AN ERGONOMICS PROGRAM TO CONTROL WORK-RELATED CUMULATIVE TRAUMA DISORDERS OF THE UPPER EXTREMITIES

by

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In memory of my mother for giving me the confidence, determination, and perseverance to achieve my goals, and to my wife, Nancy, for her love and belief in me.

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16. Abstract (Limit: 200 words): A program was established in a hand intensive manufacturing facility to control upper extremity cumulative trauma disorders (CTDs). The plan consisted of four distinct components: job analysis; education and training of management and workers in the principles of ergonomics and identification of risk factors; development of a task force; and implementation of a health surveillance system. The control approach indicated that facility designed tools were the most successfully implemented attribute, followed by changes in work practices to reduce work stresses. The original program stressed administrative controls including worker rotation, job enlargement and market available tools, while the plan for new jobs stressed engineering controls such as work station design, gravity feed racks, and facility designed tools. The shift from administrative to engineering controls may be attributed to application of ergonomic principles by facility engineers during the design of new workstations, flexibility in production quotas during the work startup phase, and financial resources for ergonomic enhancements to new work stations after startup. The author concludes that the best time to implement ergonomic suggestions is during work station design and start up; that the success of retrofitting existing work stations by ergonomic design depends on the support of management and labor at all levels; and that any long term effectiveness of the Task Force is a direct function of key management and labor support.

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1 Introduction

There is evidence that manually-intensive jobs which require the use of force, repetition, and awkward postures are associated with upper extremity cumulative trauma disorders (CTD's). Such disorders affect the musculoskeletal system and the peripheral nervous system causing higher worker absenteeism rates and increased medical and workers' compensation costs. It has been suggested that managing such disorders through an ergonomics program may reduce the severity and possibly prevent CTD's. The essence of such a program would be to identify and reduce job risk factors through the application of ergonomic principles resulting in a reduction of CTD disease rates.

It is proposed that occupational cumulative trauma disorders can be controlled through an in-plant ergonomics program that includes: a task force steering committee, analysis of job stresses, analysis of employee health patterns, training of key plant personnel, and development and implementation of changes in work practices, work station layout, and tool design. The purpose of this thesis is twofold: (1) to develop an ergonomics program using the elements described above, and (2) to evaluate this approach in terms of its' ability to help identify and reduce occupational risk factors for CTD's.

Reports of chronic musculoskeletal disorders have been documented as far back as the year 1717 by the physician, Ramazzini. In his book *De Morbis Artificum Diatriba* ("Diseases of Workers"), Ramizzini describes certain occupations which caused "... *certain violent and irregular motions and unnatural postures of the body, by reason of which*

the natural structure of the vital machine is so impaired that serious diseases gradually develop therefrom." (Louis, 1987).[1] Later studies focused on pathologic conditions, pathogenesis, morbidity, diagnosis, and treatment (Armstrong et al, 1987).[2] Several of these studies present case reports citing certain occupational and nonoccupational risk factors which give rise to musculoskeletal injuries (Conn, 1931[3], (Pozner, 1942[4]; Reed and Harcourt, 1943[5]; Hymovich and Lindholm, 1966[6]; Wisserman and Badger, 1977[7]). However, one of the major limitations to such reports is the lack of identified risk factors which may lead to musculoskeletal disease. This has been particularly evident in occupational settings where risk factors and musculoskeletal disease have not been firmly established. Only recently have epidemiological studies attempted to examine the association between job risk factors such as repetition, awkward postures, and force with excess musculoskeletal morbidity. Several cross-sectional and case-control retrospective studies of occupational CTD's have been employed (Andersen, 1972[8]; Hadler, 1978[9]; Drury and Wick, 1984[10]; Cannon, 1981[11]; Herberts, 1981[12]; Armstrong et al, 1982[13]; Kvarnstrom, 1983[14]; and Silverstein, 1985[15]). The conclusions from these studies have drawn us closer to identifying risk factors with disease outcome. However, such studies have been limited either from health or exposure measurement parameters (Silverstein, 1985).[15] The purpose of this paper is to present the results of an ergonomics control program which sought to identify job risk factors, to establish base line rates of musculoskeletal symptoms, and to improve the musculoskeletal health status of these workers.

The first section of this study will discuss the study site, plant profile, job selection, and Task Force steering committee analysis over the control program period. The second section will discuss job

selection and job analysis changes in risk factors associated with cumulative trauma disorders. The third section will discuss the health surveillance changes over the control program period.

1.1 Study Site and Plan

A control program was established in a hand intensive manufacturing plant to control upper extremity cumulative trauma disorders. The plan consisted of four distinct components: (1) job analysis; (2) education and training of management and workers on the principles of ergonomics and identification of risk factors; (3) development of a task force; and (4) implementation of a health surveillance system. From this we attempted to systematically document the changes in the work process, work station layout, tool use, and administrative controls.

Traditional job analysis procedures were used to document potential CTD risk factors in selected departments and jobs. Management and labor were educated and trained on the principles of ergonomics in order to make them aware of CTD risk factors. A plant task force was created for two purposes: (1) to coordinate financial, material, and personnel resources in the plant for implementing the ergonomic suggestions from the outside ergonomics consultants; and (2) to encourage discussion between department and union representatives about the CTD-reducing utility of the ergonomic suggestions. Three surveys of hourly employees provided base line, mid-program, and final health status information which was then analyzed to determine if the intervention had an effect on the prevalence, incidence, and severity of the CTD.

1.2 Plant Profile

A Midwest plastics manufacturing and assembly plant requested assistance in reducing CTD's among its workers. Approximately 700 hourly and 300 salaried workers were employed at this plant at the start of this study. The primary products manufactured are automobile

consoles, molded grills, dashboards, hood, and fender parts. Though there are ten major departments which perform most of the manufacturing operations, the jobs could be logically subdivided into four categories: assemblers, press operators, finishers and routers, and stock handlers. There were several non-manufacturing departments, including quality control, material transport (forklift trucks), maintenance, and cleaning.

Assemblers work in nearly every manufacturing department. Their duties vary from manual insertion of metal clips to the use of power tools to drive metal studs and screws. There are three types of press operators: injection molders, blow molders, and compression molders. Generally, press opertions are automatic in which fabricated plastic parts are released from the press to a moving conveyor. The conveyor carries the part to the press operators who trim them for processing at the next work station. Injection molders trim and cut parts made from molten plastic forced into a die and allowed to cool. The injection molders use a knife to trim plastic flashing, and "sidecutters" (wire cutters) to cut sprues from the part. Blow molders use a linoleum knife to remove flash from air filled plastic parts (such as load floors in automobile station wagons). The blow molders then store the parts in cooling racks for later processing. Compression molders cut fibrous glass and styrene-resin sheets, approximately 1/4-inch thick and 48 inches wide, from large rolls of this material. The material is weighed and then set into dies which compress the material to the desired shape. The compression molders use a razor knife to cut this material. Finishers and routers use powered tools to sand and trim rough surfaces from parts. Stock handlers move material on and off assembly lines.

This ergonomics control program consisted of: (1) education and training of management and labor to gain general knowledge of ergonomics, and development of a Task Force steering committee consisting of plant representatives from management, labor, engineering,

medical, and safety, (2) job analysis (described in Chapter 2), and health surveillance (described in Chapter 3). Chapter 1 presents the study factors affecting program effectiveness.

2 Background - Organizational Aspects and Limitations

Certain organizational changes may facilitate identification and implementation of control measures. One such change is the use of a Task Force to skillfully guide and manage resources in a plant and thereby reduce occupationally related musculoskeletal injuries (Liker et al, in press).[16] This contrasts with a more traditional approach for intervention which is to hire professionally trained experts. These experts typically conduct a walk-through survey; interview employees, management, and medical personnel; collect data, analyze the data, and write a report containing recommendations to alleviate or eliminate the problem(s). The major drawback to this approach is the lack of "in-house" or plant expertise to carry through with recommendations, and to apply recommendations to new situations as they arise.

The organizational structure in most plants is typically a hierarchical system with top-down decision making, thus leaving a large and beneficial knowledge base (the workers) uninvolved with trouble-shooting or goal-setting. Several reasons for maintaining the traditional approach have been suggested. Resistance to change is one stumbling block. Some believe that management resists change because it may negatively influence the actual or perceived power base from which it operates. Some researchers call this the Organizational Politics Model (Cyert and March, 1963[17]; March and Simon, 1958[18]; Allison, 1971.[19] Workers may also resist change because of established work habits, routines, and because they perceive that change may affect salary, position, or status.

Change, however, does occur and is often brought about by the organization's own recognition of the problem. The organization diagnoses the problem, selects the best solution, and adapts accordingly for successful immediate and long-range goals. Some in the American automobile industry have recently attempted to change the management approach in making automobiles because of concerns about decreasing productivity, labor-management relations, and decreasing competitiveness with the world market (Peters and Waterman Jr., 1982).[20] Much was publicized about Japan's positive labor-management interaction, particularly about their use of employees as a source of information for product quality (Noro, 1983)[21], and work station quality (Noro, 1985)[22]. Some have argued that workers who have a say in their work will have increased job satisfaction, reduced absenteeism, increased production, and better quality of work life, including safety and health benefits (Seashore, 1980)[23].

This new strategy involves workers along with management in the planning and decision making process (Hackman and Oldham, 1980).[24] This approach could also be used to control CTD's through an intervention program. One method of intervention is through an in-plant multidisciplinary task force composed of management and labor with health and safety representatives. Their goal in this case was to control and reduce CTD disorders. It has been suggested that task forces are most effective when they meet regularly, discuss problem solving ideas and solutions, and follow-up on these solutions to gauge their effectiveness (Liker et al, in press).[16] Advantages of such a group include: (1) the in-house resources with a comprehensive knowledge of plant operations and efficiencies, (2) the commitment to problem identification and solution, (3) a resource base responsible for maintaining an ongoing ergonomics program, and (4) the cooperation and support of management and labor as task force decisions are passed on to workers and first-line supervisors for their support and feedback.

To date few studies have systematically examined the effect of a participative task force whose purpose was: (1) to use ergonomic principles to control and reduce upper extremity musculoskeletal injuries in an occupational setting, and (2) to monitor the effectiveness of such changes through health surveillance. Several factors need to be addressed concerning the effectiveness of a participative task force in order to determine the utility of this approach: the level of commitment from top management, the role of ergonomics experts, the acceptance of ideas by labor and management, the consideration and implementation of ergonomic suggestions from these experts, and the comparative success rate in changing worker health status based on the motivation and involvement of task force members.

2.1 Training and Education of Plant Personnel

Education and training are needed to make management and labor aware of potential problems associated with CTD. Education facilitates the transfer of techniques for identifying associated job risk factors and Musculoskeletal injuries. It also allows for the awareness of ergonomic principles which may be used to identify and change these risk factors. It allows for an understanding of the fundamental concepts of physiology, anatomy, and biomechanics of the human body and the body's relationship to manually intensive work. Training offers labor and management techniques to identify job risk factors, such as viewing videotapes of jobs in their plant, and for independent and collective thinking on problem identification and problem solution. The increased awareness resulting from education and training will identify specific risk factors in the plant and permit intervention and prevention strategies to control these problems.

2.2 Task Force Development

A task force comprised of management, labor, engineering, safety, and medical personnel from the plastics plant was assembled to oversee

this CTD control program. The ergonomic consultants provided information to move the task force through the early stages of the CTD control program. This group met biweekly during the early stages of the control program for education and training; later, while considering the implementation of control recommendations, it met monthly; toward the end of the program the task force met once every 2 months to evaluate the progress of the study.

Early in the program researchers provided an "elemental" analysis of selected jobs for task force members (Table 1). From these jobs ergonomics consultants highlighted certain elements in the job which were associated with CTD's and provided suggestions to eliminate these hazardous elements (Table 2). To develop an interactive dialog between ergonomics consultants and task force members, videotapes of plant workers on the job were shown during task force meetings. The videotapes served as a visual aid which assisted task force members in identifying CTD risk factors, and in initiating suggestions for job changes which could reduce CTD's. During the scheduled meetings between ergonomics consultants and the Task Force these suggested changes would be discussed and then assigned to department supervisors for follow-up. Progress reports based on these suggestions were reviewed in later task force meetings. Figure 1 presents an overview of when the task force meetings took place relative to other control program elements (discussed in parts 1 and 2 of this study).

In addition, the ergonomics consultants were asked to video tape some of the new jobs and offer recommendations. This was done, and while ergonomic applications for the new jobs were not a planned part of the control program, (see parts 1 and 2) the ergonomic changes were recorded and are presented in this section. The purpose of presenting the "new job" changes with the "original jobs" is to compare and contrast which types of controls which worked best. It is believed that

Table 1. Elements for One Job Cycle for Assembler: Ram Line Lead-Off

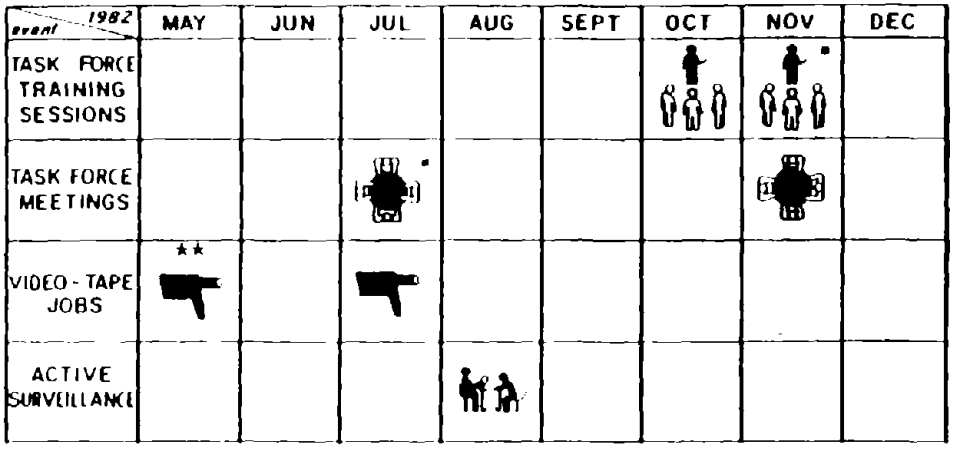
Left Hand	Right Hand
1 Reach to get dashboard	1 Reach to get dashboard
2 Grasp dashboard	2 Grasp dashboard
3 Move dashboard to line	3 Move dashboard to line
4 Pre-position dashboard	4 Pre-position dashboard
5 Position dashboard on line	5 Position dashboard on line
6 Release dashboard on jig	6 Release dashboard on jig
7 Reach to dashboard support	7 Idle (hand at rest)
8 Grasp dashboard support	8 Idle (hand at rest)
9 Move support to dashboard	9 Reach for tool
10 Position support on dashboard	10 Grasp screw driver
11 Hold dash support on dashboard	11 Move screw driver to dashboard
12 Hold dash support on dashboard	12 Position screw driver on dashboard
13 Hold dash support on dashboard	13 Use screw driver on dashboard
14 Move to load screw driver	14 Move screw driver to dashboard
15 Position screw on screw driver	15 Move screw driver to dashboard
16 Holding dashboard	16 Using screw driver on dashboard
17 Idle (hand at rest)	17 Moving screw driver to bench
18 Idle (hand at rest)	18 Position screw driver on bench
19 Idle (hand at rest)	19 Release screw driver on bench
20 Idle (hand at rest)	20 Release jig posts
21 Idle (hand at rest)	21 Grasp jig posts
22 Idle (hand at rest)	22 Move (turn) jig posts
23 Idle (hand at rest)	23 Release jig posts
24 Idle (hand at rest)	24 Idle (hand at rest)
25 Idle (hand at rest)	25 Reaching for jig posts
26 Idle (hand at rest)	26 Grasp jig posts
27 Idle (hand at rest)	27 Move (turn) jig posts
28 Idle (hand at rest)	28 Release jig posts

Table 2. Summary of Risk Factors and Recommendations for Ram Line Lead-Off operator by Element

Work Element	Problem	Recommendation
5-6 10-23	Sharp edges from work bench rubs operator's waist	Pad in front of bench
Right Hand 12,13	Pistol grip screw driver used which causes high wrist flexion	Provide in-line screw driver to straighten out wrist.
1-27	The use of gloves may decrease the sensitivity of the hands, & may contribute to the awkward work angle of the wrist.	Use a flexible light weight glove for better feel of parts, and to aid in sensory feedback for a natural wrist posture.
Left Hand 7,8	Reaching back (arm abduction) to get dash-board part.	Move dashboard supports adjacent to the work bench so the worker does not have to reach back for part.
Right Hand 21	Grasping jig sprues requires repetitive finger pinch, possibly with high force.	Provide larger grip for jig handle to avoid finger pinch.

PROGRAM FOR CONTROLLING CUMULATIVE TRAUMA DISORDERS

AUTOMOTIVE PLASTICS PLANT



** Walk-through survey 1 month prior to videotaping to identify high risk jobs.

■ Denotes two sessions in same month

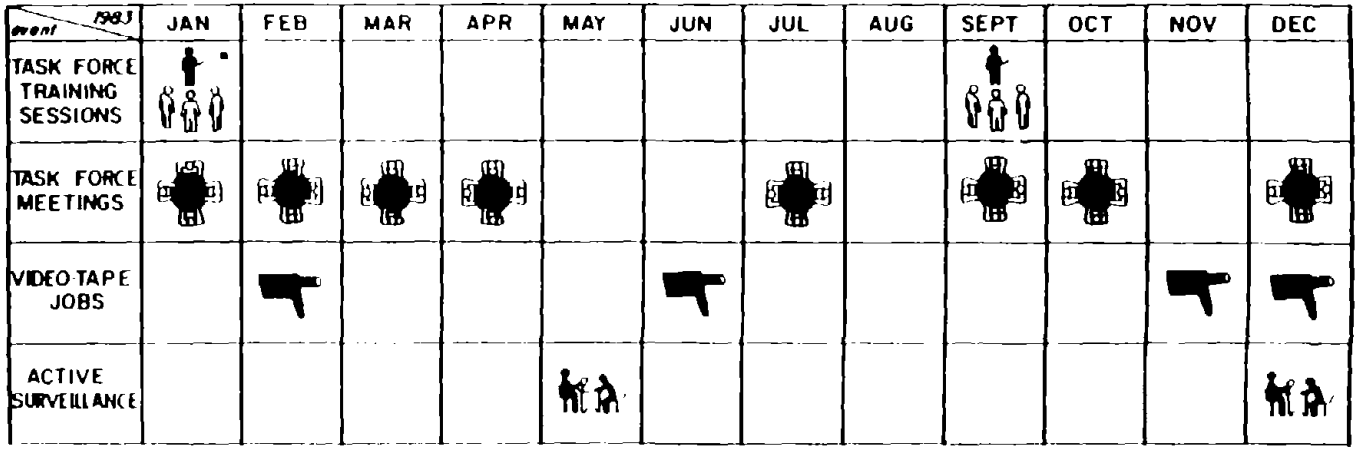


Fig. 1. Primary Elements for a Program to Control Cumulative Trauma Disorders of the Upper Extremities

the comparison between the new and old jobs will provide practical knowledge about the effective elements of an ergonomics control program in a dynamic work environment such as the automotive industry.

3 Measurement of Task Force Actions

The ergonomics consultants presented work-station, product, tool, and work-practice modifications to the task force. These four "control approach" classifications were: (1) Administrative, (2) Work Practice, (3) Engineering (Internal- (i.e., Plant Designed Tools)), and (4) Engineering (External- (i.e., Market Available)). In addition, each approach was assigned one of four "affected job attribute" classifications identifying the type of control. The four job attributes are: (1) Tool Design, (2) Production, (3) Work Methods, and (4) Work Station. The scope of the definitions for the Control Approach Classification and Affected Job Attribute Classification are shown below.

