour, 247 sets of hog viscera per worker per hour, and 14.6 seconds per set of hog viscera. Observed times from the videotape revealed a task cycle time of 13.3 seconds per hog. The percentage duration of exertion was 30% for the guts hand and 100% for the knife hand. There were 4.5 exertions per minute (once per set of viscera). The duration of task per day was 9.5 hours.

In terms of motions and exertions, the task involved the following steps.

- Grasp and wrap bung around one hand (Figure 4)
- Apply traction to the bung and cut the peritoneal tissue to free the rectum
- Grasp near the stomach (Figure 5)
- Cut the diaphragm to free remaining viscera
- Cut the laryngeal tissue (Figure 6)
- Hold, turn, and carry the viscera to the pan (Figure 7)

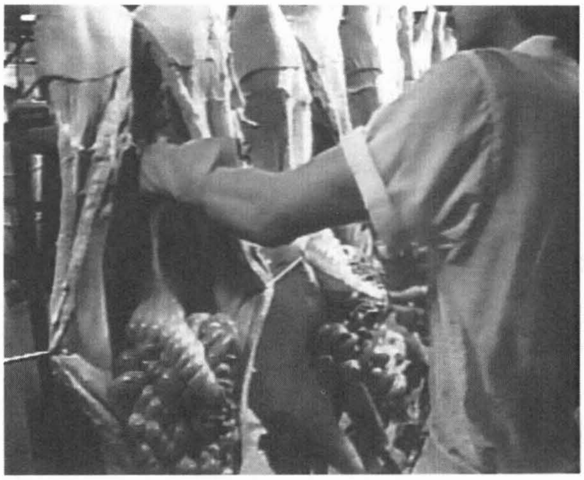

Figure 4. A the beginning of the work cycle, the Gut Snatcher reaches up to wrap the bung around the hand, then pulls down to free the rectum from the abdominal wall.

The set of viscera weighed approximately 26 pounds. The estimated intensity of exertions were very hard for the guts hand and light for the knife hand. Hand and wrist postures were rated good and speed of work was fair. The SI score was 30.4 for the guts hand and 13.5 for the knife hand (Table VI). Even though the exertional patterns of the hands were different, brief forceful effort with the guts hand compared with prolonged light effort with the

Figure 5. After freeing the rectum, the worker grasps the viscera near the stomach with the left hand and continues to cut with the right.

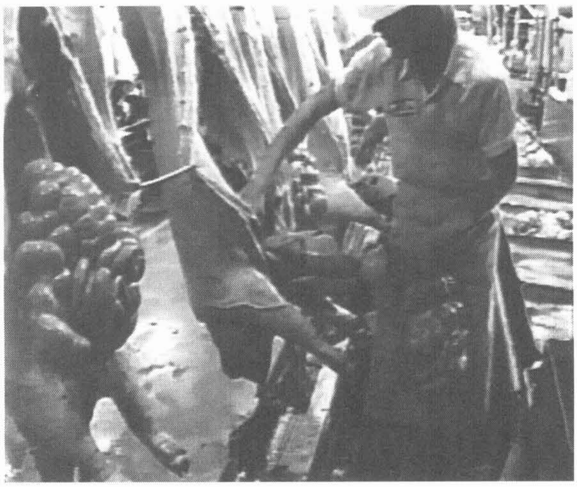

Figure 6. The abdominal and thoracic viscera are now free. The worker is holding the viscera with the left hand while completing the cut through the laryngeal area with the right (viscera weight: approximately 26 pounds).

knife hand, the SI scores suggested that both hands were at increased risk for developing a distal upper extremity disorder, but the risk was higher for the guts hand than the knife hand.

Figure 7. The worker has carried and lifted the viscera to place them into a pan located opposite the carcass. The pans are approximately at knee height.

Effects Data

The musculoskeletal morbidity data from the OSHA 200 logs are presented in Tables VII and VIII. In terms of turnover, eight individuals filled three positions in the last 2 years. This represented 133% turnover per year. Results of the worker feedback survey, based on interviews of four workers, are in Tables IX and X.

Based on this information, the team identified the following problems with this job.

- Handling the viscera required forceful grasping of a slippery amorphous object
- Lifting and carrying the viscera with one hand required significant strength
- The pan was located behind the worker
- It was necessary to lift the viscera into the pan

Solution Development

The industrial engineers had been working on a proposed solution prior to the ergonomics team's review of this job. The team agreed with the proposed intervention. As a result, there was no solution brainstorming for this targeted job.

Table VI. Strain Index Ratings, Multipliers, and Scores for Both Hands for Snatching Guts

Exposure Factor	Rating	Multiplier
Guts hand		
Intensity of exertion	4	9.0
% Exertion per cycle	3	1.5
Exertions per minute	3	1.5
Posture	2	1.0
Speed of work	3	1.0
Duration of task per day	5	1.5
Strain Index Score		30.4
Knife hand		
Intensity of exertion	1	1.0
% Exertion per cycle	5	3.0
Exertions per minute	5	3.0
Posture	2	1.0
Speed of work	3	1.0
Duration of task per day	5	1.5
Strain Index Score		13.5

TABLE VII. Musculoskeletal Morbidity Related to Snatching Guts for Years (1988–1992)

Year	Condition	Days Restricted	Days Lost
Distal upper extremity disorders			
1988	CTS (left)	2	1
1989	CTS (bilateral)	25	71
1990	None reported	0	0
1991	CTS (bilateral)	53	13
1992	None reported	0	0
Shoulder disorders			
1988	None reported	0	0
1989	None reported	0	0
1990	Rotator cuff (right shoulder)	52	8
1991	Pain (right shoulder)	0	0
	Strain (left shoulder)	0	24
1992	None reported	0	0

Note: There were no recorded low back problems during this period.

The renovated design involved breaking the gut snatching job into three serial tasks somewhat analogous to the method used in plants processing beef. The first worker, standing on an adjustable platform so he or she could work near chest height, would free the bung and abdominal organs. The second, standing at a lower level to work near chest height, would cut the diaphragm to free the thoracic organs. The third, standing at the lowest level, would

TABLE VIII. Average Incidence and Severity Rates for Snatching Guts (1988–1992)

Body Part	Incidence Rate	Severity Rate
Upper extremity	20	1100
Shoulder	20	560
Lower back	0	0

TABLE IX. Worker Feedback Data on Affected Body Parts for Snatching Guts

Body Part	Right	Left	Bilateral	Total
Neck	—	—	—	1
Shoulders	0	4	0	4
Elbows	0	1	0	1
Forearms	0	0	0	0
Wrists	0	1	3	4
Hands	0	0	4	4
Upper back	—	—	—	0
Lower back	—	—	—	2

perform the final cut to free the entire viscera from the laryngeal area. The viscera would fall passively into a pan riding on a conveyor below the carcass. This new design and layout eliminated all forceful grasping and lifting and placed the workers in a more efficient position relative to their work.

TABLE X. Worker Feedback Data on Perceived Problems and Recommended Improvements for Snatching Guts

Employee Responses	Total
Perceived problems	
Inadequate room	1
Difficult to pull bungs out correctly	1
Recommended improvements	
Open the H-bone	2
More room	1
Pull bungs out correctly	1
Develop a new method	1

Solution Implementation

The revised layout is scheduled for installation as part of the renovation project.

Solution Evaluation

A simulation of the proposed solution worked well; however, one major obstacle was subsequently uncovered—the United States Department of Agriculture (USDA). The USDA was concerned about the possibility of contamination of the viscera by debris falling from the workers' shoes. In addition, the viscera must stay with the carcass through the inspection process. Both obstacles were eventually overcome, and the plant ultimately received USDA approval to proceed with the renovation.