Control Approach Classification

Administrative: Any management initiative which modified the work process and/or work exposure to reduce CTD stress. Examples include: worker rotation, changes in work/rest cycles, the provision of gloves for workers, and quality control assurance in vendor-supplied parts.

Work Practice: Any behavioral change with regard to the worker and work cycle resulting from modification to the work station, tools, assembly part, and/or process that does not require engineering intervention. An example is the repositioning of the work piece clips and stud-gun closer to worker's functional reach.

Engineering (Internal- Plant Design): Any modification to the work station, tools, assembly part, and/or process through engineering

controls developed in the plant. Examples include: the elevation of work bench height, the relocating of press buttons from worker's head to waist level.

Engineering (External - Market Available): Any modification to the work station, tools, assembly part, and/or process through engineering controls developed outside the plant. Examples include: the installation of powered cutters to cut plastic sprues, the provision of a knife sharpener, and the substitution of a knife with angled handle for one formerly used.

Affected Job Attribute Classification

Tool Design: Any tool addition, or tool change which reduced physical job stress for the worker. Examples include: a new handle for powered sander, installation of a flexible hose for stud gun, and a smaller knife-handle diameter.

Production: Any change in the production process which reduced physical job stress for the worker. Examples include: better maintenance of presses to reduce manual trimming of plastic flash from finished parts, improved quality control of vendor-supplied parts such as well-machined screws which are used for assembly, and fabrication of easy to assemble parts such as plastic clips.

Work Method: Any work-practice change in the way the work is done. Examples include: repositioning of the work-piece loading rack and stud gun closer to worker, and the securing of the work piece before flash cutting.

Work Station: Any modification to the physical layout of a work station which reduces CTD stress on the worker. Examples include: loading bins that tilt toward worker, padding on front edge of work bench, and adjustable benches to prevent worker from stooping or reaching.

The four control approaches and four affected job attributes can be paired together in 16 possible combinations. For example, the control approach for Engineer (Internal) could be paired with the affected job attribute of Tool Design, or Work Station, depending upon the type of job attribute observed. Similarly, an Administrative control approach could be paired with Production or Work Method job attribute. While this list of approach and attribute classifications is not inclusive, it does provide a method for measuring the CTD recommendations suggested, considered, and acted upon by the task force.

4 Task Force Results

There were 46 distinct activities resulting in program advancement performed over the twenty-month period. Task Force activities included: establishing work assignments, setting surveillance survey dates, setting task force meetings, and requests for job evaluations. Representatives of the plant Task Force were divided into four subgroups: management (including engineers), safety, medical, and labor; also included were the ergonomics consultants. The ergonomics consultants were involved and partially responsible for ninety-three percent of the control program activities; the plant safety and health representative and labor representatives, forty-six percent; management, forty-one percent; and medical, twenty percent (Table 3).

Table 3. Task Force Activity by Subgroup* for Ergonomics Control Program

Sub Group	# of Activities[1]	Percent
Management	19	41
Safety	21	46
Medical	9	20
Union	21	46
Ergonomics Consultants	43	93

* Total N = 46 distinct activities; some activities were performed by more than one subgroup.
1. An activity is defined as a contribution by a sub group which resulted in the advancement of the Ergonomics Control Program.

4.1 Task Force Results for Original Studied Jobs

This section summarizes the recommendations considered and implemented by the Task Force for the "original study jobs" that were in operation at the time this ergonomics control program began. The task force maintained its education, training, and meeting schedule to consider and implement control recommendations. It first considered the jobs of "Ramline" Assembly (Department 1610), small and large Injection Mold Press Operators (Department 1700), Blow Mold Press Operators (Department 1750), and Compression Mold Press Operators (Department 1790). For the Ram Line, ergonomics consultants made five recommendations; four were considered by the task force; one adopted. Of thirteen recommendations advanced for the small and large Injection Mold Press Operators, four were considered and three were implemented. Blow Mold Press Operators received four recommendations; three were considered feasible and two were implemented. Compression-Mold Operators were given two recommendations, both of which were implemented. In Blow Molding, a work bench was built which could be tilted toward the worker. Its purpose was to reduce shoulder and arm stress while trimming flashing from the part. A few workers tested the new bench but said

that the larger size made it more awkward and difficult to dispose of manual scrap. The absence of effective bench design probably was the main factor inhibiting worker acceptance of this control recommendation. Table 4 summarizes the original job recommendations and actions of the Task Force.

The ergonomics consultants suggested a total of 51 changes, the task force considered 17 (33%) recommendations, and implemented 9 (18%). There were a number of reasons why so few of the recommendations were considered, and fewer implemented. Two of the primary reasons include: attendance of supervisors at the task force meeting to discuss work station changes which would have an impact in their department, and financial resources available for implementing change.

4.2 Task Force Results for New Studied Jobs

This section summarizes the recommendations considered and implemented by the Task Force for the "new study jobs" that were evaluated after the ergonomics control program began. Ten months into the control program, several new console assembly jobs were being prepared for full production. The Task Force asked the ergonomics consultants to perform job analyses and provide recommendations while many jobs were in the prototype stage. Four console assembly jobs were evaluated from March to November 1983, and the bumper assembly job in December 1983. The researchers presented thirteen recommendations for the console and bumper jobs; ten recommendations were considered and six were implemented. Five of nine console assembly job recommendations were acted upon. Several of the console assembly recommendations involved work station design enhancements. The bumper-assembly job recommendations were not as successful, possibly due to the lack of time between the recommendations and implementation. Because of the complexity there were several quality control and production problems in the bumper program in December 1983. These problems received a higher

Table 4 Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach Work Practices Engineer (Int) Engineer (Ext.) Administrative	Affected Job Attribute Work Method Work Station Tool Design Production
1600 Assembly	Move workpiece closer to worker's functional reach.			Work Practices	Work Method
	Pad front edge of workbench.			Engineer (Internal)	Work Station
	Design new tool or new clip for easier assembly.			Engineer (Internal)	Work Station
	Move clips to front of bench.			Work Practices	Work Method
1610 Assembly	Pad front edge of bench.			Engineer (Internal)	Tool Design
	Provide inline screwdriver.	X		Engineer (External)	Tool Design
	Provide gloves.	X	X	Administrative	Tool Design
	Move bracket assembly.	X		Engineer (Internal)	Work Station
	Reorient alignment pins.	X		Engineer (Internal)	Work Station
1700 Press Op. (Small Presses).	Install catch cart for new molded parts.			Engineer (Internal)	Work Station

Table 4 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach Work Practices Engineer (Int) Engineer (Ext.) Administrative	Affected Job Attribute Work Method Work Station Tool Design Production
	Obtain power cutters for cutting sprues from workpiece.	X	X	Engineer (External)	Tool Design
	Elevate bench height to prevent worker from stooping.			Engineer (Internal)	Work Station
	Round bench corners.			Engineer (Internal)	Work Station
	Move assembly clips to front of workbench.			Work Practices	Work Methods
1700 Press OP. (Large Presses).	Install catch cart at end of conveyor to receive finished parts.			Engineer (Internal)	Work Station
	Secure workpiece on jig before cutting flash with knife.			Work Practices	Work Methods
	Provide fixture to hold knife when not in use.	X	X	Engineer (Internal)	Work Methods
	Reshape knife angle.			Engineer (Internal)	Work Methods
	Increase knife handle				

Table 4 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach: Work Practices / Engineer (Int) / Engineer (Ext.) / Administrative	Affected Job Attribute: Work Method / Work Station / Tool Design / Production
	diameter to 1.4"	X	X	Engineer (External)	Tool Design
	Install powered "sidecutters" to cut plastic sprues.	X		Engineer (External)	Tool Design
	Install catch cart for finished parts.			Engineer (Internal)	Work Station
	Relocate press buttons from above worker's head to waist level.			Engineer (Internal)	Work Station
1750 Press Op.	Provide knife sharpener for worker's knives.	X	X	Engineer (External)	Tool Design
	Install catch carts at bench level to catch flashing.	X		Engineer (Internal)	Work Station
	Install break-away clamp to secure load floor while trimming flashing.			Engineer (External)	Tool Design
	Build a workbench tilted 36 degrees toward the worker.	X	X	Engineer (Internal)	Work Station

Table 4 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach: Work Practices, Engineer (Int), Engineer (Ext.), Administrative	Affected Job Attribute: Work Method, Work Station, Tool Design, Production
1750 Assembly	Move assembly clips next to bench.			Work Practices	Methods
	Use spring-loaded cart for load floors.			Engineer (External)	Work Station
	Reposition stud gun closer to worker.			Work Practices	Methods
	Install more flexible hose for stud gun.			Engineer (External)	Work Station
	Enlarge holes in workpiece to make assembly easier.			Administrative	Production
	Install adjustable jig for worker.			Engineer (External)	Work Station
1790 Press OP.	Obtain knife with angled handle.	X	X	Engineer (External)	Tool Design
	Get automatic feed roll.	X		Engineer (External)	Tool Design
1790 Assembly	Use rubber mallet to seat clips on workpiece.	X	X	Administrative	Tool Design

Table 4 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Apporach Work Practices Engineer (Int) Engineer (Ext.) Administrative	Affected Job Attribute Work Method Work Station Tool Design Production
	Move workpiece loading rack closer to worker.			Work Practices	Work Method
	Install padding on front edge of workbench.			Engineer (Internal)	Work Station
	Provide gloves for workers	X	X	Administrative	Tool Design
1790 Surface Finishers	Move clipboard closer to worker.			Work Practices	Work Method
	Move sander closer to operator.			Work Practices	Work Method
	Provide jig to hold workpiece.			Engineer (External)	Work Station
	Develop new handle for sander	X		Engineer (External)	Tool Design
	Provide an exhaust hose for sander.	X		Engineer (Internal)	Tool Design
	Provide load bins that tilt toward worker.			Engineer (Internal)	Tool Design

Table 4 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- Original Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach: Work Practices / Engineer (Int) / Engineer (Ext.) / Administrative	Affected Job Attribute: Work Method / Work Station / Tool Design / Production
1790 Router	Adjust router for left handed worker.			Engineer (External)	Tool Design
	Design angle for head of router.			Engineer (External)	Tool Design
	Use light-weight hose material for router.			Engineer (External)	Tool Design
	Provide spring loaded cart for finished parts.			Engineer (External)	Work Station
1800 Spray Painters.	Install 150 degree rotatable jig for spraying workpiece.			Engineer (Internal)	Work Station
	Remove foot barrier in front of paint booth.			Engineer (Internal)	Work Station
	Install adjustable height controls for jig.			Engineer (Internal)	Work Station

priority and obviously had to be worked out before ergonomic controls could be instituted. Table 5 summarizes the new job recommendations and Task Force adoptions.

4.3 Comparison between Original and New Studied Jobs

Tables 6(a) and 6(b) depict a comparison of control approaches suggested, considered, and acted upon for the original versus new studied jobs. Table 7 shows the significant differences between original and new studied job control approaches. Specific differences between original and new jobs with regard to control approach are explained below.

4.3.1 Control Approach Classification Findings

Administrative Controls Administrative controls were acted upon more often in the original studied jobs than in the new jobs. Administrative controls were particularly evident in Department 1700 (Injection Molding), and Department 1610, (Ram line) where management directed worker rotation and job enlargement to reduce worker exposure to CTD risk factors. Worker rotation and job expansion, and the ergonomic equipment purchased for the plant (i.e., external engineering controls) were more evident in the original jobs. In addition, time standards, production quotas, and limited money for major modifications made administrative controls easier to implement.

Work Practices The implementation of work practices as a means of control did not significantly differ between original and new jobs. It is interesting that none of the nine work-practice suggestions was discussed or acted upon in the original studied jobs. This compares to one of two work practice recommendations acted upon in the new studied jobs. Modified work practices resulted from work station redesign and

Table 5 Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- New Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Approach Work Practices Engineer (Int) Engineer (Ext.) Administrative	Affected Job Attribute Work Method Work Station Tool Design Production
1632 Console Assembler	Install jigs on work surface to hold part.	X	X	Engineer (Internal)	Work Station
	Install tool retractors for easier tool use and storage.	X		Engineer (External)	Work Station
1633 Console Assembler	Fabricate clip holder for clip insertion	X	X	Engineer (Internal)	Tool Design
	Install jig to hold console during clip assembly.			Engineer (Internal)	Work Station
	Fabricate new clip for easier part assembly	X	X	Engineer (Internal)	Production
1634 Console Assembler	Provide fixture to hold stud gun after use.	X	X	Engineer (Internal)	Work Station
	Install breakaway clamp to hold console during assembly.	X	X	Engineer (Internal)	Work Station

Table 5 (Continued) Task Force Considerations and Actions for Control Recommendations of Cumulative Trauma Disorders -- New Studied Jobs.

Depart./Job	Ergonomics Consultant Suggested Recommendations	Actions Considered	Actions Taken	Control Attribute Work Practices Engineer (Int) Engineer (Ext.) Administrative	Affected Job Attribute Work Method Work Station Tool Design Production
	Enlarge holes in workpiece to make assembly of part easier.			Administrative	Production
	Locate tools and parts within easy functional reach of worker.	X	X	Work Practices	Work Method
1640 Bumper Assemble	Use in-line screw gun to vertically drive screws into part.			Engineer (External)	Tool Design
	Provide jig to hold bumper during assembly.	X		Engineer (Internal)	Work Station
	Locate tools and parts within functional reach of worker.	X		Work Practices	Work Method
	Trim plastic sprues with powered cutters.	X		Engineer (External)	Tool Design

Table 6(a) Control Approach - Recommendations Provided by Ergonomics Consultants for Original Studied Jobs

Recommendations (N=51)	Suggested	%	Considered	%	Acted	%	A/S x 100*
Administrative	4	(8)	3	(6)	3	(6)	75
Work Practices	9	(18)	0	(0)	0	(0)	0
Engineering (Internal-Plant Designed)	21	(41)	6	(12)	2	(3)	10
Engineering (External-Market Avail.)	17	(33)	8	(16)	4	(8)	24

* A/S x 100 - Acted/Suggested x 100 - % Suggested approach acted upon.

Table 6(b) Control Approach - Recommendations Provided by Ergonomics Consultants for New Studied Jobs

Recommendations (N=13)	Suggested	%	Considered	%	Acted	%	A/S x 100*
Administrative	1	(8)	0	(0)	0	(0)	0
Work Practices	2	(15)	2	(15)	1	(0)	50
Engineering (Internal)	7	(54)	6	(46)	5	(38)	71
Engineering (External)	3	(23)	3	(23)	0	(0)	0

* A/S x 100 - Acted/Suggested x 100 - % Suggested approach acted upon.

Table 7 Comparison of Control Approach for Original and New Studied Jobs

Control Approach	Studied Jobs Original	New	Fishers Exact Test P value
1. Administrative	3/4 - 75%	0/1 - 0%	0.4
2. Work Practices	0/9 - 0%	1/2 - 50%	0.18
3. Engineer (Internal)	2/21 - 10%	5/7 - 71%	0.003
4. Engineer (External)	4/17 - 24%	0/3 - 0%	0.49
Overall (N - 64)	9/51 - 18%	6/13- 46%	0.04

layout; moving parts closer to workers; organizing the work station layout to reduce excess reach and movement; and redesign of certain assembly parts (e.g., assembly clips).

Engineer (Internal- Plant Design) Internal engineering changes to the work station, tools, assembly parts, and processes were significantly ($p < 0.003$) higher among the new jobs. Only two of twenty-one (10%) recommendations were acted upon by the task force for original jobs compared to five of seven recommendations acted upon for new jobs. This difference probably results from the flexibility of start-up work station design, lack of established time standards and production quotas, and "launch" money available for new jobs.

Engineer (External- Market Available) External engineering changes, usually in the form of new equipment or tools were more prevalent in the original jobs. While not significantly different ($p = .49$), one in four recommendations in the original jobs were acted upon, compared to zero for three recommendations acted upon in new jobs. This difference may result from the ease with which the plant could purchase rather than develop or invent ergonomically oriented tools and equipment. Later it was shown that commercially available tools were not as well suited to the tasks as tools developed in-house.

4.3.2 Affected Job Attribute Classification Findings

The comparison of affected job attributes suggested, considered, and acted upon for the original versus new studied jobs is shown in Tables 8a and 8b. Significant differences between original and new studied job recommendations for these attributes are shown in Table 9. Specific affected job attribute findings between original and new studied jobs are explained below.

Tool Design Tool design recommendations were acted upon more often (37%) than any other affected job attribute category for original jobs.

Table 8(a) Affected Job Attribute. Recommendations Provided by Ergonomics Consultants for Original Studied Jobs

Recommendations (N=51)	Suggested	%	Considered	%	Acted	%	A/S x 100*
Tool Design	19	(37)	12	(24)	7	(14)	37
Production	1	(2)	0	(0)	0	(0)	0
Methods	10	(20)	2	(2)	1	(2)	10
Work Station	21	(41)	3	(6)	1	(2)	5

* A/S x 100 - Acted/Suggested x 100 - % Suggested improvements acted upon.

Table 8(b) Affected Job Attribute. Recommendations Provided by Ergonomics Consultants for New Studied Jobs

Recommendations (N=13)	Suggested	%	Considered	%	Acted	%	A/S x 100*
Tool Design	3	(23)	3	(23)	1	(8)	33
Production	2	(15)	1	(8)	1	(8)	50
Methods	2	(15)	2	(15)	1	(8)	50
Work Station	6	(46)	5	(38)	3	(23)	50

* A/S x 100 - Acted/Suggested x 100 - % Suggested improvements acted upon.

Table 9. Comparison of Affected Job Attribute for Original and New Studied Jobs

Affected Job Attribute	Studied Jobs Original	New	Fishers Exact Test P value
1. Tool Design	7/19 - 37%	1/3 - 33%	0.71
2. Production	0/1 - 0%	1/2 - 50%	0.66
3. Methods	1/10 - 10%	1/2 - 50%	0.32
4. Work Station	1/21 - 5%	3/6 - 50%	0.025
Overall (N - 64)	9/51 - 18%	6/13 - 46%	0.04

However, tool design was the least affected job attribute for new jobs (33%). A comparison between the original and new tool design attributes show no significant difference for this type of control activity. It is interesting to note that tool design for original jobs was the most successful of the four categories for implementation of suggestions from the ergonomics consultants (seven acted upon for twelve suggested). Suggestions such as increasing knife diameter for a better grip, obtaining angled knives to reduce awkward wrist postures during use, and providing better fitting tools were the most successful recommendations implemented.

Production Production changes (i.e., methods or procedures) were the least frequently recommended job attribute changes forwarded by the ergonomics consultants for the original jobs because of the complex network of part orders, assembly process, and high level management input. The one production recommendation, "Enlarge holes in work piece to make part assembly easier", was not adopted because it was expensive to retool the dies and because of managerial inertia. New jobs however, were more amenable to recommendations during their development. While a similar request as that noted above was not acted upon, the request for a new clip was accepted. The new clip was very successful because musculoskeletal stress was reduced, production increased, quality control enhanced, and this clip was less expensive than the metal clip it replaced. Because of the small number of recommendations for this category there was no significant difference between original and new production affected job attribute activities.

Work Methods Out of ten suggestions on work method in original jobs, one was accepted. The majority of examples included relocation of existing tools and/or parts for easier access during the work cycle. Examples included: "secure work piece on jig before cutting flash with knife"; "position stud gun closer to worker"; and "move work piece loading rack closer to worker". Each of these recommendations would

have involved surveillance and education of workers about proper work methods by first line supervisors. Because of production quotas, scheduling changes, and the myriad of other demands put upon these supervisors at the time of this study there was very little time to instruct and enforce these changes. The new studied jobs were again proportionately more successful because of the flexibility in the work station layout and the lack of any established work routines for these jobs. There was no significance difference ($p = .32$) between the original and new job work method attributes.