Based on observations of the simulation and feedback from workers who participated in the simulation, the proposed solution appeared to reduce the biomechanical stresses to the workers. Since the viscera were no longer handled manually, the biomechanical stresses to the low back, the shoulders, and the guts hand related to lifting and carrying the viscera were eliminated. Since the simulation did not mimic actual production speed, it was not possible to estimate reliably the effects of the solution on the knife hand for the three new positions. Overall, the team felt that the knife hand stresses would also decrease. Follow-up morbidity data was not available.

Pulling Ribs

Background Data

The purpose of this job was to remove ribs from the belly. There were two tasks related to this job: (1) pulling ribs and setting them on the aside conveyor and (2) packing the ribs. Three workers rotated between these two tasks every 15–30 minutes. Two workers pulled ribs (using a special knife that requires two hands) while the third packed the ribs (materials handling). The team focused on the pulling ribs task.

Exposure Data

For temporal characteristics, production data predicted 765 hogs per hour, 765 bellies per worker per hour (two bellies per hog and two workers), and 4.76 seconds per rib. The standard time was 0.0794 minutes per rib per worker with 98.9% job load and 1.1% recovery. The observed cycle time was 4.6 seconds per rib, and the observed duration of exertion with the hands was 0.75 seconds. The percentage duration of exertion was 16%, and the exertions per minute was 26 (two per rib). The duration of the job was 9.5 hours per shift, with approximately 5.7 hours spent pulling ribs per day.

The average weight of one rib was 3.13 pounds. The average length of one rib was 15 inches. A description of the motions and exertions revealed the following sequence: grasp the knife; reach forward to begin cut; pull the knife to cut; grasp the cut rib; lift, turn, and place the rib on the aside conveyor.

The knife was held with two hands. Its design required that the workers extend and abduct their thumbs to place them on the handle (Figure 8). The thumbs pressed against the upper part of the handle to provide torque to oppose torque created by the knife blade (cutting through the meat below the little fingers). The forward reach required some trunk and shoulder flexion (Figure 9). After the cut the workers grasped the end of the rib with a pinch grasp with the forearm supinated (Figure 10), then lifted it to approximately head height, reached forward, turned the rib over, and placed it into a trough on the aside conveyor (Figure 11). The estimated intensities of exertion for pulling, grasping, and lifting were "somewhat hard." The hand and wrist posture was rated bad (thumbs abducted for pulling and pinch grasp for grasping the rib). The speed of work was rated fair. The SI score for this task was 18.0 (Table XI), thus predicting that workers were at increased risk of distal upper extremity disorders.

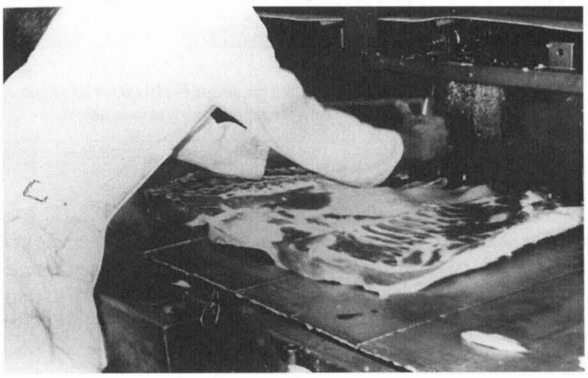

Figure 8. The worker uses a special knife to pull ribs. The design of the knife requires that the worker's thumbs be placed up on the handle to overcome mechanical disadvantages.

Effects Data

The musculoskeletal morbidity data from the OSHA 200 logs are summarized in Tables XII and XIII. In addition, one team member had performed this job and experienced bilateral radial