Work Station Attribute There were twenty-one work station job attribute changes recommended by the ergonomics consultants; one of these was acted upon for originally studied jobs. The recommendations included: "installation of an automatic feed roll for compression molding"; "install spring-loaded cart for stacking load floors"; "installation of a catch-cart for finished parts"; and "build a workbench tilted 36 degrees toward the worker." Only the last example was implemented. There are many possible reasons for the lack of action on these recommendations: scarce financial resources to build and install the required equipment; the lack of interest in changing the established work routine; the perception that a change at one job might affect something further down the line; and, perhaps most important, the possibility that this job (Compression Molding - Department 1790) might be replaced by the new bumper program which was to begin within the next few years.

The new work station attributes were more successful (three out of six) because the work stations could be easily modified. There was money available to modify these work stations and there were more precise recommendations by the ergonomics consultants (i.e., their skill at determining what was needed and what could be done improved over the course of the program). The difference between the implementation of

original and new job work station attributes was significant (p=.025). Table 10 shows a summary of the Task Force considerations and actions for control recommendations comparing original versus new studied jobs.

4.3.3 Specific Changes to Department/Jobs Regarding Tool Design, Production, Method, and Work Station

Implementation of tool, part, and work station changes was more prevalent in the new jobs set up since the beginning of the CTD control program. The majority of these new jobs were for console assembly. The job design changes included: holding racks angled toward the worker, part carts which angled toward the worker, in-line power tools supported by retractors or jigs, and use of robots for certain assembly tasks. One notable part change was the reduction in hand-held metal clips used for console assembly. Since the workers on this console assembly job complained of sore fingers while working with these clips, a tool was developed which held the clip during assembly. Its purpose was to translate the stress forces from the fingers to the hand. The workers reported that the tool helped but slowed down assembly because of its awkward size and shape. Finally, a plastic "thumb" clip was developed to replace most of the original metal clips. The thumb clip was easy to insert during assembly and featured collapsible probe fasteners.

Another change which resulted in a reduction in risk for CTD, although not intended for this purpose, was the substitution of a hard plastic material (polycarbonate additive) for a soft plastic material (acrylonitrile butadiene styrene additive), in Department 1700 (Injection Molding). The Task Force was made aware of the benefit of this process change when workers said trimming the new material was easier and less stressful on their hands. The polycarbonate material was substituted for acrylonitrile butadiene styrene material approximately 12 months into the CTD program.

4.4 Worker Initiated Changes for Ergonomic Stress Reduction

As part of the control program ther ergonomics consultants were in constant contact with workers on the plant floor. During the video taping and health surveillance it was observed that some workers, on their own initiative, had conceived and fabricated several hand-held tools which made their jobs easier. Examples include: (1) a plastic runner sharpened at one end and used as an auger to ream holes in parts so that part assembly was easier; (2) extending the handles of "sidecutters" so that two hands instead of one could be used for better leverage to cut plastic runners and sprues; (3) two types of tools which hold and insert metal clips into plastic parts (one tool was a modified ice pick, the other was fabricated from metal casting); and (4) the modification of a pistol-grip trigger which activates the nozzle of 16 ounce spray paint cans.

Upon questioning, these workers mentioned that the reason they developed and used these tools was partly because of their awareness of ergonomic principles in reducing stress, but mostly out of necessity. In the examples cited above each worker said his tool helped reduce stress and made his job easier. For example, by enlarging the holes with the plastic auger, part assembly was made easier because of less force needed for inserting screws or studs. In another case, several female workers complained of sore wrists as a result of trimming sprues and runners with sidecutters. A mechanic at the plant welded extended handles on the sidecutters so that these workers could use two hands for better leverage. The two hand-held clip holders were of interest because each reduced stress to the hands, increased productivity three to five fold, and aided in the consistency of product quality. The first hand-held clip was made from a scratch awl handle. The scratch awl was removed and a clip holder was fashioned to hold the clip while inserting it into a plastic part. This clip holder was made because the worker had severe arthritis in her thumbs (she previously used her thumbs to

insert clips), and needed to translate the concentration of forces from her thumb to the eminences of her hand. The second hand-held clip was made from a metal casting which was drilled out to reduce its weight and fashioned to hold and insert clips. This clip holder was developed because the clips sharp edges caused mechanical trauma to the worker's fingers and because the clip was hard to insert in the confined spaces of the console. The pistol-grip spray paint can holder and nozzle activator was used because of the finger tip trauma and fatigue while touching up approximately 1100 plastic parts on a moving conveyor per 8-hour shift. By translating the forces from the small and concentrated area of the finger tip to the medial grip of the hand, mechanical leverage is gained and trauma and fatigue is greatly reduced. In all the cases mentioned above workers may not have known the biomechanical principles used to reduce these physical stresses, but they did know that something was needed for job improvement.

When the workers were questioned about why they did not submit their inventions through the plant sponsored Suggestion Program several workers responded that often these suggestions are not recognized for their true monetary value and are not worth the effort. The ergonomics consultants examined the plant suggestion form and felt that workers may be intimidated by the initial complexity of these forms. Also, workers are not equipped with the resources to present their ideas on paper to their fullest potential. Therefore, the ergonomics consultants assisted a few of the workers who developed the tools mentioned earlier and filled out these suggestion forms documenting before-work and after-work cycles with and without these tools. In addition to the general documentation of these new tools, the suggestion form contained photographs of these tools. A few months later these workers responded that they received a significant monitory reward for their tool designs. The problem in not tapping the full potential of worker invented tools

may be: (1) the mechanism (i.e., suggestion form) for presenting worker ideas and inventions is inadequate and, (2) workers may not feel adequately compensated for their ideas and inventions.

5 Discussion

The purpose and objective of the Task Force formation was to facilitate identification and implementation of CTD control measures, and to have an effective resource management team in the plant to reduce CTD's. The short term goal of the Task Force was to use this collective expertise in identifying problem areas, devise strategies to reduce problems, and act on them. The long term goal of the Task Force was to develop ergonomic expertise in the plant for problem solving when new problems arise.

During the control program several new jobs were created which were not part of the original program and management wanted advice from the ergonomics consultants regarding ergonomic changes to reduce or prevent occupational CTD's. As this program progressed, several suggestions were made to the Task Force and the results were categorized in the same manner as the original jobs described above. The control approach showed that plant designed tools were the most successfully implemented attribute (71%), followed by changes in work practices to reduce work stresses. The job attribute affected was production, work methods, and work station changes, all at (50%), followed by tool design (33%).

Original jobs stressed administrative controls (worker rotation, job enlargement, and market available tools), while new jobs stressed engineering controls (work station design, gravity feed racks, and plant designed tools). The shift from administrative to engineering controls may be attributable to: (1) application of ergonomic principles by plant engineers during the design of new work stations, (2) flexibility in

production quotas during the work start-up phase, and (3) financial resources for ergonomic enhancements to new work stations after start-up.

The Task Force evaluation activities lead to the conclusion that: (1) the best time to implement ergonomic suggestions is during work station design and start up, (2) the success of retrofitting existing work stations by ergonomic design depends on the support of management and labor at all levels, and (3) any long-term effectiveness of the Task Force is a direct function of key management and labor support.

One key objective of this study was to transfer the ergonomic knowledge from the ergonomics consultants to the Task Force so that the Task Force could problem solve without outside intervention. Unfortunately, this was not apparent. There are several possible explanations for this, the most important being the organizational complexity of a large corporation. While a plant manager has the latitude to direct resources in his plant, he must seek corporate approval for initiatives which may involve significant capital expenditures. For example, new jobs in this plant are are given "launch money" for the development and design of jobs and for refinement of the job in in the early stages of production to assure success. This launch money is used for changes in the work station design and layout so that production runs more smoothly. Older jobs, however, do not have a large reservoir of money to draw from if costly work station changes are needed. This difference was very evident when comparing work station changes suggested by the Task Force Committee for new versus old jobs.

Another limitation is the established time standards for old jobs. Often ergonomic suggestions will not only reduce stress, but make the job more efficient and thereby reduce the time needed to make parts. If there is a significant reduction in time, then a new time standard may be given for this work station. Such changes may be resisted by the

Union because the the new time standard could threaten other jobs, resulting in one worker doing the work of two. New jobs often do not have established time standards because the job is still under development and therefore offers production flexibility until all work changes are implemented.

Beyond the organizational hurdles of implementing ergonomic changes, are the psychological obstacles such as worker and management resistance to change, perceived threats to job security, cost-benefits of ergonomic programs, communication, and personal priorities. Liker (1984)[25] proposed four obstacles to the utilization of ergonomics in the workplace: (1) lack of general ergonomic knowledge, (2) lack of job knowledge, (3) poor inter-departmental communication, and (4) perceived cost-benefits (sub-unit interest or suboptimization). Liker argues that despite years of research data, ergonomics has not found its niche in the workplace. Research in this plant confirms this notion with regard to intervention strategies, especially for older jobs where there is a potential mine field of organizational hurdles and psychological obstacles to overcome.

Perceptions between the benefits of an ergonomics program between Management and Labor also differed including: (1) reasons for having an ergonomic program, (2) the dollar cost of CTD injuries, (3) the value of training and education regarding ergonomics in the plant, (4) the impact of ergonomics in reducing worker's compensation costs, and worker pain and suffering, and (5) the continuance of an ergonomic program after the ergonomics consultants completed their study. In an independent research study (Lifshitz and Joseph, 1984)[26], investigators found that the Task Force had opened some lines of communication between labor, management, and engineers; that in itself was a benefit from the program. They also knew that CTD's were costly (their estimates ranged from 10,000 to 40,000 dollars per case). However, if it was perceived that fixing machinery was more costly than worker CTD's then

administrative controls would be implemented until the department or job was retooled or eliminated. Finally, there was concern about continuation of the Task Force after the ergonomics consultants had finished its study. Both management and labor said that they felt the ergonomics consultants were both the fuel and catalyst for the Task Force, and once gone the Task Force would cease to function. It this is true, then it is hypothesized that CTD's in this plant could be a reoccurring problem, even though management and labor had an awareness that such injuries are preventable.

6 Conclusions

This study has identified factors affecting the effectiveness of the ergonomics control program. This pertains not only to the types of recommendations considered and implemented by the Task Force, but also some of the organizational limitations that need to be considered when developing an ergonomics control program. Of the sixty-four recommendations provided by the ergonomics consultants (51 for original study jobs and 13 for new study jobs), 33 percent were considered for the original study jobs, and only 18 percent implemented. For the new study jobs, 85 percent of the recommendations were considered, and 46 percent implemented. The difference between the original and new study jobs appeared to be a function of available resources, and the organizational structure of this plant. The original study jobs tended to have recommendations considered and implemented if they were easy and not costly, such as purchasing new tools, or improving the maintenance of presses. The new jobs tended to have more emphasis on ergomomic work station design during the work station develop phase, and ergonomic enhancements during job setup. Often the worker would be consulted for ideas during new work station setup. "Launch Money," (a term used by engineers in this plant for assuring successful production), appeared to make the difference in implementing recommendations. Older jobs did not have launch money and appeared to require more "paper work" to have

ergonomic work station changes implemented. This combined with possible resistence to change, established work habits, and production standards, for the older jobs may have made ergonomic intervention efforts much harder to implement than on new jobs where such obstacles were minimized. This program had some positive side benefits. An ergonomic awareness among workers was developed in which many were motivated toward conceiving and fabricating job specific tools which made their jobs less stressful and more productive. It was also discovered that the suggestion program which brings worker ideas to the attention of management may not be very effective as is, and needs to be made easier so that both the employee and employeer may benefit. The lessons learned from this research may be particularly useful when considering future control programs in which work behavior and processes are well established, and resources limited. While this ergonomics control program showed promise in decreasing worker pain and suffering for older jobs, it appears that such a program needs consistent committment from top management and labor to significantly reduce the incidence and severity of occupational CTD's.

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CHAPTER 2

WORK DOCUMENTATION AND ANALYSIS

1 Introduction

Upper extremity cumulative trauma disorders (CTDs) are a growing health problem in manufacturing processes throughout the United States (Blair, 1987).[1] The most frequently cited occupational risk factors associated with upper extremity CTDs are repetition, force, and awkward postures (Armstrong, 1983).[2] CTD risk has also been associated with mechanical stress, vibration, gloves, and cold temperatures (Table 1 (a-b)) (Armstrong and Lifshitz, 1987).[3] The National Institute for Occupational Safety and Health has shown that these factors are present in a variety of industries involved in the fabrication and assembly of products including: electrical, automotive, plastic, glass, metal, and food (Table 2). In recent years, the U.S. automotive industry has shown a high prevalence of CTDs associated with the job risk factors described above (Silverstein, 1985[4]; Joseph, 1986[5]). It is proposed that if these risk factors are reduced or eliminated, then a reduction in CTD reporting will follow. The relationship between changes in job risk factors and health status, however, has yet to be established. This paper is the second of three in a series which describes how job risk factors can be measured before and after the implementation of a program to control CTD's.

2 Identification of Risk Factors

Traditional time and motion study techniques can form the basis for the first phase of job analysis. Work methods analysis serve to determine the work content of the job. It describes a job as a set of tasks, with each task consisting of a series of steps or elements

Table 1a. Occupational Risk Factors Associated with Upper Extremity Cumulative Trauma Disorders

Disorder and Occupational Factors	References
Neck	
Tension Neck Syndrome	
Static arm, elbow elevation of 60-90 degrees.	Valtonen (1968)[10]
Prolonged neck, shoulder bending	Cohen (1980)[11]
Thoracic Outlet Syndrome	
Drawing shoulders down and back with extended arm.	McCleery (1951)[12]
Reach beyond outer limits of reach envelope.	Kremer(1975)[13]
Overhead work (repeated or sustained)	Urshell (1968)[14]
Cervicobrachial Disorder	
Static or dynamic burden on arms (elevated)	Komike et al,(1975)[15]
Shoulder	
Bicipital Tenosynovitis	
Overhead reaching, lifting repeated minor trauma	Neviaser (1980)[16]
Continuous use in abduction and rotation.	Meyer (1921)[17]
Rotator Cuff Tendinitis	
Excessive or forcible shoulder exertion.	Booth, Marvel (1975)[18]
Prolonged tension of shoulder stabilization muscles while performing hand intensive work.	Kvarnstrom (1983)[19]
Loading of the arm above 60 degrees Abduction or flexion.	Herberts, Kadefors (1976)[20]
Elbow & Forearm	
Cubital Tunnel Syndrome	
Repeated or prolonged elbow flexion with wrist extension.	Macnicol (1979)[21]
Repeated trauma or leaning elbow on workbench.	Feldman et al (1983)[22]
Pronator Teres Syndrome	
Repeated pronation or grasp	Hartz et al (1981)[23]
Forceful pronation with finger flexion	Morris, Peters (1976)[24]
Radial Tunnel Syndrome	
Repetitive wrist flexion with pronation or wrist extension with supination.	Lister (1984)[25]
Epicondylitis	
Repeated supination/pronation	Rasch, Brubaker (1957)[26]
Unaccustomed or repetitive	Goldie (1964)[27]
Movements with forearm or finger extensors	Kurppa (1979)[28]

Table 1b. Occupational Risk Factors Associated with Upper Extremity Cumulative Trauma Disorders

Disorder and Occupational Factors	References
Wrist & Hand	
Carpal Tunnel Syndrome	
Repeated flexion or hyper-extension of the wrists.	Armstrong et al. (1981)[29]
Pressure at the base of the palm	Feldman (1983)[30]
Wrist extension with forceful pinch.	Rabourn (1977)[31]
Hyper extension of the wrist	Wherle (1976)[32]
Ulnar Nerve Entrapment	
Prolonged flexion or hyperextension	Eckman (1975)[33]
Use of hypothenar eminence as a hammer	
Perineural fibrosis of Digital Nerves	
Grasping sharp objects in the hand.	Dobyns (1972)[34]
Ulnar Arterial Thrombosis	
Vibrating tools, pushing, twisting pounding with hands	Conn et al (1970)[35]
Tenosynovitis, Tendinitis, Dequervains's. Peritendinitis.	
Repetitive motion in combination with ulnar deviation with fixed thumb	Eichoff (1927)[36]
Extreme hand postures with maximal extension of fingers.	Luopajarvi et al. (1979)[37]
More than 2000 manipulations per hour.	Hammer (1934)38
Trigger Finger	
Excessive flexion and extension of digit against resistance	Fahey and Bollinger (1954)[39]
Over use of index finger with pistol air-tool.	Tichauer (1978)[40]

Table 2. Summary of NIOSH Hazard Evaluations and Technical Assistance (HETA) Reports for Cumulative Trauma Disorders

Company Product	HETA Request	# Exp	Cases	Risk Factor	Ref.
Electrical extension cords & cordsets	Tendinitis, Ganglions, CTS, Tenosynovitis	415	56	Cutting wire from bent spool, 5000 hand pinches 10,000 arm twists/day.	Babes D.[41]
Combustion exhaust systems	CTS, hand tingling	200	33	Pinch grip to hold parts in place	Badger D.[42]
Laminated plastic products	CTS, Tendinitis	700	19	Cutting plastic sprues with finger nail cutters.	Boiano, et al.[43]
Fibrous glass reinforced plastics (typewriter cases)	CTS, Swelling hands, pain	120	18	Use of hand files and sanders to deflash plastic (17,850 moves/day)	Boiano, et al.[44]
Photographic products	Tendinitis, ganglions, CTS, bursitis, myositis, Thoracic Outlet Syndrome	3300	104	Hand intensive wrapping and packing of photochemical rolls. Avg. 325 pt/day. Heavy use of tape and tape cutters.	Wasserman[45]
Metal fabrication	CTS	96	16	Hand intensive, 5040 repetitions/day. combined perchlorethylene exposure.	Moody[46]
Glass manufacturing	CTS	?	?	Open fisted pinch grip to pack glasses for shipping.	Salisbury[47]
Electrical parts manufacturing (armature winding)	CTS	121	68	Hyperextension and flexion of wrist combined with high force.	Stephenson[48]
Metal fabrication (catalytic converters)	Tendinitis, CTS	1100	17	Repetitive hand/wrist motions. Static work postures. Poor workplace design.	Lipscomb[49]
Fish Filleting	Tendinitis	?	?	Repetitive mechanical trauma to hand/wrist comb with high force when using knife to fillet fish. Awkward postures.	Badger[50]
Food Processing	CTS, Tendinitis	?	20	Awkward postures, high forces, poor work station design/tools	Badger, et al.[51]
Ammunition manufacturing	Ganglionic Cysts, Tendinitis	1700	13	Lifting and carrying ammo charges. Handle charges weighing 23-48 lbs up to 4500 times/day. Forceful/static postures.	Zey et al.[52]
Metal fabrication (hand-held lubrication equipment)	CTS	157	19	Excessive cutting stamping, assembly of metal parts.	Badger[53]

(Barnes, 1972)[6] that is, the fundamental movements or acts (reaching, grasping, moving, positioning, use, etc.,) required to perform a job. Though Gilbreth suggested formal element definitions, which he called "Therbligs" (Gilbreth, 1911)[7], were arbitrary in that one could increase or decrease detail as necessary. For example, "get" adequately describes the process of "reach-grasp-move", and "put" works well on "move-position-release." One identifies elements by observing the job or by observing slow-motion videotapes of the job. "Tasks" are groups of elements that are usually performed in the same sequence to accomplish a common end. Examples of tasks might include: "load machine", "operate machine", and "clean-up." For the purpose of this study, managers, supervisors, and workers provided the job descriptions and demonstrations from which to determine these tasks; time-study and production records, and timed observations provided the necessary interval data.