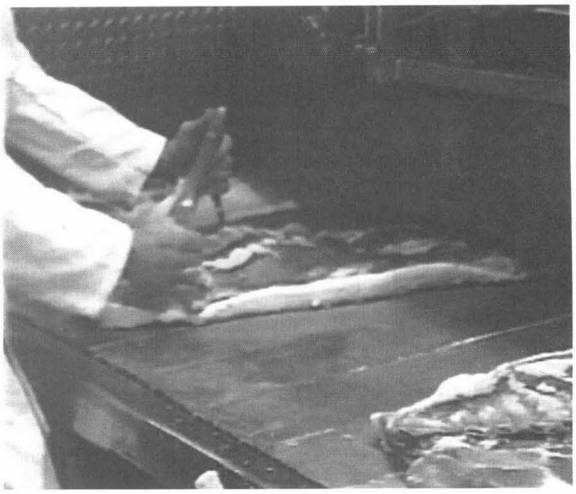

Figure 9. The distal end of the bellies are held in place by a spike conveyor. The worker reaches to the far end of the belly to start the cut. The knife slides under the ribs.

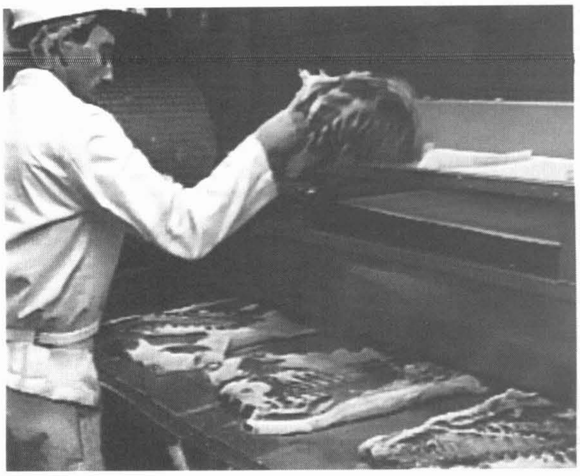

Figure 11. To set the ribs on the aside conveyor properly, they must be turned over. As a result, the worker pronates the forearm just prior to placement. Note that the aside conveyor is elevated and away from the worker, thus requiring shoulder and trunk flexion to reach it.

wrist soreness (suggestive of DeQuervain's tenosynovitis). This job was associated with 68 restricted days in the last 12 months and total medical costs for 1993 (year-to-date) was $2400. Regarding turnover, 10 individuals filled these 3 positions within the last 12 months. This was 333% turnover per year. Workers on the team stated that people often posted into this job for higher pay. Worker feedback is summarized in Tables XIV and XV.

Figure 10. The worker uses a pinch grasp combined with forearm supination to get the ribs.

Based on the available information, the team concluded the following.

- The floor stand was irregular because the ends of the existing mats did not match.
- The existing conveyor designs contributed to the difficulty of the pulling task.
- The ribs were put into the roller with their long axis parallel to the axis of the roller drum. They might be flattened better (thus easier to cut) if rolled the other way. (This occurred just prior to rib pulling. The roller is visible in most of the figures to the left of the worker).
- The existing knife placed the user at a mechanical disadvantage, especially regarding the thumbs (loaded and extended).
- The existing system required the spike conveyor operator to align the bellies by sight alone. As a result, some bellies came to the pullers with the ribs impaled by the spikes on the conveyor.

TABLE XI. Strain Index Ratings, Multipliers, and Score for Pulling Ribs

Exposure Factor	Rating	Multiplier
Intensity of exertion	2	3.0
% Exertion per cycle	2	1.0
Exertions per minute	5	3.0
Posture	4	2.0
Speed of work	3	1.0
Duration of task per day	4	1.0
Strain Index Score		18.0

- The current technique of setting the ribs aside required use of pinch grasp combined with poor mechanical advantage (held at the end of the rib) and forearm pronation.