The second phase of job analysis is an actual review of the job for recognized occupational risk factors for upper extremity CTDs, listed in Table 1. These can be summarized as repetition, force, posture, contact stress, low temperature, and vibration. Table 1 serves as a check-list for identification of risk factors in each work element. A more comprehensive summary is provided by Armstrong and Silverstein (1987).[8] This two-phased job analysis forms the basis for proposed engineering and control procedures aimed at reducing the incidence of CTD's.

3 Work Analysis

The work analysis focused on the identification of upper extremity cumulative trauma disorder (CTDs) risk factors in an automotive plastics manufacturing and assembly plant. The objectives were to: (1) document job risk factors associated with CTDs, (2) rank order these study jobs by quantifying CTD risk factors; and (3) identify and describe changes in CTD risk factors at the beginning and end of the control program.

3.1 Job Selection

Included in the study were all jobs in the plant which met the following criteria: (1) number of workers in selected departments should equal 25 or more; (2) job analysis would be performed in departments where health surveillance information was being gathered; (3) jobs studied had to exist over the course of the control program; and (4) workers had at least two-years seniority prior to the initial health surveillance screening.

Many of the Assembly and Press Operator jobs were similar in nature, and had similar work cycle times. In order to compare the jobs with epidemiological data, jobs which were similar in nature were aggregated by department and job category. For example, ergonomics consultants videotaped eleven Ramline Assembly workers in Department 1610; there, each worker assembled parts onto a dashboard panel which was moving at a constant speed. These eleven assembly jobs were aggregated into one category. The result reduced twenty-three individual jobs to 10 job categories in 7 departments. Table 3 shows the study jobs analyzed for work risk factors.

3.2 Documentation of Work Content

A portable videotape ensemble consisting of a recorder, light-sensitive VHS tape and camera documented the work content. The camera recorded workers as they performed their jobs at various times throughout the control program. Every effort was made to videotape each worker for at least 3 job cycles. The videotapes were played back in a laboratory in slow-motion and stop-action to provide detailed information on posture, environment and equipment.

3.3 Documentation of Body Posture

The videotapes helped researchers determine upper-body posture, bilaterally, for each major work element, by observing and recording:

Table 3. Category, Department Number, & Department Description of Workers Studied for Job Stress

Category/ Department Number	Department Description
Stock Handlers	
1550	Regrind Operator. Manually unloads large bins of scrap plastic on conveyor which leads to a grinder.
1800	Stock Handlers. Loads and unloads automobile stock from assembly lines.
Assemblers	
1600	Assembler. Assembles small clips, screws, plugs, etc., on plastic automotive parts.
1610	Ram Line Assemblers. Stand in series and perform specific tasks for Ram panel assembly.
1750	Blow Mold Assembler. Assembles metal parts to plastic parts with power tools for structural reinforcement.
1790	Assembler. Assembles clips, screws, plugs, etc., on fibrous glass resin auto parts.
Press Operators	
1700	Injection Mold Press Operator. Trims excess flashing with knife from plastic automobile parts and loads flashing in cart.
1750	Blow Mold Operator. Trims excess flashing with knife from plastic automobile parts and loads flashing in cart.
1790	Compression Mold Operator. Cuts fibrous glass and resin plastic with a razor knife, and inserts into mold which compresses material in dye.
Stock Finishers	
1790	Surface Finisher. Uses power sander to sand out rough spots from plastic automobile parts.
1790	Router. Uses powered router drill to remove hard flashing from plastic automobile parts.

(1) the posture of the neck when flexed, (2) locations about two axes of rotation in the shoulder, (3) location about two axes in the elbow, (4) location about two axes in the wrist and, (5) hand grip posture. Figure 1 shows the posture classification positions for the neck, shoulder, elbow, wrist, and hand which provided a basis for work analysis documentation.

The neck was classified as "flexed" when the head was tilted more than 40 degrees forward. Neck "extended" postures were not classified because no study jobs were observed which involved repetitive neck extension.

The shoulder was classified with reference to the angle between the humerus and trunk, and the position of the elbow. For example, the shoulder was "neutral" ($\leqslant$ 45 degrees) if the elbow was at the worker's side; it was "flexed" (> 45 degrees) if the elbow was away from the trunk such as manually lifting an object over the head. The shoulder was "adducted" ($\lessdot$ 45 degrees) if the elbow was in front of the worker, such as carrying a large box and "abducted" (> 45 degrees) when behind the body such as reaching back for a part or tool.

The extension or flexion of the forearm with respect to the upper arm determined the classifications for elbow position. For example, with a small object held in an outstretched arm, the elbow would be classified as "extended." In contrast, if the same object were brought close to the body by flexing the arm more than 90 degrees the elbow would be classified as "flexed." The classification would be "elbow rotation" when the forearm and hand were rotated from the supinated to the pronated position (wrist rotation > 150 degrees) and/or back again while performing work, e.g., using a power sander on the underside of a part, then rotating the forearm and hand to sand the top side.

A "flexed" or "extended" wrist position was classified when the angle between the hand and forearm was greater than 30 degrees. Similarly, if the angle between the forearm and hand was greater than 20

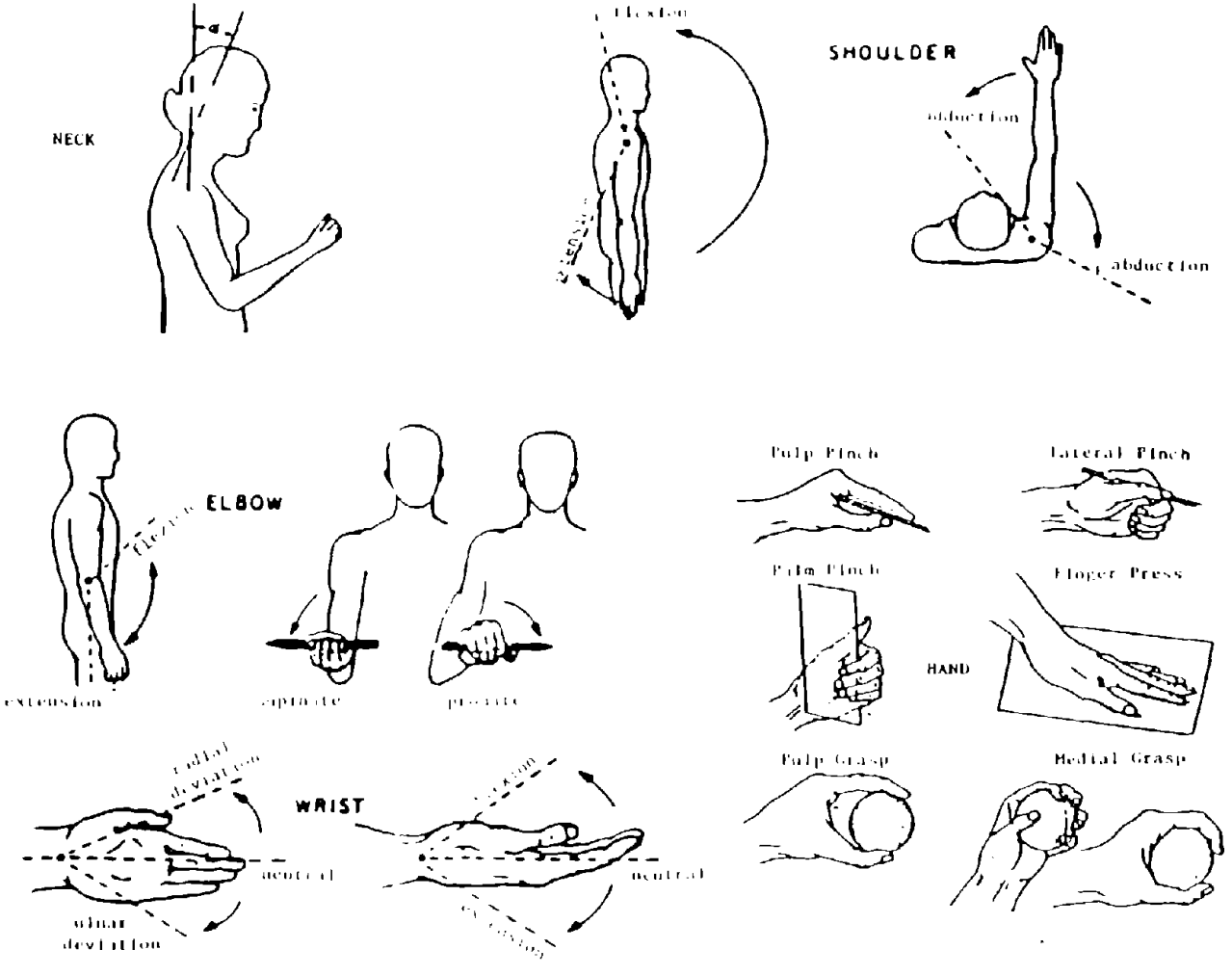


Fig. 1. Posture Classification Positions for Neck, Shoulder, Elbow, Wrist, and Hand for Work Analysis Documentation

degrees from a neutral (straight) posture the wrist classification was "radially" or "ulnarly" deviated. The "hand pinch" posture occurred when hand and finger activities were observed as part of the work cycle.

Data was also recorded for: job cycle time, temperature of environment and/or tool being used (cold ($\leq$ 65°F, ambient 65°F), tool vibration (either from the tool such as a power sander, and/or during its use, such as sanding a part), tool type (including name, number of tools used, and whether manually or power driven), tool hold and use time, time use tool (note that time using tool was always less than time holding and using tool), use of gloves, and force. The force exerted by the upper extremities was subjectively estimated and categorized as low to medium ($\leq$ 12.0 Kgs), or high (> 12 Kgs).

The classification system for documenting postures during work was based on a review of the literature in which these postures were cited as CTD risk factors, and the in-plant experience by the author in observing and documenting worker activities over the course of the CTD control program. Force measurement was a combination of subjective evaluation, in-plant experience, and literature review. The break points for low to medium, and high force were largely dependent upon work by Silverstein (1985) where force measurements were derived for similar job tasks. Table 4 shows the classification of posture angles and related job attributes used for work documentation.

3.4 Identification and Documentation of CTD Risk Factors

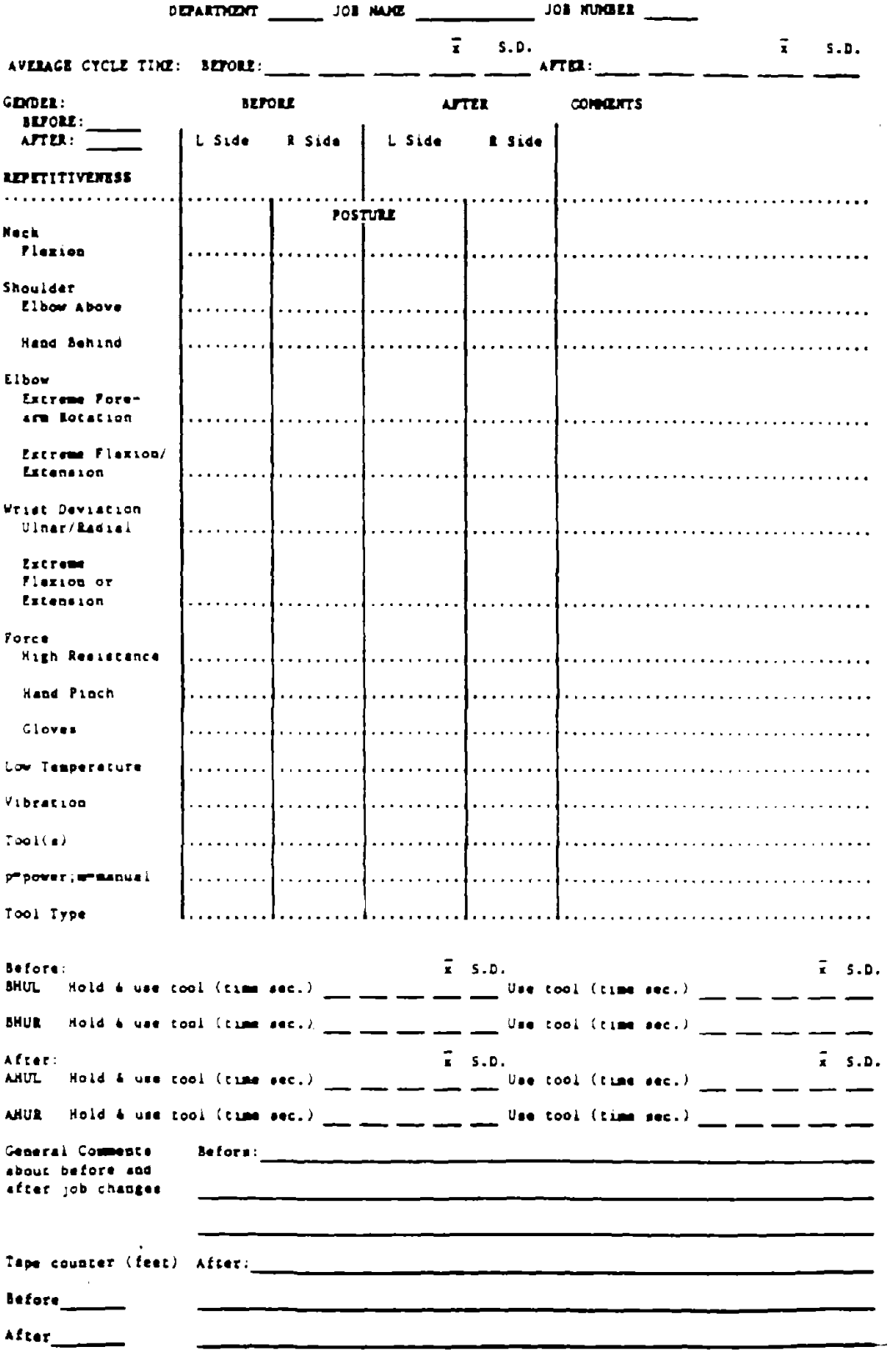
With work content and body posture described, each study job was reviewed via videotapes for CTD risk factors. Tables 1a and 1b were used as guides to identify work related CTD's. Documentation of CTD risk factors was performed by extracting "critical" risk factor elements which occurred during the work cycle from jobs videotaped at the beginning and end of the control program. Documentation was summarized on a job-analysis form developed by ergonomic consultants (Fig. 2). Each

critical element was recorded on the job analysis form as either a "yes" or "no" based on the classification criteria for body posture, work cycle repetition, physical force, and other risk factors previously described. Jobs videotaped at the end of the control program were then matched to jobs videotaped at the beginning and compared for any engineering, maintenance, administrative, or work practice changes in these risk factors resulting from the control program.

3.5 Data Entry for Job Analysis

A commercially available software package (Symphony TM) served for quantitative job analysis of the data on work cycle repetition, force, and body posture. The jobs videotaped at the beginning and end of the control program could then be rank-ordered by comparing the change in these risk factors. This total is based on the average cycle time of a worker performing his job during video taping. For example, if a job cycle took one minute to complete then sixty cycles could be performed in one hour, or 480 cycles in an 8-hour work shift. Subtract sixty of these cycles to account for thirty minutes for lunch and another thirty minutes for fifteen minute work breaks at the mid-points of the beginning and end of the work shift and the result is 420 cycles that could be performed for an 8-hour shift. Where there were multiple, but similar, jobs in a department, such as Assemblers in Department 1610, Press Operators in Department 1700, and Assemblers in Department 1600, the average value for all jobs in this department was derived by adding up the total number of cycles in an 8-hour shift for each of these jobs, and dividing by the number of jobs in the department. This had to be done in order to match changing job risk factors with active epidemiologic surveillance results (discussed in the first paper of this series). The study used the same procedure in determining the number of cycles in which force was applied, as well as the number of times the worker had to be in a specific body posture to perform his job. Jobs which had repeated elements within the job cycle, such as clip assembly

Fig. 2. Coding Form for Work Analysis Documentation



DEPARTMENT _____ JOB NAME _____ JOB NUMBER _____

AVERAGE CYCLE TIME: BEFORE: ___ ___ ___ ___ ___ $\bar{x}$ S.D. AFTER: ___ ___ ___ ___ ___ $\bar{x}$ S.D.

GENDER:
BEFORE: _____
AFTER: _____

	BEFORE		AFTER		COMMENTS
	L Side	R Side	L Side	R Side	
REPETITIVENESS					
		POSTURE			
Neck Flexion					
Shoulder Elbow Above					
Hand Behind					
Elbow Extreme Forearm Rotation					
Extreme Flexion/ Extension					
Wrist Deviation Ulnar/Radial					
Extreme Flexion or Extension					
Force High Resistance					
Hand Pinch					
Gloves					
Low Temperature					
Vibration					
Tool(s)					
p=power; m=manual					
Tool Type					

Before: $\bar{x}$ S.D. $\bar{x}$ S.D.
BHUL Hold & use tool (time sec.) ___ ___ ___ ___ ___ Use tool (time sec.) ___ ___ ___ ___ ___

BHUR Hold & use tool (time sec.) ___ ___ ___ ___ ___ Use tool (time sec.) ___ ___ ___ ___ ___

After: $\bar{x}$ S.D. $\bar{x}$ S.D.
AHUL Hold & use tool (time sec.) ___ ___ ___ ___ ___ Use tool (time sec.) ___ ___ ___ ___ ___

AHUR Hold & use tool (time sec.) ___ ___ ___ ___ ___ Use tool (time sec.) ___ ___ ___ ___ ___

General Comments about before and after job changes
Before: _____
_____
_____

Tape counter (feet)
Before _____
After _____
After: _____
_____
_____

Table 4. Posture Angles and Related Job Attributes Used for Work Documentation

Measured Attribute	Criteria/Units
Posture	**degrees**
Neck Flexion	40
Shoulder	
Flexion/Extension	45
Adduction/Abduction	45
Elbow	
Flexion/Extension	90
Supination/Pronation	150
Wrist	
Flexion/Extension	30
Ulnar/Radial	20
Hand Pinch	(power or precision grip)
Force	(Low to Medium ≤ 12 Kgs, High > 12 Kgs)
Job/Environmental Characteristics	**Units/Response**
Job Cycle Time	seconds
Temperature of Environment/Tool Cold (≤ 65°F), Ambient (> 65°F)	Fahrenheit
Tool Vibration	yes/no
Tool Type	descriptive
Time Hold and Use Tool	seconds
Time Use Tool	seconds
Use of Gloves	yes/no

of parts were counted and multiplied by the primary cycle time. For example, the assembly of 5 clips on a part during a one minute work cycle adds to a total 300 clips per hour or 2100 clips per 8-hour shift. If these clips required a handpinch posture then this would translate to 2100 handpinches per shift. The same "within-cycle repetition" was also recorded for force and body posture. In addition, the study also recorded the percentage of handpinches by the left hand and right hand: e.g., a worker grabs a handful of clips with the left hand and uses the right hand to insert the clips. In doing this, the left hand would perform 420 handpinches, to grab and hold the clips, while the right hand would show 2100 handpinches. Generally, these repeated elements (sub-elements) within the job cycle were counted when the activity was judged to be a significant work element which advanced the job cycle to completion.

3.6 Department/Jobs Summarized by Risk Factor Activity

Based on the total number of risk factors observed and the number of times these risk factors were repeated during an 8-hour shift, jobs were summarized by risk factor activity for the beginning and end of the control program. The left and right sides of the worker's upper extremity were tabulated showing the total number of repetitions per 8-hour shift for each of the department/jobs.

4 Work Analysis Results

Work analyses of the study jobs have been organized into categories of: cycle time, work cycle repetition, posture, force, and environmental characteristics. The environmental characteristics include: temperature, vibration, glove use, tool type and tool use.