TABLE XII. Musculoskeletal Morbidity Related to Pulling Ribs (1988–1992)

Year	Condition	Days Restricted	Days Lost
Distal upper extremity disorders			
1988	Possible CTS	0	0
1989	None reported	0	0
1990	CTS (right)	7	0
1991	None reported	0	0
1992	Tenosynovitis (left fifth finger)	11	0
Shoulder disorders			
1988	None reported	0	0
1989	None reported	0	0
1990	Strain (right shoulder)	42	0
1991	Strain (left AC joint)	31	0
1992	None reported	0	0
Low-back disorders			
1988	None reported	0	0
1989	None reported	0	0
1990	None reported	0	0
1991	Strain	7	0
1992	None reported	0	0

APPLIED STUDIES

TABLE XIII. Average Incidence and Severity Rates for Pulling Ribs (1988–1992)

Body Part	Incidence Rate	Severity Rate
Distal upper extremity	20	120
Shoulder	13	487
Lower back	7	47

■ The aside conveyor was located up and away from the worker, thus requiring an extended forward reach, trunk flexion, and lifting to approximately shoulder height.

TABLE XIV. Worker Feedback on Affected Body Parts for Pulling Ribs

Body Part	Right	Left	Bilateral	Total
Neck	—	—	—	2
Shoulders	5	0	3	8
Elbows	3	0	0	3
Forearms	2	1	1	4
Wrists	0	2	5	7
Hands	0	0	5	5
Upper back	—	—	—	1
Lower back	—	—	—	3

Solution Development

Brainstorming identified several intervention strategies for improving this job.

■ Upgrade the flooring material.
■ Design the spike conveyor for a taller worker and install adjustable stands for shorter workers.
■ Consider hooking the bellies instead of spiking them.
■ Roll the ribs lengthwise.
■ Use a light to consistently align bellies on spike conveyor.
■ Install steam or hot water sinks to keep the knife blade warm (reduces friction).

TABLE XV. Worker Feedback on Perceived Problems and Recommended Improvements for Pulling Ribs

Employee Responses	Total
Perceived problems	
Dull knife	6
Pulling the knife	5
Setting the rib on the aside conveyor	4
Thumb pressure	3
Grasping the rib	3
Grasping the knife	2
Bellies pull of the spike conveyor	2
Bone cuts	1
Recommended improvements	
Improve the knife handle	5
Change the spike conveyor	5
Change floor stands	3
Get a better knife	2
Lengthen the table	1
Lower the aside conveyor	1
Add a person to the packing task	1
Try gloves	1

■ Design a new knife to eliminate awkward use of the thumb and extended forward reach.
■ Leave the pulled ribs on the bellies and install some device to push them off.
■ Place the ribs in a chute next to the puller so it drops to a conveyor.
■ Add a third worker: two pull ribs and one sets the ribs on the conveyor (two hands).
■ Lower the aside conveyor (not feasible to move it closer).

Solution Implementation

Layout changes (stands and conveyors) were incorporated into the renovation design plans. New flooring material was installed. Work practice changes will be incorporated into the renovation plans. Either steam or hot water sinks will be installed with the renovation. A revised knife handle was designed and a prototype built (Figure 12). The team's recommendation to add another worker to the rotation scheme was accepted. This worker will remove pulled ribs from the bellies thus eliminating the asiding of the ribs from the pullers' task list. Worker rotation will continue with four workers instead of three.

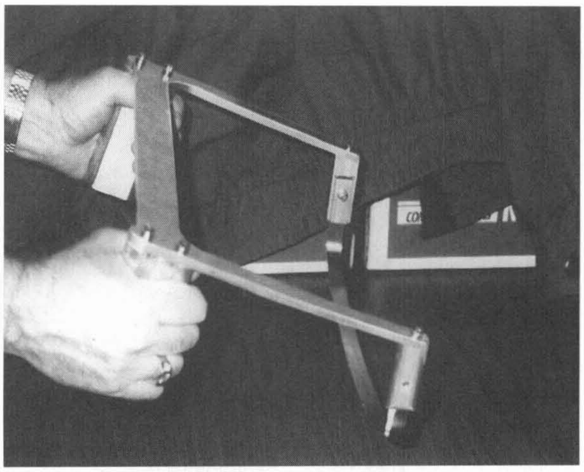

Figure 12. The prototype knife increased the distance between the cutting blade and the site where the hands grasped the knife. This allowed the worker to grasp the knife with a power grasp (eliminating the awkward thumb position) and decreased the amount of forward reach (trunk and shoulder flexion) needed to begin the cut.

Solution Evaluation

None of the interventions deferred to the renovation were available for direct evaluation. Several workers used the prototype knife handle in an actual production situation as part of a trial. Based on observations and worker feedback from this trial, the new design effectively addressed the major biomechanical issues related to pulling (awkward thumb posture for the distal upper extremities and forward reach for the shoulders and low back). However, the dimensions of the new knife handle needed to be changed because the end of the knife hit the conveyor during the pull. It was undergoing further modifications at the end of the project.

For the pulling task with the prototype knife, the intensity of exertion was unchanged (somewhat hard, rating = 2). Since the asiding component of this task was eliminated, the percent exertion per cycle decreased, but its rating (2) did not change. The number of exertions per minute was reduced by 50% to 13 (rating = 3). The hand and wrist posture when using the new knife handle was rated as good (rating = 2). The speed of work was unchanged (rating = 3). Even though the duration of task per day will decrease when the new worker is added, the duration still fell within the 4–8 hour per day range (rating = 4). The SI score for the modified pulling task was 4.5. An SI score for the proposed asiding task could not be reliably determined. Follow-up morbidity data are not available.

DISCUSSION

These case studies were presented with the intent of demonstrating one method for ergonomics teams to approach evaluation of problem jobs. This part of the project involved working with ergonomics teams from two departments in the plant. It was a demonstration project, not an epidemiologic or experimental investigation. The investigators' roles with the teams were primarily as trainers and facilitators.

Both teams were participatory in nature with representatives from production workers, supervision, and management. Even though workers performing targeted jobs might not be on the teams, their input was incorporated through the interviews using the worker feedback surveys. The teams' targeted jobs were some of the most difficult jobs in the plant in terms of number, severity, or cost of injuries and turnover.

While the problem-solving process used by the teams was prescribed by the investigators, it was observed that the team members seemed to rely primarily on subjective feedback from workers performing the targeted jobs and their own subjective assessments of the jobs. Quantitative ergonomics data and methods were rarely needed by the teams. It appeared that, for these jobs, the presence of a hazard was undisputed by the team members. The injury and illness data plus the worker feedback data were used to identify the body parts most adversely affected by the jobs. Videotapes and worker feedback data were used to identify task elements that were believed related to the affected body parts. The exposure data and effects data were compared when identifying the root causes of the problem(s). Solutions were then directed at fixing these problems. In general, both teams followed the sequence of steps recommended by the investigators. There were a few circumstances, however, when solutions were recommended prior to completion of data collection and analysis. Given the limited duration of the project, few of the developed solutions were fully implemented. Evaluations of the proposed solutions were somewhat limited and based primarily on information collected from trials or simulations. To date, there has been no opportunity for further follow-up.

These case studies were presented as documentation of each teams' work. They were originally abbreviated, visually intensive summaries that would allow others to quickly examine the scope and methods of the team's data collection, data analysis, problem assessment, proposed solutions, and final recommendations. These summaries were sometimes used as an attachment for an appropriations request or as a reference when subsequent changes in process or productivity warranted reevaluation of the job. As demonstrated in these case studies, it appeared desirable for the teams to have members who were hands-on technicians or engineers and who were good at design or layout and could assist in making prototypes and setting up simulations.

Even though the teams did not need semiquantitative or quantitative exposure analyses to evaluate these jobs, the investigators analyzed the study jobs with the SI and presented the analyses to the teams. The SI scores for these jobs were consistent with the observed musculoskeletal morbidity, thus contributing additional evidence of the validity of this proposed method as a tool that predicts risk of distal upper extremity morbidity. In addition, the observations from these three case studies suggest that the SI score may also correlate with turnover and severity rates. It is not possible to determine whether the reduced SI scores for these jobs will translate into reduced morbidity or turnover.