4.1 Comparison of CTD Risk Factor Changes for all Studied Jobs

Job Cycle Time: The job-cycle time mean at the beginning of the control program was 55.8 seconds (s.d. $\pm$ 67.7) and at the end it was

54.5 seconds (s.d. ± 68.8) (Table 5). A t-test comparing means was not significant (p = .88). The shortest cycle time was observed for Stock Handlers in Department 1800 (6.8 seconds) while the longest was for Compression-Mold Press Operators (174 seconds). Both extremes for work cycle repetition were determined by machine-pacing. Jobs which were self-pacing typically took more than 30 seconds but less than one minute to complete.

Work Cycle Repetitions: The mean number of work-cycle repetitions for an 8-hour day at the beginning of the control program was 1043 (s.d. ± 761) and at the end it was 1039 (s.d. ± 768) (Table 6). A paired t-test comparing means was not significant (p = .91). Stock handlers had the most repetitions per shift at 3722 while Compression Molders showed the least number of repetitions at 144. Again, both jobs were machine-paced. Self-paced jobs were as high as 1100 per shift (1600 Assembly), but more typically averaged 400-600 job cycles, or parts per 8-hour work day.

The change in repetition rate between departments was primarily from a modification in parts such as in Blow Mold Press Operators in Department 1750, and Assemblers in Department 1600 and 1790. In these departments such changes decreased the basic work cycle time and subsequently increased productivity 15 to 26 percent. Stock Handlers in Department 1800 had the highest number of repetitions at 3722 repetitions per shift while Compression Molders had 144 repetitions per shift. Both jobs were machine paced with Stock Handlers removing stock from a moving conveyor, and Compression Mold Operators curing parts on a press.

4.2 Posture

Neck Flexion Repetitions: The mean number of neck flexion repetitions for an 8-hour day at the beginning of the control program was 520 (s.d. ± 525) and at the end it was 556 (s.d. ± 509) (Table 7).

Table 5. Cycle Times for Original Studied Jobs at the Beginning and End of the Control Program

Depart. Number	Job Name	# Jobs Studied	Begin: Mean & (Std. Dev.)	End: Mean & (Std. Dev.)
1500	Regrind Operator	1	300.2 ± (20.1)	316.4 ± (25.3)
1600	Assembler	2	44.4 ± (24.8)	34.9 ± (14.9)
1610	Assembler	11	21.0 ± (4.2)	23.0 ± (6.5)
1700	Inj. Press Oper.	3	51.9 ± (8.7)	53.5 ± (11.6)
1750	Assembler	1	81.4 ± 2.9)	68.7 ± (2.8)
1750	Blow Press Oper.	1	64.6 ± (6.5)	51.1 ± (5.7)
1790	Assembler	1	27.6 ± (2.1)	32.6 ± (1.9)
1790	Surface Finisher	1	147.4 ± 24.8)	131.0 ± (---)
1790	Comp. Press Oper.	1	174.5 ± (7.6)	170.0 ± (---)
1800	Stock Handler	1	6.8 ± (1.3)	6.6 ± (1.3)
Mean & s.d.			92.0 ± (90.9)	88.8 ± (94.5)

Table 6. Total Work Cycle Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin	End	%-Change
1800	Stock Handler	1	3722	3841	3.2
1550	Regrind	1	2000	1900	-5.0
1610	Assembler	11	1210 (200)	1186 (243)	-2.0
1790	Assembler	1	911	774	-15.0
1600	Assembler	2	764 (547)	848 (461)	9.9
1700	Inj. Press Oper.	3	497 (100)	477 (103)	-4.1
1750	Blow Press Oper.	1	390	493	26.4
1750	Assembler	1	309	367	18.8
1790	Surface Finisher	1	171	192	12.3
1790	Comp. Press Oper.	1	144	148	2.8
Mean			1043	1039	-0.4
S.D.			761	768	

Table 7. Neck Flexion Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin	End	%-Change
1610	Assembler	11	745 (611)	840 (566)	11.3
1600	Assembler	2	764 (547)	261 (369)	-100.0
1700	Inj. Press Oper.	3	497 (100)	477 (103)	-4.3
1750	Blow Press Oper	1	390	493	26.4
1790	Surface finisher	1	171	192	12.3
1790	Comp. Press Oper.	1	144	148	2.8
1550	Regrind	1	40	37	-7.5
1750	Assembler	1	0	0	0.0
1790	Assembler	1	0	774	100.0
1800	Stock Handler	1	0	0	0.0
Mean			254	332	23.5
S.D.			273	309	

A paired t-test comparing means was not significant ($p = .78$). Assembly Jobs had the most number of neck flexions per work cycle (approximately 500/8-hr day) compared to other study jobs. Ramline Assemblers, however, had the most neck flexions (745 repetitions /8-hr) overall which was attributed to looking down to get several parts within the work cycle. Neck flexions did not increase significantly between the beginning and end of the control program. Changes in neck flexions occurred when parts were raised by putting them on jigs, the bench height was raised (thus reducing neck flexion), or when there was a worker change from a short to tall worker where the bench height was fixed, thus neck flexions were increased.

Left-Shoulder Abduction (High Shoulder): The mean number of left shoulder abduction (high shoulder) repetitions for an 8-hour day at the beginning of the control program was 850 (s.d. $\pm$ 1722) and at the end it was 417 (s.d. $\pm$ 758) (Table 8). The difference was not significant ($p = .23$). **Right-Shoulder Abduction (High Shoulder)**: The mean number of right shoulder abduction (high shoulder) repetitions for an 8-hour day at the beginning of the control program was 2024 (s.d. $\pm$ 1981) and at the end it was 1622 (s.d. $\pm$ 1344). The difference was not significant ($p = .24$). The lack of differences may reflect the limited number of job changes over the program period.

There was 2.5 times more right side shoulder abduction than left side (2024 to 850 repetitions/8-hr), propably a function of the right hand dominance of workers, and orientation of work assembly from right to left. There was a reduction in abducted shoulder repetitions over the course of the program which was associated with less use of vertical oriented tools and more horizontal tools. This was particularly evident among Injection Mold Press Operators where less force was required to trim flash. The implementation of case-hardened steel knives, which maintained a sharper edge, appeared to reduce the amount of mechanical leverage needed (i.e., less shoulder strength) to trim the plastic

Table 8. **High Shoulder** Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (± S.D.)	End (± S.D.)	%-Change
Left Side					
1610	Assembler	11	1354 (2405)	584 (1041)	> -100.0
1750	Blow Press Oper.	1	1171	493	-57.9
1800	Stock Handler	1	744	768	3.2
1550	Regrind	1	625	589	-5.8
1750	Assembler	1	619	0	> -100.0
1700	Inj. Press Oper.	3	502 (457)	176 (305)	> -100.0
1600	Assembler	2	0	0	0.0
1790	Comp. Press Oper.	1	0	774	0.0
1790	Assembler	1	0	0	0.0
1790	Surface Finisher	1	0		0
Mean			850	417	> -100.0
S.D.			1722	758	
Right Side					
1800	Stock Handler	1	3722	3841	3.2
1610	Assembler	11	2862 (2339)	2343 (1168)	-22.1
1550	Regrind	1	1877	1786	-4.9
1700	Inj. Press Oper.	3	1710 (1485)	176 (305)	> -100.0
1750	Blow Press Oper.	1	1561	1973	26.4
1790	Surface Finisher	1	1025	1152	12.4
1750	Assembler	1	619	1468	137.0
1600	Assembler	2	575 (814)	0	> -100.0
1790	Comp. Press Oper.	1	0	0	0.0
1790	Assembler	1	0	774	100.0
Mean			2024	1622	-24.8
S.D.			1981	1344	

parts. However, the reduced shoulder abduction was offset by an increase in wrist and hand action needed to perform the job. There was a slight increase in shoulder abduction among Stock Handlers as a function of a shorter work cycle. This was observed when some workers reached for a part on a moving conveyor before it arrived at their station.

Left and Right Hand Behind Shoulder: The average number of left and right hand behind the shoulder repetitions for an 8-hour day at the beginning of the control program was 98. At the end of the control program there were no observed reaches with the left hand, while the right hand reached back approximately 103 times per work shift. Reaching behind to retrieve parts during the assembly process was infrequent and observed only among assembly oriented jobs. Part carts located next to assembly work stations required the worker to reach back for parts during the assembly process. Often carts could not be placed next to the workers because of space limitations between the workers (Table 9).

Left Elbow rotation: The mean number of right elbow rotation repetitions for an 8-hour day at the beginning of the control program was 138 (s.d. $\pm$ 320) and at the end it was 109 (s.d. $\pm$ 446) The difference was not significant ($p = .74$). **Right Elbow Rotation:** The mean number of right elbow rotation repetitions for an 8-hour day at the beginning of the control program was 430 (s.d. $\pm$ 975) and at the end it was 305 (s.d. $\pm$ 642) (Table 10).

Left Elbow Flexion and Extension: The mean number of left elbow flexion and extension repetitions for an 8-hour day at the beginning of the control program was 661 (s.d. $\pm$ 1024) and at the end it was 358 (s.d. $\pm$ 658) (Table 11). The difference was not significant ($p = .93$). **Right Elbow Flexion and Extension:** The mean number of right elbow

Table 9. **Hand Behind Shoulder** Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1600	Assembler	2	1135 (1605)	0	> -100.0
1550	Regrind	1	0	0	0.0
1610	Assembler	11	0	0	0.0
1700	Inj. Press Oper.	3	0	0	0.0
1750	Blow Press Oper.	1	0	0	0.0
1750	Assembler	1	0	0	0.0
1790	Surface Finisher	1	0	0	0.0
1790	Assembler	1	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			99	0	> -100.0
S.D.			473	0	
Right Side					
1610	Assembler	11	202 (450)	215 (478)	6.1
1550	Regrind	1	0	0	0.0
1600	Assembler	2	0	0	0.0
1700	Inj. Press Oper.	3	0	0	0.0
1750	Assembler	1	0	0	0.0
1750	Blow Press Oper.	1	0	0	0.0
1750	Assembler	1	0	0	0.0
1790	Surface Finisher	1	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1790	Assembler	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			97	103	5.8
S.D.			320	340	

Table 10. **Elbow Rotation** Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1790	Surface Finisher	1	513	384	-25.7
1750	Blow Press Oper.	1	781	0	> -100.0
1610	Assembler	11	170 (386)	193 (640)	11.9
1550	Regrind	1	0	0	0.0
1600	Assembler	2	0	0	0.0
1700	Inj. Press Oper.	3	0	0	0.0
1750	Assembler	1	0	0	0.0
1790	Assembler	1	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			138	109	-26.6
S.D.			320	446	
Right Side					
1790	Surface Finisher	1	513	576	12.3
1700	Inj. Press Oper.	3	1059 (950)	1073 (930)	1.4
1610	Assembler	11	563 (1275)	292 (690)	-47.4
1550	Regrind	1	0	0	0.0
1600	Assembler	2	0	0	0.0
1750	Assembler	1	0	0	0.0
1750	Blow Press Oper.	1	0	0	0.0
1790	Assembler	1	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			430	305	-41.0
S.D.			975	642	

flexion and extension repetitions for an 8-hour day at the beginning of the control program was 858 (s.d. ± 1189) and at the end it was 839 (s.d. ± 1075) (Table 11). The difference was not significant ($p = .93$).

There was a decrease (-41%) in elbow rotation which was attributed to the replacement of fixed jigs with rotatatable jigs in assembly jobs. This made it possible to position parts in ways to avoid awkward postures associated with reaching. As with the shoulder, there were more elbow extensions and flexions with the right arm than the left arm. Assembly jobs showed more change in elbow and forearm activity which was associated with the proximal location of parts which needed to be assembled. If the parts were placed close together there was less reaching; if placed apart there was more reaching. For example, Assembly jobs in Departments 1790 and 1750 showed an increase in elbow flexions and extensions at the end of the control program because they were more spread out compared to the beginning of the control program. Sometimes the job layout was a function of the worker, sometimes it was the physical layout. Decreases in elbow flexion and extension repetitions usually were associated with a change in work station design, such as the elimination of "cooling racks" at the end of the table where Press Operators in Blow Molding (Department 1750) would put the plastic flash to cool before depositing the cooled scrap into large boxes.

Left Wrist Radial and Ulnar Deviation: The mean number of right elbow radial and ulnar deviation repetitions for an 8-hour day at the beginning of the control program was 331 (s.d. ± 868) and at the end it was 53 (s.d ± 150) (Table 12). The difference was not significant ($p = .15$). **Right Wrist Radial and Ulnar Deviation:** The mean number of right wrist radial and ulnar deviation repetitions for an 8-hour day at the beginning of the control program was 1011 (s.d. ± 1296) and at the end it was 970 (s.d. ± 1278). The difference was not significant ($p = .44$).

Table 11. **Elbow Flexion and Extension** Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1750	Blow Press Oper.	1	1952	493	-74.7
1550	Regrind	1	1876	1501	-20.0
1600	Assembler	2	1493 (1614)	0	> -100.0
1790	Surface Finisher	1	683	576	-15.7
1700	Inj. Press Oper.	3	886 (642)	544 (943)	-62.8
1610	Assembler	11	560 (1204)	109 (362)	> -100.0
1750	Assembler	1	309	367	18.8
1790	Comp. Press Oper.	1	144	148	2.8
1790	Assembler	1	0	2322	100.0
1800	Stock Handler	1	0	0	0.0
Mean			661	358	-84.6
S.D.			1024	658	
Right Side					
1550	Regrind	1	3752	3001	-20.0
1800	Stock Handler	1	3722	3841	3.2
1750	Blow Press Oper.	1	1952	1973	1.1
1700	Inj. Press Oper.	3	795 (481)	544 (943)	-46.0
1790	Surface Finisher	1	683	600	12.4
1750	Assembler	1	619	733	18.4
1610	Assembler	11	486 (958)	396 (571)	-22.6
1600	Assembler	2	568 (803)	361 (511)	-57.0
1790	Comp. Press Oper.	1	144	148	2.8
1790	Assembler	1	0	2323	100.0
Mean			858	839	-2.3
S.D.			1189	1075	

Table 12. **Wrist Radial and Ulnar** Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1610	Assembler	11	571 (1210)	0	> -100.0
1750	Assembler	1	309	0	> -100.0
1700	Inj. Press Oper.	3	433 (612)	176 (305)	> -100.0
1790	Surface Finisher	1	171	192	12.3
1550	Regrind	1	0	0	0.0
1600	Assembler	2	0	0	0.0
1750	Blow Press Oper.	1	0	493	100.0
1790	Assembler	1	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			331	53	-100.0
S.D.			868	150	
Right Side					
1800	Stock Handler	1	3722	3841	3.2
1700	Inj. Press Oper.	3	2665 (2049)	2557 (1763)	-4.2
1750	Blow Press Oper.	1	2342	493	-79.0
1750	Assembler	1	1857	2933	57.9
1790	Comp. Press Oper.	1	577	0	> -100.0
1610	Assembler	11	547 (633)	554 (639)	1.2
1600	Assembler	2	284 (402)	362 (511)	21.4
1790	Surface Finisher	1	171	192	12.2
1550	Regrind	1	0	370	100.0
1790	Assembler	1	0	0	0.0
Mean			1011	970	-4.2
S.D.			1296	1278	

Radial/ulnar wrist deviation occurred most often in Assembly jobs during tool holding and clip assembly. It also occurred in Stock Handlers in Department 1800 who showed ulnar deviation while putting parts in storage bins, and among Press Operators during flash trimming with knives. Generally, the decrease in wrist radial or ulnar deviation was offset by the increase in hand pinches and power grip activity to compensate for the increased number of parts to be assembled at the end of the control program. Also, there appeared to be more wrist activity and less shoulder activity during plastic trimming. This may have been due to sharper knives which made trimming easier. Left hand wrist deviation was most prevalent among Assemblers who used their hands to insert clips, and for the right hand which was used to hold tools (Table 12).

Left Wrist Flexion and Extension Deviation: The mean number of left wrist flexion extension deviation repetitions for an 8-hour day at the beginning of the control program was 372 (s.d. $\pm$ 856) and at the end it was 153 (s.d. $\pm$ 303) (Table 13). The difference was not significant ($p = .24$). **Right Wrist Flexion and Extension Deviation:** The mean number of right wrist flexion and extension deviation repetitions for an 8-hour day at the beginning of the control program was 990 (s.d. $\pm$ 1351) and at the end it was 856 (s.d. $\pm$ 1304). The difference was not significant ($p = .29$).

Wrist flexion/extension deviation was observed among Assemblers, Press Operators, and Surface Finishers at the beginning and end of the program. Right wrist flexion/extension was four times more prevalent than left wrist flexion/extension. There was a slight but nonsignificant decrease in wrist deviation over the course of the control program. Assemblers were observed to have left wrist flexion when inserting clips or while holding parts to be assembled. Stock handlers had the highest right hand wrist flexion/extensions at 3722, followed by blow mold press operators at 2342 repetitions, and injection mold press operators at

Table 13. **Wrist Flexion and Extension Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs**

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1610	Assembler	11	571 (1210)	109 (362)	> -100.0
1790	Surface Finisher	1	512	576	12.5
1750	Blow Press Oper.	1	390	493	26.4
1700	Inj. Press Oper.	3	353 (317)	296 (270)	-19.4
1750	Assembler	1	309	367	18.8
1550	Regrind	1	0	0	0.0
1600	Assembler	2	0	0	0.0
1790	Comp. Press Oper.	1	0	0	0.0
1790	Assembler	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			372	153	> -100.0
S.D.			856	303	
Right Side					
1800	Stock Handler	1	3722	3841	3.2
1750	Blow Press Oper.	1	2342	1973	-15.8
1700	Inj. Press Oper.	3	1969 (1850)	2204 (1308)	10.7
1790	Surface Finisher	1	854	768	-10.1
1610	Assembler	11	800 (1257)	556 (1161)	-43.9
1600	Assembler	2	575 (814)	0	> -100.0
1550	Regrind	1	0	0	0.0
1750	Assembler	1	0	367	100.0
1790	Comp. Press Oper	1	0	0	0.0
1790	Assembler	1	0	0	0.0
Mean			990	856	-15.6
S.D.			1351	1304	

1780 repetitions. This compares to 950 repetitions for all jobs combined. The change in wrist flexion/extension for the right hand resulted from the use of power tools, such as pistol-grip screw guns, to vertically insert screws at the beginning of the control program. At the beginning of the program, Press Operators in Department 1700 showed a high number of left wrist flexions and extensions which was attributed to the awkward shape of the part and use of their hand as a jig to hold the part while trimming plastic flash with a knife with their right hand. At the end of the control program, wokers in this department showed a decrease in flexion/extensions of the right hand which was associated with a decrease in plastic trimming operations. Assemblers also showed a decrease in wrist flexion/extension of the right hand which was attributed to the installation of more power tools which fit the job such as in-line screw guns for vertical assembly tasks and pistol grip screw guns for horizontal tasks.

Left Hand Pinch Repetitions: the mean number of left hand pinch repetitions for an 8-hour day at the beginning of the control program was 3810 (s.d. $\pm$ 1855) and at the end it was 4250 (s.d. $\pm$ 2047). The difference was not significant ($p = .12$). **Right Hand Pinch Repetitions:** The mean number of right hand pinch repetitions for an 8-hour day at the beginning of the control program was 4826 (s.d. $\pm$ 2344) and at the end it was 5966 (s.d. $\pm$ 2571) (Table 14). The difference was significant ($p = .026$).