CONCLUSIONS

Participatory ergonomics teams from two departments analyzed and proposed solutions for some of the most difficult jobs in the plant. Time constraints for the project did not allow for an opportunity to see most of the interventions through to implementation. Solution evaluation was limited to information from trials and simulations. The teams used a structured problem-solving method that was, in part, derived from principles associated with quality improvement processes. Workers performing the targeted jobs were involved in the problem-solving process, even if they were not members of the team. Overall, the demonstration component of this project showed that the use of participatory ergonomics teams that rely on structured problem-solving methods worked effectively to address musculoskeletal hazards in the red meat packing industry.

ACKNOWLEDGMENTS

This work would not have been possible without the patience, assistance, support, and permission of the employees who participated in this project.

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APPENDIX

Worker Feedback Survey

The Ergonomics Committee is evaluating your job to look for potential improvements. One part of this evaluation involves obtaining information from the people who perform the job. This survey helps the committee (1) identify what parts of your body are affected, what type of symptoms you feel, how significant these symptoms are; (2) what you see as the problems with the job; and (3) your recommendations for improvement. This initial section is background information.

Name: ______________________________
Department: ______________________________
Supervisor: ______________________________
Job Title: ______________________________
How long have you held this job? ______________
Have you held jobs similar to this in the past? ______________
If yes: How many years? Where? ______________
Did you have similar problems then? ______________
What kind? ______________________________
Have you had any surgery related to that problem? ______________
Are you right- or left-handed? Right ________ Left ________
Do you have a second job elsewhere? ______________
Do you participate in sports? ______________

The next part of the survey asks about what parts of your body have been affected by your job, the type of symptoms you feel, and their intensity. There are two diagrams, one for the whole body and one for the hands, for you to indicate where these symptoms occur.

Do you experience discomfort or strain in any part of your body during the day or when you go home at night? If yes, please mark the sheet below. Mark "N" for numbness or tingling. Mark "P" for pain (add rating from scale below).

	Never	Rarely	Some, but it doesn't interfere with work	Sometimes I need to stop working because of the pain	I've missed work because of the pain
1. Neck	☐	☐	☐	☐	☐
2. Shoulders					
Left	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐
3. Elbows					
Left	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐
4. Forearm					
Left	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐
5. Wrist					
Left	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐
6. Hand					
Left	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐
7. Upper Back	☐	☐	☐	☐	☐
8. Lower Back	☐	☐	☐	☐	☐
9. Hips	☐	☐	☐	☐	☐
10. Thighs	☐	☐	☐	☐	☐
11. Lower Legs	☐	☐	☐	☐	☐
12. Feet	☐	☐	☐	☐	☐
13. Other (list)	☐	☐	☐	☐	☐

Pain Rating Scale

0	1	2	3	4	5
No Pain	Mild	Moderate	Distressing	Horrible	Excruciating

Job Efforts Requirements

This page is a scale, called the Borg 10-Point Scale. The scale is used to indicate the effort required to perform your job just once. It is a measure of the strength requirement of your job, not endurance.

Indicate in the boxes below how much effort is required by each of the body parts listed to do your job. Remember that this scale measures effort in terms of strength, not endurance.

	Left	Right
Shoulders	☐	☐
Elbows	☐	☐
Forearms	☐	☐
Wrists	☐	☐
Hands	☐	☐
Upper Back	☐	☐
Lower Back	☐	☐
Legs	☐	☐

Enter one of these numbers in each box.

Borg's 0–10 Category-Ratio Scale

0	Nothing at All
0.5	Just Noticeable
1	Very Light
2	Moderate
3	Moderate
4	Somewhat Hard
5	Heavy
6	
7	Very Hard
8	
9	
10	Extremely Heavy (Maximal)

Finally, we want your opinion and ideas on what aspects of the job contribute to these symptoms and how the job can be changed to eliminate these problems.

Do you think a particular operation or machine causes this discomfort? If yes, please describe it.

____
____
____
____
____

Do you have any ideas or recommendations for improvements that could be made to your job?

____
____
____
____
____