Hand grip and finger pinch repetitions were the most frequent activity of all repetitive motions within the work cycle. The right hand showed 30 percent more activity (4976) repetitions per 8-hour shift) than the left hand (3413 reps/8-hr shift). In addition, there was approximately 8 percent more activity for the left hand and 6 percent more activity for the right hand at the end of the control program compared to the beginning. The increase for left hand activity may be attributed in part to a better balance between left and right hand work

Table 14. Hand Pinch Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1750	Assembler	1	6499	5500	-15.4
1600	Assembler	2	5955 (1701)	6814 (2915)	12.6
1790	Assembler	1	4559	5416	18.8
1610	Assembler	11	3954 (1604)	4465 (2915)	11.4
1700	Inj. Press Oper.	3	3562 (1796)	4479 (1739)	16.0
1800	Stock Handler	1	3727	3841	3.1
1750	Blow Press Oper.	1	2732	3453	26.4
1550	Regrind	1	1876	1501	-20.0
1790	Comp. Press Oper.	1	864	1186	37.3
1790	Surface Finisher	1	683	576	-15.7
Mean			3810	4250	10.0
S.D.			1855	2047	
Right Side					
1750	Blow Press Oper.	1	10929	8387	-23.3
1600	Assembler	2	5617 (581)	5794 (2143)	3.1
1750	Assembler	1	7118	6966	-2.1
1700	Inj. Press Oper.	3	6219 (1694)	7464 (973)	16.7
1790	Assembler	1	5470	7742	41.5
1550	Regrind	1	4377	3502	-20.0
1610	Assembler	11	4316 (1768)	5794 (2143)	25.5
1800	Stock Handler	1	3722	3841	3.2
1790	Comp. Press Oper.	1	1152	1631	41.6
1790	Surface Finisher	1	854	768	-10.0
Mean			4826	5966	19.1
S.D.			2344	2571	

as observed in Department 1600 because of work layout and modified work practices. This increase in hand activity was caused by an increase in manipulation tasks where more clips were inserted to fasten parts together, and more power tools increased usage of the right hand. Assemblers were very active with approximately 5000 hand pinches for the left hand; the left hand being the service hand using a precision grip, and 6000 pinches for the right hand; the right hand being the work hand using a power grip. High hand activity was also observed among Press Operators who used their knife to trim parts on the average 6000 repetitions per 8-hour day. When short work cycles are examined as potential CTD risk factors it should also include hand and wrist activity.

4.3 Force

Left Side Force Repetitions: The left side force repetitions for an 8-hour day at the beginning of the control program was 535 (s.d. ± 801) and at the end it was 184 (s.d. ± 397). The difference was significant ($p = .042$). **Right Side Force Repetitions:** The right side force repetitions for an 8-hour day at the beginning of the control program was 1893 (s.d. ± 1374) and at the end it was 1235 (s.d. ± 1730) (Table 15). The difference was marginally nonsignificant at the 5 percent level ($p = .076$).

Overall, force repetitions decreased more than two-fold, from 535 to 184 for the left side and 53 percent from 1893 to 1235 for the right side from the beginning to the end of the control program. The decrease in force was particularly obvious among Press Operators in Injection Molding (-68%), Blow Molding (-50%), Assemblers in Department 1600 (-60%), and Ramline Assemblers (-44%). Assemblers in Department 1750 were the only workers to show an increase in force (57.9 percent). The increase in force in this department was attributed to the forceful assembly of fasteners and studs which did not easily fit into the

Table 15. Side Force Repetitions for an 8-hour Shift Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1700	Inj. Press Oper.	3	2014 (924)	239 (414)	> -100.0
1750	Blow Press Oper.	1	1561	0	9.9
1790	Assembler	1	912	148	-83.8
1550	Regrind	1	625	687	9.9
1610	Assembler	11	276 (482)	230 (513)	-20.1
1790	Comp. Press Oper.	1	144	148	2.8
1600	Assembler	2	0	0	0.0
1750	Assembler	1	0	0	0.0
1790	Surface finisher	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			535	184	> -100.0
S.D.			801	397	
Right Side					
1750	Blow Press Oper.	1	3903	1973	-49.5
1800	Stock Handler	1	3722	3841	3.2
1700	Inj. Press Oper.	3	3306 (760)	2742 (3871)	-20.6
1600	Assembler	2	2630 (1163)	1044 (1476)	> -100.0
1550	Regrind	1	1876	2063	10.0
1750	Assembler	1	1857	2933	36.7
1610	Assembler	11	1345 (1307)	529 (934)	> -100.0
1790	Assembler	1	912	445	> -100.0
1790	Surface Finisher	1	854	576	-48.3
1790	Comp. Press Oper.	1	433	445	2.8
Mean			1893	1235	-53.3
S.D.			1374	1730	

pre-assembled part and had to be forced into position by the worker's hand tool (usually a power screw or stud gun). The decrease in force in the other departments is attributed in part to: (1) sharper knives and fewer trimming motions from Press Operators, (2) improved production and quality of parts so better fit was achieved between parts such as screws, studs, and clips, (3) less awkward positions adopted from not having to force parts into position (i.e., mechanical advantage so workers can orient part to a more natural posture), and (4) part changes such as from hard c-clips to soft flexible plastic clips (observed in one of the jobs established after the control program began). This last change was especially noteworthy because it was associated with a reduction in work stress, improved productivity, and better quality of manufacturing and assembly process (i.e., less scrap or rework of parts).

4.4 Related Work and Environmental Attributes

Temperature and Force: Temperature changes were not a factor for the majority of jobs examined at this plant. However, there were a few jobs worth noting. The most obvious temperature effect was an increase in force among Regrind Operators. The problem was observed when plastic scrap parts were stored outside during winter months and brought in to the Regrind area. When the cold parts were brought in they had to be forcefully pulled apart; this was not the case when parts were stored outside during summer months. In another example, work practices may have been a factor for the interactive effects of temperature and force for Injection Mold Press Operators. For example, trimming flash, runners and sprues with knives and sidecutters while plastic stock was still warm was much easier than trimming after the stock has cooled. If a worker got behind then it would require much more force to trim excess plastic from the part.

Vibration: Surface Finishers and Routers in Department 1790 were the only workers the appeared at risk for segmental vibration-related disorders. Use of rotary sanders and power routers to finish parts or remove excess flash was often done in awkward positions and could have been a CTD risk factor. This was especially noted among women who sometimes tried to preserve their fingernails by holding the sander in a "claw-like" fashion when activating the trigger at the top of the sander.

Tool type and use: Stock Handlers and some Assemblers in Department 1600 were among the few workers who did not commonly use tools to perform their job. When tools were used, the right hand was primarily the power hand (used to hold manual and power tools), and the left hand was the service hand (used to get and place parts on the part being assembled or put on the tool for assembly). Tool use time for both power and manual tools for all departments which used tools averaged 82 ± 86 minutes (right hand) per 8-hr day or 20% of the work cycle. All manual tools were used on the average of 55 ± 43 minutes per 8-hr day or 13% of the work cycle (Table 16). All power tools which primarily included nutrunners, fasteners, rotary sanders, and routers averaged 124 ± 153 minutes per 8-hr day or 29% of the work cycle. When power tools are stratified by task such as assembly or surface finishing the average time assembly tools were used (i.e., nutrunners, screw guns, stud guns, etc.,) was 47 ± 17 minutes or 11% of the cycle time, and the average time the power sander is used is 353 minutes or 84% of the 8-hr day. When compared with other studies the power tool usage for assembly-type jobs shows these type of tools were used nearly twice as long as previous estimates (VanBergeijk, 1987)[9]. Injection Molders in Department 1700 used the most tools compared to other departments studied. Press Operators reported using up to 6 tools including, knives, sidecutters, files, and a hammer. At the end of the control program there was an increase in power tool usage, especially among assemblers

Table 16. **Hand Tool Use Time (minutes)** Repetitions for an 8-hour **Shift** Comparing Beginning versus End of CTD Control Program for Departments and Jobs

Depart. Number	Job Name	# Jobs Studied	Begin (S.D.)	End (S.D.)	%-Change
Left Side					
1790	Comp. Press Oper.	1	8.42	0	> -100.0
1610	Assembler	11	2.91 (9.7)	0	> -100.0
1550	Regrind	1	0	37.0	100.0
1600	Assembler	2	0	0	0.0
1700	Inj. Press Oper.	3	0	0	0.0
1750	Blow Press Oper.	1	0	0	0.0
1750	Assembler	1	0	0	0.0
1790	Surface Finisher	1	100.0	73.7	-26.3
1790	Assembler	1	0	0	0.0
1800	Stock Handler	1	0	0	0.0
Mean			6.1	4.8	-27.1
S.D.			21.6	16.9	
Right Side					
1790	Surface Finisher	1	334.3	352.7	5.5
1750	Blow Press Oper.	1	249.6	101.1	-59.5
1700	Inj. Press Oper.	3	82.6 (56.6)	82.9 (45.4)	0.36
1610	Assembler	11	79.7 (59.0)	64.4 (43.7)	-24.0
1600	Assembler	2	40.9 (4.5)	59.4 (20.5)	31.1
1750	Assembler	1	26.8	28.1	4.9
1550	Regrind	1	0	11.1	100.0
1790	Comp. Press Oper.	1	0	9.6	100.0
1790	Assembler	1	0	54.1	100.0
1800	Stock Handler	1	0	0	0.0
Mean			82.2	73.7	-11.5
S.D.			86.2	73.2	

workers on the Ramline. The increase in power tool usage may be attributed to more in-line and pistol-grip screw guns being installed so that workers could more easily use the right tool for the job (i.e., vertically placed screws fastened with in-line screw guns, horizontally placed screws fastened with pistol-grip screw gun). As mentioned earlier, the right hand was the dominant hand for power tools, and the left hand was used for retrieving clips, inserting clips, or holding and placing parts such as screws on the ends of power tools. Even with more tools installed some workers did not always use them because it required an increase in handling of such tools, and some workers preferred less handling over awkward posture. The decrease in tool hold time at the end of the control program may be attributed to: (1) more tools suspended on overhead retractors, (2) better proximal location of these tools to the worker's functional range of motion, (3) part changes which required less tool use time (also some parts required more assembly time), (4) better maintenance of presses which decreased time to hold and use tools, and (5) use of knife holsters which decreased the amount of time workers had to search for their knives at the beginning of each cycle.

Gloves: Gloves (or some form of hand protection) were worn by the majority of workers in this plant. Gloves, finger cots, or duct tape wrapped around the fingers were the preferred methods of hand protection both at the beginning and end of the control program. The primary purpose of the hand covering was to reduce the mechanical trauma imposed on the fingers and hands. The use of finger cots and finger tape increased toward the end of the control program, especially for the left hand to offer better tactile and flexibility manipulation of getting and sanding small parts for assembly with the right hand. The company provided hand supplies at the request of the worker.

5 Discussion of Analysis Changes

Table 17 compares the mean, and standard deviations for the measured job attributes at the beginning and end of the control program. The overall quantitative mean for job risk factors including job repetition, posture, and force decreased by 7.4 percent. A t-test comparing the overall change in risk factors for all jobs at the beginning and end was not significant ($p = 0.37$). No significant changes in work stations, tools, or materials, and the large variance between jobs reduced opportunities to detect changes that might have resulted from the ergonomic control program.

Compared to other studies which used work activity (i.e., work repetition) as a measure of work stress, this study shows that repetition was near the low end of the reported occupational CTD's in the literature. However, the methods used to characterize work repetition or work activity were not standardized for these studies and may vary significantly. One study which offers a more direct comparison was by Silverstein (1985). In her study, high repetition was characterized as a fundamental work cycle which takes less than 30 seconds, or more than 50 percent of the cycle time spent performing the same fundamental cycle. Stock Handlers (6.3 sec/cycle), Ramline Assemblers (21 sec/cycle), and Assemblers in Department 1790 met the high repetition criteria of less than 30 seconds per cycle. Three other departments which appeared to have a high frequency of CTD complaints had somewhat longer work cycles: Injection Mold Press Operators in Department 1700 (52 sec/cycle), Assemblers in Department 1600 (44 sec/cycle), and Load Floor Assemblers in Department 1750 (81 sec/cycle). Based on the data from this control program, and supporting published research, it appears that CTD risk with regard to repetition may be a factor for jobs for cycle-times as high as one to one and one-half minutes. Equally important is the amount of manual activity that takes place within that cycle. A high amount of work activity, such as

Table 17. Comparing the Mean, and Standard Deviations for the Measured Job Attributes at the Beginning and End of the Control Program

Work Attribute	Begin mean (std dev)	End mean (std dev)	Percent Change	Signif.
Job Cycle Time (Seconds)	55.8 (67.7)	54.5 (68.8)	-2.3	NS
Work Cycle Reps (8-hr).	1043 (761)	1039 (768)	-0.4	NS
Work Posture Reps (8-hr).				
Neck	520 (525)	556 (509)	6.5	NS
Shoulder				
Abduction				
Left	850 (1722)	417 (758)	-100	NS
Right	2024 (1981)	1622 (1344)	-24.8	NS
Flexion				
Left	99 (473)	0 (0)	-100	NS
Right	97 (320)	103 (340)	5.8	NS
Elbow				
Rotation				
Left	138 (320)	109 (446)	-26.6	NS
Right	430 (975)	305 (642)	-41.0	NS
Flex/Ext.				
Left	661 (1024)	358 (658)	-84.6	NS
Right	858 (1189)	839 (1075)	-2.3	NS
Wrist				
Rad/Ulnar				
Left	331 (868)	53 (150)	-100	NS
Right	1011 (1296)	970 (1278)	-4.2	NS
Flex/Ext.				
Left	372 (856)	153 (303)	-100	NS
Right	990 (1351)	856 (1304)	-15.7	NS
Hand Pinches				
Left	3810 (1855)	4250 (2047)	10.0	NS
Right	4826 (2344)	5966 (2571)	19.1	.026
Force				
Left	535 (801)	184 (397)	-100.0	.042
Right	1893 (1374)	1235 (1730)	-53.3	.076
Time Hold & Use Tools(min)				
Left	7.7 (24.2)	4.2 (18.7)	-83.3	NS
Right	185 (143)	207 (117)	10.6	NS
Time Use Tools (min).				
Left	6.1 (21.6)	4.8 (16.9)	-27.1	NS
Right	82.2 (86.2)	73.7 (73.2)	-11.5	NS

fastening several screws to a part, or several trimming motions with a knife to remove flash, may also be a factor, particularly with the number of hand-activities performed over an 8-hour work cycle. Assembly Jobs and Press Operator Jobs in the study plant typically required more than 6000 distinct hand motions in an 8-hour day to perform a job.

Repetitive activity increased from neck flexion to right shoulder abduction, decreased for elbow and forearm activity, then steadily increased for wrist, hand and finger activity. Generally, the right side was more active than the left side for repetitive job activity. Also, work activity at the beginning of the control program was higher than at the end. An exception to this was left and right hand pinch postures which increased slightly. There was a decrease in force (significant $p = 0.04$ reduction for the left side), and right side (not significant, $p = .08$) over the course of the program. Most jobs which require high repetition show high activity for the hands and fingers and were determined by machine-paced jobs rather than self-paced jobs (see for example Ramline Assembly Jobs (Department 1610) and Assembly Jobs in Department 1600). Exceptions to this rule are for machine-paced jobs which have a long cycle time such as Compression Molding (Department 1790).

Neck flexion activity increased slightly from 520 repetitions to 558 repetitions over the course of the control program for all jobs. Left shoulder abduction activity at the beginning of the control program was 850 repetitions per shift for all jobs and was reduced 40 percent to 417 repetitions at the end. Right shoulder abduction at the beginning of the control program was twice that of the left shoulder averaging 2,000 repetitions per shift at the beginning of the control program, then decreasing 20 percent to 1600 repetitions at the end. Because of the arrangement of assembly parts around work stations and work station

layout, reaching behind to retrieve objects during manufacturing or assembly tasks was negligible for both the beginning and end of the control program.

Right elbow rotation was observed three times more often than left elbow rotation (430 versus 138) for the beginning of the control program. A similar pattern was observed at the end of the control program. Elbow flexion and extension activity was twice that of elbow rotation (left 661, right 858). Left shoulder flexion/extension activity decreased over the course of the control program, but did not change for right flexion/extension.

Wrist radial, ulnar, flexion, and extension activity averaged approximately 1000 repetitions per shift for the right hand. Left wrist posture activity was approximately one-third to one-half that of the right wrist. Left and right radial and ulnar deviation decreased 44 percent, while wrist flexion and extension decreased 36 percent over the course of the control program. Left hand pinch repetitions increased 12 percent from 3810 to 4250 for an 8-hour period, while right hand pinch repetitions increased 24 percent from 4826 to 5966 over the course of the control program. As mentioned earlier, left hand force decreased significantly from 535 forceful repetitions at the beginning of the control program to 184 repetitions (66 percent decrease) at the end. Right side force also decreased (38 percent), but not significantly, over the course of the program from 1893 to 1234 repetitions.

For all jobs, time holding and using tools for the right hand increased from 185 minutes to 207 minutes per shift (12 percent), but time actually using tools decreased 10 percent (82 to 74 minutes). The increase in tool holding time was due to work practices which involved more inspection tasks in combination with assembly work (especially those outside the Ramline jobs) which may be a result of increased emphasis on quality control of these parts.

6 Comparison of Job Risk Factors with Published Studies

Table 18 compares some of the published data with the automotive plastics manufacturing and assembly plant data for working conditions during an 8-hour shift. The range of repetitive movements reported to cause CTDs during a normal work shift ranged from 33,000 repetitions for counting money (Maeda, 1980)[54], to 75 repetitions for trimming flash from typewriter cases (Boiano, 1981).[44] This compares to the jobs studied at the plastics plant which ranged from 3722 repetitions for stock handlers to 144 repetitions for compression mold operators. When the published data are compared to the plastics plant data, the studied jobs do not appear as repetitive. This is because the published data represent various aspects of the job with regard to work activity during a normal shift. For example, the 33,000 repetitions reported by Maeda for counting money does not represent a job cycle but observation and quantification of the number of bills counted over the work shift.

This is also true for researchers who found 12,250 hand manipulations for tobacco packing (Hammer 1935)[55], 25,000 hand manipulations during assembly line packing (Luopajarvi 1979)[37], and 12,000 poultry cuts (Armstrong et al, 1982).[57] CTDs are also found with low work cycle repetition which have 8-hour work cycles of only 75 typewriter cases deflashed per shift (Boiano, 1981)[44], or the assembly of 300 shoe tops by machinists (Birkbeck and Beer, 1975).[61]

To accurately assess the problem of <u>total work activity</u> versus <u>work cycle activity</u>, the published data on <u>work activity</u> should be compared with the total number of right-hand pinch-postures observed at the beginning of the control program for the study jobs. The data more accurately represents the work activity required to perform the manufacturing and assembly tasks. For example, some assembly jobs in Department 1600 would require more than 10,000 hand pinches per 8-hour shift; other assembly jobs would routinely exceed 5,000 repetitions. Work activity was also high for some Injection Mold Press Operators who

Table 18. Published Literature on Work Activity Associated with CTDs for an 8-hour Day

ACTIVITY	WORK REPETITIONS per 8-HOUR DAY.	REFERENCE
Published Literature		
Counting money	33,000	Maeda, 1980[54]
Assembly line packing	25,000	Luopajarvi, 1979[37]
Tobacco packing	12,250	Hammer, 1935[55]
Tea packers	12,000	Obolenskaja, 1927[58]
Poultry cutting	12,000	Armstrong et al, 1982[29]
Data processing	10,400	Ryan, (in press)[38]
Computer keystrokes	9,800	Meada, 1974[59]
Assembly-power tools	7,500	Louis, 1987[60]
Knitter avg. stitches	7,000	Birkbeck & Beer,1975[61]
Mail sorter keystrokes	6,450	Arndt, 1981[62]
typist keystrokes	6,100	Birkbeck & Beer, 1975[61]
Writing copy slips	5,500	Maeda, 1977[54]
Metal fabrication	5,000	Moody, 1981[46]
Assembler-screws	5,000	Tichauer, 1978[40]
Assembler-electrical cord	2,600	Habes, 1981[41]
Sewing shirt sleeves	1,800	Maeda 1974[54]
Quality Assur. part inspect.	1,500	Habes, 1981[41]
Shoe handling-machinists	300	Birkbick & Beer, 1975[61]
Amplifiers	150	Maeda, 1974[59]
Typewriter case deflashing	75	Boiano, 1981[44]
Study Jobs		
Stock handler	3,722	Department 1800
Regrind operator	2,000	Department 1500
Ramline assembler #11	1,501	Department 1610
Ramline assembler #10	1,401	Department 1610
Ramline assembler #5	1,395	Department 1610
Ramline assembler #8	1,311	Department 1610
Ramline assembler #6	1,232	Department 1610
Ramline assembler #12	1,220	Department 1610
Assembler #2	1,151	Department 1600
Ramline assembler #3	1,163	Department 1610
Ramline assembler #7	1,111	Department 1610
Ramline assembler #1	1,112	Department 1610
Ramline assembler #13	1,112	Department 1610
Assembler	912	Department 1790
Ramline assembler #9	758	Department 1610
Large press operator #1	612	Department 1700
Large press operator #2	446	Department 1750
Blow mold press operator	390	Department 1750
Assembler #1	377	Department 1600
Assembler	309	Department 1750
Surface finisher	171	Department 1790
Compression mold press op.	144	Department 1790

would use knives over 7,000 times per shift to deflash plastic from parts. Jobs which did not require highly repetitive subtasks such as assembly or deflashing tended to be jobs where the tools were used and were held constantly through-out the work cycle, (Surface Finishers in Department 1790), or were jobs that were machine-paced by a long curing time for each unit fabricated (Compression Mold Operators in Department 1790).

The published literature also notes force as a risk factor in the development of CTDs (Silverstein, 1985).[4] While this study did not take electromyographic measurements of workers during work, estimates of job tasks which required force in the performance of the job were derived by researcher's actual plant experience and worker interviews. When the number of forceful activities over an 8-hour shift for the study jobs is compared to the published literature on job activity, the study jobs show no particular job or department dominating the force risk factor category. Force was observed in Assembly, Stock Handler, and Press Operator jobs. As conventional wisdom would dictate, jobs which required high force tended to be less repetitive that those with medium to low force (less than 12 Kgs). Regrind operators in Department 1550, or Load Floor Assemblers in Department 1750 had jobs which required high force (i.e., pulling apart scrap material for regrinding, or forcing metal studs into position during assembly for load floor assemblers). As expected, jobs which required medium to low force tended to be more repetitive, such as some Ramline Assembly jobs, and Press Operator jobs (i.e., Compression Mold, and Injection Mold Press Operators). Jobs of medium to low force tended to have a higher percentage of female workers, and low force jobs had an even higher percentage (Surface Finishers in Department 1790, and Injection Mold Press Operators in Department 1700). It is important to note that force and repetition on some low-force jobs would increase as the presses needed maintenance or knives got dull: more effort was required during trimming. While it

makes sense to report bad presses or sharpen dull knives to make the job easier, the degradation of a process or manufactured part is subtle and not immediately noticed by workers or front-line supervisors. What is noticed is the cumulative effect of working harder to produce the same number of parts day after day.

Awkward posture of right hand flexion/extension activity of the study jobs can also be compared with the work activity in the published literature. Generally, Press Operators and Stock Handlers were observed to have a high frequency wrist flexion/extension associated with job demands. The use of knives to trim plastic flash from hard-to-reach corners was typical for Injection and Blow Mold Press Operators. This posture was observed less frequently in most Assembly jobs.

When comparing the literature for occupationally related CTDs it is important to note the quality and quantity of risk factors: repetition, force, and posture. When such risk factors are combined and compared between jobs then the resolution toward weighting such risk factors in CTD disease etiology can be assessed. At this time the published literature reports CTD patterns in more general terms through interviews of workers and reports or observations of job tasks. Because jobs are usually not systematically evaluated for job repetition, force, or posture, reports tend to address these activities in the broadest of categories, such as "work activity" (see Maeda, 1980[54]; Ryan, in press[58]; and Arndt, 1981[62]). These work activities are then compared to questionnaire results which report specific CTD symptoms such as carpal tunnel syndrome, tennis elbow, or tension neck syndrome. Some studies have gone further in quantifying job risk factors by discerning the origin, or aggravation of CTDs (Armstrong et al, 1982)[57], than postulating that such risk factors lead to disease. More recently, job risk factors have been compared to epidemiological data to determine an association between the two (Silverstein, 1985). While an association has been determined, few if any studies have been published which have

shown that CTDs reported by workers are decreased or increased by planned manipulation of job risk factors over time. Such a study may increase the association between occupationally related risk factors and CTD outcome, as well as provide a basic formula toward answering the question of what does and does not work with regard to controlling musculoskeletal disease of the upper extremities.

7 Study Limitations

Before beginning research into the development and implementation of a CTD control program, there was no information on the consistency of job risk stresses in manually-intensive industries. An early premise was that jobs designed to produce parts, if not modified, would display consistent stresses over time. However, there was significant evidence of changes in job stresses from week-to-week and possibly from day-to-day, even when the job remained the same. This unanticipated variance required additional investigation.

In this facility the production process is molding, assembling, and shipping plastic parts to whole body assembly plants. Deficient parts are either reprocessed (put in the plastic regrind machine) or discarded as unusable scrap. To perform these functions, there are three primary categories of production workers: Press Operators, Assemblers, and Stock Handlers; each experiences transient variation in his work which gives rise to episodic CTD reporting. Subtle changes in the work process can have a significant impact on changing job stress patterns and can effect individual jobs, departments, and the plant. Listed below are examples of how production changes can result in job stress changes.

Press Operators: Transient CTD's may be caused by the day-to-day or week-to-week variation in the process of doing work. For example, a Press Operator may have a good day at a press which is making good parts: there is little flash to trim, a low rejection rate, time to trim parts while they are still warm and help from relief operators when the

primary operator goes on break. However, on another day the same operator may be doing the same job, but with a press that is producing poor parts; with excess flash to trim, the worker gets behind. He can not sharpen his knife as often or is too tired to do so from the extra trimming, which requires increasing force to perform as the knife gets dull There may be no relief operators, so parts get cool and harder to trim. The stress variation is not a function of the job process so much as it is a function of the changing conditions of the job. Therefore, the early premise of job consistency was incorrect; work days are not similar. For the Press Operator, they may change a great deal. Changes may also occur from week to week - as a press gradually goes out of adjustment and produces parts that become increasingly difficult to work with.

Assemblers: Assemblers experience similar process variation. If the parts produced from the press are of substandard quality, and are "moved down the line" these parts are eventually incorporated into the assembled component. If the amount of flash in assembly lines is greater than normal, then more force is required to insert the screws. At the rate of 5-6 thousand screws per day, there can be a significant accumulation in the added forces needed to perform the job. This certainly increases the amount of stress. Batch inconsistency of parts also causes stress variations. If screws are not well machined, or are not of uniform size, there will be a change in the force levels during the assembly process. As force levels increase during assembly other components of the work process may deteriorate; the tips of screw guns wear faster and begin to slip out of the screw fitting more often. In order to prevent this, the operator has to press harder to keep the drive bit engaged in the screw. This adds to the amount of force needed, as well as the length of time the operator has to hold and use

the tool. As it becomes harder to assemble parts, workers may "chase" parts in order to maintain production, leading to quality control and productivity problems, and an increase in fatigue.

Regrind Operators, Surface Finishers, and Stock Handlers: As the rejection rate increases, there is extra material handling by the Stock Handlers and Surface Finishers, and Regrind Operators. Extra parts mean extra handling and extra stress. When this occurs, the materials may have to be stored outside. In the Winter, when the material is brought inside, it has to be forced apart and fed into the machine in small pieces because the Regrind machine clogs with large pieces. Surface Finishers and Routers (Department 1790) have to work much harder to get substandard parts finished to acceptable standards. Sanding means more work, and longer tool hold-and-use times. If the sanding pad on the tool is not changed regularly, the amount of applied force has to be increased. Stock Handlers also have varied day-to-day stress patterns as the stock they handle changes from day-to-day, e.g., from glove box doors, which weigh less than one pound each, to dash board panels, which weigh up to 7 pounds each.

In addition to the changes mentioned above, other internal factors (employee variability, task variability, competing risk factors, changing jobs, age, the lack of knowledge about the interactive effects of risk factors, and limited resources to analyze every job in the plant), decrease the precision with which risk factors can be assessed. External risk factors may also have some influence. A stronger economy may mean longer work hours or a larger work force; increased medical benefits may affect physically intense outside activity or hobbies; seasonal changes mean activity changes for the more athletically inclined; and as production technology evolves, so do the tasks it affects.

8 Summary of Job Changes Related to CTD Stresses

Documentation of work risk factors was performed over the course of the control program in which changes in work repetition, posture, force, and environmental attributes were evaluated. There was no significant difference in cycle time, or posture, from the neck to the hands between the beginning and end of the program. This is attributed to the lack of substantial changes to the work stations, work environment, and the plastic fabrication and assembly process. Force, while subjectively estimated, appeared to be the greatest factor of change which may be attributed to: (1) better maintenance of plastic presses which had a two-fold benefit (a) it reduced the amount of plastic flash that had to be trimmmed by the press operators, and (b) it appeared to reduce the amount of force required by assemblers to manually insert screws and studs (because of less flash in the holes) into plastic part fittings, and (2) better tools such as sharper knives and extended handles to improve mechancial leverage for the press operators, and more power tools and tool supports (i.e.,retractors) for assemblers.

In the course of this study, transient job risk factors emerged as a potentially significant finding in CTD etiology. These transient risk factors, like a moving target, are hard to isolate especially when jobs are periodically monitored. Ergonomics consultants who evaluate jobs may or may not observe such risk factors depending on the day of observation. However, if the experts have an awareness of changing manufacturing conditions, perhaps through in-depth worker interviews, then better targeting of these risk factors may help the experts focus on effective recommendations for CTD prevention.

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CHAPTER 3

HEALTH SURVEILLANCE

1 Introduction

Cumulative trauma disorders (CTD'S) are associated with manually-intensive jobs which require the use of force, repetition, and awkward postures. Such disorders cause higher worker absenteeism and increased medical and workers' compensation costs (Kelsey 1978[1], Joseph et al, 1986)[2]. It is suggested that the use of health surveillance, analysis of ergonomic stresses, and management of CTD'S through an ergonomics program may control and possibly prevent such disorders.

1.1 Health Surveillance

An active surveillance program was initiated at this plastics plant to determine the prevalence, incidence, and severity of CTD's in various departments during the implementation of the control program. This surveillance, conducted at month 4, month 12, and month 19 was aimed at monitoring the change in health status among workers. The active surveillance program included a main questionnaire and a physical examination of the upper extremities for all interviewed workers. Supplemental questionnaires were administered to some of the interviewed workers indicating recurrent symptoms possibly related to CTD's, or workers who indicated restricted range of motion (ROM) upon examination. There were three supplemental questionnaires, each focused on the upper extremity of interest: (1) neck, shoulder, and upper arm, (2) elbow and forearm, and (3) wrist, hands, and fingers. The standardized questionnaires were developed by Silverstein and Fine (1984)[3] at the University of Michigan School of Public Health.

Worker Selection

All workers meeting the following criteria were selected: (1) number of workers in selected departments should equal 25 or more; (2) job analysis would be performed in departments where health surveillance information was being gathered; (3) jobs studied had to exist over the course of the control program; and (4) workers had at least two-years seniority prior to the initial health screening.

Health Status Evaluation

Workers were interviewed in private offices, located in the center of the plastics manufacturing and assembly plant. All interviews were conducted during the workers' regular shift hours.

Outside health practitioners conducted interviews using standardized active surveillance questionnaires which obtained descriptive information about the workers, their work histories, and their current job-related symptoms, to evaluate the presence of CTD symptoms among workers. The main questionnaire also collected potential confounder data: gender, age, prior injuries to the upper extremity, chronic diseases, reproductive status for females, recreational activities, and prior job activities. Remaining questions addressed upper extremity pain or discomfort experienced with the workers' jobs. If the worker experienced recurring difficulty in one or more parts of the upper extremity, one or more of the supplemental questionnaires specific to the injury area were used by the interviewers. The supplemental questionnaires were designed to obtain additional information about worker symptoms which included injury location, onset, duration, aggravating factors and treatment. The interviewers were unaware of the specific job risk factors associated with each job.

1.2 Statistical Analysis of Health Data

Because of the dynamic production environment in this plant, worker movement from various jobs and departments over the course of this

program caused changes in worker exposure to specific job tasks. This in turn reduced the number of workers exposed to the same tasks over time. To reduce the impact of this problem, and answer the hypothesis in a more general way, the thrust of the statistical approach was to examine changes in health status by trend for the group at large, rather than on individual jobs and departments. Since the goal of this control program was to evaluate and reduce CTD risk factors, this general descriptive analysis will indicate whether the control program had an effect.

In order to test the hypothesis that CTD's can be controlled through an in-plant ergonomics program, the period-prevalence, incidence, and severity rates computed from questionnaire responses were used to measure changes in employee health status. The study population was divided into three categories: (1) all cases, (2) core cases, (3) and (3) subcore cases. "All" cases refers to workers who were interviewed at the time of the first, second and/or third survey, but for a variety of reasons did not participate in all three surveys. "Core" cases, which is a subset of "All" cases, refers to workers who were interviewed for all three surveys. "Subcore" cases are a subset of "Core" cases who were interviewed on all three surveys and stayed in the same job. "Core" cases are distinguished from "Subcore" cases because some of the workers moved to different departments or jobs over the course of the program (Table 1).

The first survey reported data of injuries between August 1980 and August 1982; the second survey reported data for September 1982 through May 1983; the third covered the interval from June 1983 to December 1983. There was no adjustment among the surveys for the time variance for the qualitative data; there was an adjustment for the quantitative data.

Table 1. Health Surveillance Study Population.			
Available for Interview	"All" Workers Interviewed	"Core" Workers Interviewed	"Subcore" Workers Interviewed
387 Available for interview -46 Not Interv[1]. ---------->	341 Interviewed (1st. Survey Study Jobs) -68 Not Interv[2]. ---------->	273 Interviewed all 3 Surveys -104 Not Interv[3]. ---------->	169 Interviewed[4] all 3 Surveys,
1. (14 Vacation, 29 Medical leave, 3 Refusal)	2. (11 Vacation, 15 Medical leave, 10 Furloughed, 5 Refused, 27 Other	3. All 104 Workers Moved to Different Departments	4. Did not Change Departments

Descriptive analyses were used on all three surveys to show changes in CTD reporting and as a preliminary indicator to determine control program impact. Chi-square tests were performed on CTD reporting rates for the first and third surveys to determine the significance of these changes (Fox D.J., 1976).[4] The first survey determined the base line CTD reporting patterns before any engineering, administrative, or work practice controls had been initiated; the third survey determined the longest possible period in which the controls may have had an impact on health status changes.

The direction and magnitute of change, and and significance of the severity rates were determined by the Wilcoxon's matched pairs test (Armitage, P. 1974).[5] Calculations for normalizing exposure for the three survey periods were performed to compare severity rates in each survey. In many instances the severity rates for workers reporting CTD

disorders were large and lognormal in distribution. Log transformation resulted in more normal distributions to enhance the probability of significance (F-tests) between surveys.

The Michigan Terminal System (MTS) and Michigan Interactive Data Analysis system (MIDAS) were used for manipulation and statistical analysis of the data (Fox, JD, Guire, K.E., 1976).[6]

2 Health Surveillance Results

2.1 Study Group Characteristics and Health History

In August 1982, 360 workers were interviewed; 147 females and 213 males. The mean age was 32.2 $\pm$ 8.6 years. The injury history tabulation for workers' upper extremities included broken bones or dislocations, strains, sprains, pulled muscles, arthritis, and chronic diseases. The health-history questions elicited confounding effects between the workers' past injury experience and occupationally related symptoms of CTD's. Analysis of the first survey data found no relationship between the potential confounders of: age, preexisting injury history, arthritis, chronic diseases, and symptoms of CTD's. The relatively young work force may have been a factor in the low reporting of these chronic diseases.

Table 2 shows the basic demographic profile of the study population, and results of worker responses for injuries occurring over the three survey periods to the hands, wrists, arms, shoulders, neck, and back (including fractures, industrial accidents, automobile accidents, and sports injuries). Table 3 shows the the past injury history and carpal tunnel syndrome reporting over the three survey periods. Upper extremity injury reporting showed a general downward trend from the first survey to the third, with a significant decrease in upper extremity injury reporting for the third survey. This decrease may be due to the short exposure period between the May 1983 Survey and the December 1983 Survey.

Table 2. Demographic Profile of the Study Population and Reported CTD Symptoms at Survey 1

All Cases (N=360)		Core (N=288)	Subcore (N=171)
Age	(years)		
Mean	32.2	32.3	31.7
S.D.	8.6	8.6	7.8
Gender	Percent		
Female	40.6	38.2	38.6
Male	59.4	61.8	61.4
Arthritis	Percent		
yes	15.7	15.2	16.1
no	84.3	84.8	83.9

Table 3. Injury History and Carpal Tunnel Syndrome Reporting

Past Injury History Percent	All Cases (N=360) Survey			Core (N=288) Survey			Subcore (N=171) Survey		
	1st.	2nd	3rd.	1st.	2nd	3rd.	1st.	2nd	3rd.
yes	58.2	47.3	16.8	56.3	43.9	16.0	57.3	41.5	17.0
no	41.8	52.7	83.2	43.8	56.3	84.0	42.7	58.5	83.0
CTS Percent	1st.	2nd	3rd.	1st.	2nd	3rd.	1st.	2nd	3rd.
yes	9.9	11.8	7.0	8.8	10.4	9.0	6.5	7.6	7.6
no	90.1	88.2	93.0	91.2	89.6	91.0	93.5	92.4	92.4

2.2 Carpal Tunnel Syndrome

Carpal tunnel syndrome reporting increased slightly between the first and second surveys, then returned to a lower level on the third survey (Table 3). Thirty-five Carpal Tunnel Syndrome (CTS) cases were reported on the first survey, with injection mold press operators showing the most frequent reporting. CTS reporting varied less for the core and subcore workers.

2.3 Injury Reporting by Region and Symptom - Categorical Analysis

Workers with symptoms of cramping, swelling, stiffness, tingling, or numbness answered a series of questions regarding the upper extremity

regions: neck, shoulder, upper arm, elbow, wrist, and hand (Table 4). Because of the unequal exposure time between surveys, statistical comparison for these categorical variables may be misleading.

Neck Discomfort As a whole, the number of workers reporting neck discomfort decreased from the first to third survey (10 percent). This trend was observed in most departments, except for forklift operators who showed a slight increase. The increase in forklift materials-handling may have resulted in increased body and neck rotation.

Shoulder Discomfort Shoulder discomfort reporting decreased 15 percent from the first to the third surveys. There are several reasons for this decrease. For example, there was an administrative control applied for stock handlers in the middle of the control program in which female workers unloaded automotive parts and male workers loaded parts on a moving conveyor. These workers reported that it took less time to unload parts than to load them, thus reducing the amount of time the part had to be handled.

Arm Discomfort The frequency of discomfort reporting decreased 15 - 17 percent from the first to third surveys. Injection mold press operators showed a 15 percent reduction in reporting of arm discomfort from the second to third survey. Compression mold press operators on the other hand, showed an increase in arm discomfort for the third survey compared to the previous two surveys. The decrease in symptoms for arm discomfort among injection mold press operators may have been due to better maintenance of presses to reduce excess flash, or better flash trimming knives. The increase in symptoms among compression mold operators may have been from the phaseout of these jobs toward the end of the control program, and job enlargement where in addition to molding, the workers had to use power routers to remove flash from the compressed parts. Because flash was located in hard to reach places, the power router had to be used in a variety of awkward positions. Another minor element causing the increase in symptoms among compression

mold operators may have originated from the change to ergonomic knives which neutralized the wrist during material cutting. These ergonomic knives were not durable enough for industrial use and the workers had to go back to the original knives which required ulnar wrist deviation during normal use.

Elbow Discomfort Reporting of elbow discomfort decreased 10 percent over the three surveys for most departments/jobs. Ram-line assembly operators were typical of most departments in reporting a decrease in elbow discomfort from the first to third surveys. This decrease may have resulted from additional tools suspended on retractors, modified work practices which resulted in less forearm rotation, and balanced work loads between the left and right hands.

Wrist Discomfort Wrist discomfort reporting decreased 10 percent from the first to the third surveys for most departments. However, when individual departments were examined, Ram-line assemblers and injection mold operators showed a significant decrease, possibly due to job improvements such as: more in-line power tools on the assembly-line (Ram-line) and maintenance improvements which minimized flash trimming on the injection mold press operators

Table 4. CTD Injury Reporting by Upper Extremity Region*

Upper Extremity Disorder Reporting	All Cases[1]			Core[2]			Subcore[3]		
	1st.	2nd	3rd.	1st.	2nd	3rd.	1st.	2nd	3rd.
Neck Disorders Percent	25	24	15	24	21	15	24	22	16
Shoulder Disorders Percent	35	32	22	37	29	19	36	29	20
Arm Disorders Percent	32	26	14	32	25	15	32	20	15
Elbow Disorders Percent	30	25	19	29	25	19	27	22	19
Wrist Disorders Percent	45	40	28	45	42	30	41	41	31
Hand Disorders Percent	47	38	26	47	38	28	47	37	30

1. All cases for first survey=359, second survey=397, third=418.
2. Core cases=288 for all three surveys.
3. Subcore cases=169 for all three surveys.
* Statistical comparison may be misleading because of the unequal exposure time between surveys.

Hand Discomfort There was a 17 to 20 percent decrease in hand discomfort from the first to third survey. The most notable decrease was shown by the injection mold press operators who had to perform less trimming, because of the reduced flash from better maintenance of these presses.

2.3.1 Injury Reporting by Region and Symptom Summary

The analysis of injuries by region showed a decrease in reported symptoms from the neck (10%) to the hands (20%) from the first to third survey. The decrease in reported symptoms between the first and third survey was more pronounced for the hands compared to the other upper extremity regions. This decrease may be attributable to two factors. The first is the short duration for responses to injury between the first survey (i.e., "Have you had pain or discomfort in the past two years?"), versus the last survey (i.e., "Have you had pain or discomfort

since the last survey?" - i.e., 7 months ago). The second factor for the decrease in CTD reporting may be attributed to the installation of several manual power tools, work station enhancements such as tool retractors, and improved fabrication of parts to decrease manual force during processing and assembly. If we assume that there was no bias in the reporting of injuries for workers interviewed on the first survey, then the impact of duration may be less of a concern, and the second factor may have played a more important role in reduced CTD reporting.

2.4 Range of Motion Physical Examination

Selected variables for shoulder and wrist movement were analyzed for the range of motion (ROM) examination of all workers who participated in the health status surveys. These ROM variables included: shoulder abduction, shoulder flexion (putting hands behind head), wrist extension, wrist radial deviation, wrist ulnar deviation, and Finkelstein's Test. Worker subjective assessment of pain was the primary indicator for restricted range of motion. There were three categories for pain scoring for restricted range of motion: None, Mild (range 1-4), and Severe (5-9). McNemar's test was used to determine significant differences in pain reporting between surveys.

2.4.1 Shoulder Pain

Shoulder Abduction Mild shoulder pain from abduction was 2.8 percent of those examined on the first survey, 6.9 percent on the second survey, and 4.6 percent on the third survey (Table 5). More severe shoulder abduction pain showed very little change from the first to third survey. Contingency analysis for the three surveys shows significant differences in pain reporting over the course of the program. McNemar's test for the active ROM pain/no pain between surveys showed that there was a significant 4.6 fold increase in pain reporting from the first to second survey. However, there was no difference in pain/no pain reporting for the first and last surveys. "Transient"

episodes of exposure to job risk factors for CTD's may explain the differences between surveys. This phenomenon of transient exposures will be discussed later in this section.

Shoulder Flexion Mild shoulder pain from putting the hands behind the head decreased from the first survey (4.5%) to second survey (3.6%), then increased again in the third survey (4.6%). More severe shoulder pain did not change over the three surveys.

2.4.2 Wrist Pain

Restricted Wrist Extension Pain Mild wrist pain from extension steadily decreased from 10 percent in the first survey to 2.4 percent in the third survey. A similar pattern was observed for more severe pain which decreased from 4.7 percent to 1.2 percent. Wrist extension pain/no pain reporting showed a significant decrease ($p < .0004$) from the first to last survey. Much of this decrease occurred between the second and third survey where there was a three fold decrease.

Wrist Radial Deviation Pain Mild wrist pain from radial deviation decreased from 8.9 percent to 2.4 percent, while severe pain decreased 2.2 to 1.2 percent. There was no significant decrease in pain/no pain reporting between the first, second and/or third surveys.

Wrist Ulnar Deviation Pain Wrist pain for ulnar deviation decreased from 6.1 to 1.2 percent for mild pain, and from 2.0 to 0.7 percent for more severe pain between the first and third surveys. Ulnar pain/no pain reporting decreased significantly ($p < 0.0007$) from the first to last survey.

2.4.3 Finkelstein's Test

Hand and wrist pain reported by workers for the Finkelstein's Test increased slightly from 10.3 percent in the first survey, to 14.7 percent in the second, and to 11.3 in the third. For more severe pain, 9.8 percent of the workers reported symptoms in the first survey, 9.0

percent in the second, and 6.5 percent in the third. There was an increase in severe pain reporting from the first to second survey, but an overall decline in severe pain reporting which was significant ($p < 0.03$) between the second and third surveys.

2.4.4 Range of Motion Examination Results Summary

Generally, there was a slight increase in mild discomfort reporting for shoulder abduction (2.8 to 4.6%), and shoulder flexion (hands behind the back) (4.5 to 4.6%) between the first and third survey. This was offset by a slight decrease in severe discomfort or pain reported for the same maneuvers (shoulder abduction 2.5 to 2.2%) with no change in severe pain reporting (1.4 percent) for shoulder flexion.

For wrist deviation there was an 7.5 percent decrease in mild discomfort and pain reporting and a 3.5 percent decrease for severe pain and discomfort pain reporting. The decrease in severe pain reporting was significant for wrist extension. Mild pain reporting for radial wrist deviation decreased 6 percent, severe pain reporting decreased only 1 percent. The decrease for both was not significant. Mild pain reporting for ulnar deviation decreased 5 percent and 1.3 percent for severe pain. The decrease was significant. The Finkelstein's's Test, a screening test for detecting symptoms of DeQuervain's's disease, increased from 10 percent to 11 percent for mild pain or discomfort. However, this same test showed a decrease in more severe pain or discomfort from 9.8 percent to 6.5 percent. This decrease was not significant.

Table 5. Range of Motion Physical Pain Score by Survey[1] for "All" Workers

	Mild (1-4)[2] Percent	Severe (5-9) Percent	None Percent
Shoulder Pain from Abduction			
First Survey	2.8	2.5	95
Second Survey	6.9*	2.3	90
Third Survey	4.6	2.2	93
Shoulder Pain from Flexion			
First Survey	4.5	1.4	94
Second Survey	3.6	1.3	95
Third Survey	4.6	1.4	94
Wrist/Hand Extension			
First Survey	10.0	4.7	85
Second Survey	7.7	2.3	89
Third Survey	2.4	1.2*	95
Wrist/Hand Radial Deviation			
First Survey	8.9	2.2	89
Second Survey	4.6	1.5	94
Third Survey	2.4	1.2	95
Wrist/Hand Ulnar Deviation			
First Survey	6.1	2.0	92
Second Survey	3.6	1.0	95
Third Survey	1.2*	0.7	97
Wrist/Hand Finkelstein's Test			
First Survey	10.3	9.8	80
Second Survey	14.7	9.0	76
Third Survey	11.3	6.5*	81

1. First survey worker population interviewed = 360, second survey = 389, and third survey = 416.
2. Pain score had nine levels, mild pain was categorized from 1-4, and severe pain was scored from 5-9.
* $p < .01$ (McNemar's Test)

While there was a slight increase in reported discomfort for shoulder movement and for low pain for the Finkelstein's's Test, there was a consistent decrease in all other categories, especially for worker reporting of more severe pain for all regions evaluated. The decrease in worker reporting of wrist discomfort was the most noticeable for the mild category reporting.

The reason for the decrease in symptom reporting appears consistent with the decrease in discomfort reporting for the categorical data reported earlier. Table 5 summarizes the Range of Motion Physical Pain Score and Finkelstein's Test for this study population.

2.4.5 Recurrent Upper Extremity Disorders

Recurrent disorders of the upper extremities were reported one-half to one-third as often by workers compared to the less severe and less frequent symptoms presented for the categorical data in section 3.4. In the analysis of these data, there was a decrease in symptoms from the neck to elbow (5%) with a much larger decrease for the wrist and hands (30%) between the first and third surveys (Table 6). However, between the first and second surveys, there was an increase in recurrent CTD reporting. Table 6 shows the results for recurrent worker reporting patterns. The reasons for the large increase in CTD reporting between the first and second survey followed by a pronounced decrease in the third survey is not clearly understood. There are several possible explanations for this reporting pattern including transient job risk factors which were prevalent at the midpoint of this program. Discussion of this reporting fluctuation is presented later in this report.

2.5 Supplemental Questionnaires

The data from the supplemental questionnaire showed a 10 percent decrease in worker symptoms of discomfort and pain from the right side for the neck, shoulder, and upper arm. There was no change for the elbow/forearm, and a 10-15 percent decrease for the wrist and hand. The decrease in right side symptoms may be associated with workers reporting a 10 percent decrease in right side body use and a 10 percent increase in left-side use: a more balanced work routine. Improved work layout makes better use of both hands, may decrease fatigue, and provide for improved product quality and productivity.

Table 6. Results for Worker Reporting of Recurrent Upper Extremity Cumulative Trauma Disorders*

	All Cases[1]			Core[2]			Subcore[3]		
	1st.	2nd	3rd.	1st.	2nd	3rd.	1st.	2nd	3rd.
Neck Disorders Percent	10	20	6	10	15	4	12	16	5
Shoulder Disorders Percent	5	33	13	6	26	8	6	26	8
Elbow Disorders Percent	19	34	18	17	29	12	11	26	12
Wrist/Hand Disorders Percent	37	60	8	37	56	4	30	54	2

1. All cases for the first survey=341, second survey=336, third=346.
2. Core cases=273 for all three surveys.
3. Subcore cases=169 for all three surveys.
* Statistical comparison may be misleading because of the unequal exposure time between surveys.

2.5.1 Quantitative Analysis

Quantitative analysis of responses for all Core and Subcore workers was similar for most categories including: number of episode days, number of days on work restriction, and number of days home because of CTD disability. By far, the number of episode days was the most frequently reported event compared to days restricted and days spent home for upper extremity CTD's (Table 7). There was a decrease in the number of workers reporting discomfort or pain episodes for the neck, shoulder and arm from 25 to 19 percent (Subcore 26% to 21%). Pairwise rank tests comparing the first, second, and third surveys showed no significant change when matching survey pairs over the program period. Episode reporting for the elbow and forearm increased slightly (16 to 20%) from the first to last survey. No significant difference was observed between survey pairs using Pairwise Rank Statistics. For the wrists, hands, and fingers the number of workers reporting episodes increased from 42 percent to 45 percent between the

first and second survey, then decreased to 41 percent on the third survey (Table 7). Similar results were seen for subcore workers. No significant differences in rates between surveys were observed.

The number of work days lost because of absence from work from discomfort or pain decreased approximately 4 percent (7% to 3%) from the neck, shoulder, and upper arm, and 5 percent for the wrist and hand (8% to 5%), while there was no change for elbow/forearm discomfort or pain (3%). Ninety percent of the workers who did report staying home from work because of pain or discomfort reported they stayed home less than 10 percent of the time (Table 8).

The number of restriction days because of discomfort or pain decreased over the course of the program of approximately 8 percent (17% to 9%), for the wrist and hand (Table 9). There was no change (5%) between the first and third survey for restriction days for elbow/forearm discomfort or pain reporting. The decrease for wrist and hand was most prominent from workers who were put on restriction less than 50% of the time, not much change was observed for workers who were on work restriction greater than 50 percent of the time.

2.5.2 Proportional Analysis of Quantitative Data

Tables 7, 8, and 9 show the results of the quantitative analysis reported in the previous sections. From the pattern of worker reporting of the number of episodes of pain or discomfort, days spent home because of CTD's, and days on work restriction, it appears that during the control program there was a decrease in workers' symptoms from the neck, shoulder, arm, wrist, and hands, but no decrease in symptoms for elbow or forearm disorders. Over the course of the program, workers generally reported less time lost while at home and fewer work restriction days. While the differences between surveys was not significant, there was a trend toward decreased reporting of discomfort and pain - especially among workers who had symptoms less

than 10% of the available work days (Table 8). However, the small number of absences or restricted workers limits this analysis. It was interesting to note that there was a slight increase in reporting for these disorders for workers with symptoms more than 50 percent of the available work time. It would appear that for the majority of workers with less severe CTD's, the program may have had some positive impact. However, for workers who had more "chronic" or severe CTD's the program did not appear to have any effect. The results showed a decrease in the frequency of worker reporting of upper extremity problems from episode days to days spent at home. Medical management of worker musculoskeletal symptoms may have been a function of this reporting trend, especially for restricted work and for medical leave to stay at home, where the worker needs medical authorization.

Table 7. Episodes of Pain or Discomfort in the Last Year, or Since Last Survey for Core and Subcore Workers

	N Indicate Episodes	Percent Positive	Proportion of Epi./Survey (>0 to.1) Percent	(>.1 to.5) Percent	(>.5) Percent
Neck, Shoulder and Upper Arm					
Core (N=288)					
1st. Survey	73	25	12	6	7
2nd. Survey	56	19	5	8	7
3rd. Survey	56	19	5	7	8
Subcore (N=171)					
1st. Survey	45	26	15	5	7
2nd. Survey	33	19	6	7	6
3rd. Survey	36	21	6	7	8
Elbow & Forearm					
Core (N=288)					
1st. Survey	46	16	8	4	2
2nd. Survey	64	22	8	8	6
3rd. Survey	57	20	5	7	8
Subcore (N=171)					
1st. Survey	26	15	9	4	3
2nd. Survey	34	20	9	6	5
3rd. Survey	33	19	5	6	8
Wrist, Hands, and Fingers					
Core (N=288)					
1st. Survey	121	42	18	8	16
2nd. Survey	130	45	17	13	15
3rd. Survey	118	41	9	15	17
Subcore (N=171)					
1st. Survey	71	42	21	6	14
2nd. Survey	78	46	21	12	13
3rd. Survey	69	40	9	13	18

Table 8. Days Stayed Home from Work Because of Pain or Discomfort for Core and Subcore Workers

	N Indicate Episodes	Percent Positive	Proportion of Epi./Survey (>0 to.1) Percent	(>.1 to.5) Percent	(>.5) Percent
Neck, Shoulder and Upper Arm Core (N=288)					
1st. Survey	19	7	6	.3	.3
2nd. Survey	11	4	2	1	.1
3rd. Survey	9	3	3	0	0
Subcore (N=171)					
1st. Survey	15	9	8	1	0
2nd. Survey	7	4	2	2	0
3rd. Survey	8	5	5	0	0
Elbow & Forearm Core (N=288)					
1st. Survey	8	3	2	0	.3
2nd. Survey	8	3	2	1	0
3rd. Survey	8	3	2	1	0
Subcore (N=171)					
1st. Survey	6	4	4	0	0
2nd. Survey	4	2	2	0	0
3rd. Survey	4	2	2	0	0
Wrist, Hands, and Fingers Core (N=288)					
1st. Survey	24	8	6	2	.3
2nd. Survey	14	5	4	1	0
3rd. Survey	9	3	3	.3	0
Subcore (N=171)					
1st. Survey	15	9	6	2	0
2nd. Survey	5	3	3	0	0
3rd. Survey	5	3	2	1	0

Table 9. Days on Light or Restricted Duty because of Pain or Discomfort in the Last Year or Since the Last Survey for Core and Subcore Workers

	N Indicate Episodes	Percent Positive	Proportion of Epi./Survey (>0 to.1) Percent	(>.1 to.5) Percent	(>.5) Percent
Elbow & Forearm Core (N=288)					
1st. Survey	13	5	3	1	1
2nd. Survey	16	6	3	1	1
3rd. Survey	13	5	1	1	2
Subcore (N=171)					
1st. Survey	8	5	3	1	1
2nd. Survey	6	4	2	0	1
3rd. Survey	6	4	2	1	1
Wrist, Hands, and Fingers Core (N=288)					
1st. Survey	50	17	7	8	2
2nd. Survey	41	14	9	5	1
3rd. Survey	26	9	4	3	2
Subcore (N=171)					
1st. Survey	29	17	8	8	2
2nd. Survey	22	13	9	4	1
3rd. Survey	16	9	5	3	2

3 Worker Movement and Changing CTD Patterns

A medical approach to control upper extremity disorders is the placement of workers in less stressful jobs once they develop symptoms of CTD's. Analysis of worker movement was conducted to examine CTD reporting patterns for Core workers (i.e., workers who may have moved to different departments, but interviewed on all three surveys), and Subcore workers (i.e., those workers who did not move). Chi-square tests showed no significant difference in CTD reporting patterns for the neck to hands between these two groups (Table 10).

While most departments showed a decrease in reported symptoms, further analysis showed that the change in symptoms reporting rate was not a function of worker movement out of study departments and into other nonstudy departments. Workers who had reported episodes of pain or discomfort on more than one survey tended to stay in the same department (Table 10). However, more detailed analysis showed that workers who had the most persistent symptoms were transferred to other jobs and departments (e.g., custodial or light maintenance) for recuperation. Because these workers stayed on light duty jobs during most of the program period, they had little opportunity to benefit from ergonomic changes on their original jobs.

Overall, all the pattern seems to indicate that those with symptoms on the first and third survey were more likely to move than those who were without symptoms on both surveys (Table 10). Similarily, those without symptoms on on the first survey but with complaints on the the third survey were also more likely to move than those without symptoms.

Table 10. Worker Movement, and Worker Reporting for Episodes of Pain or Discomfort between First and Last Survey for Core and Subcore Workers

Episodes of Pain or Discomfort	Yes on 1st. and 3rd. survey.	Yes on 1st. and No on 3rd. survey	No on 1st. and Yes on 3rd. survey	No on 1st. and 3rd. survey	Signif.
Neck,					
Worker Movement					
yes	11	16	17	24	p=0.85
no	3	86	11	116	p=0.20
Shoulder					
Worker Movement					
yes	12	31	21	40	p=0.62
no	10	63	12	95	p=0.79
Arm					
Worker Movement					
yes	7	30	11	42	p=0.96
no	9	70	15	100	p=0.90
Elbow					
Worker Movement					
yes	15	20	18	28	p=0.91
no	7	74	14	108	p=0.68
Wrist					
Worker Movement					
yes	22	38	33	36	p=0.27
no	10	46	19	80	p=0.99
Hand					
Worker Movement					
yes	21	34	29	49	p=0.95
no	9	52	20	68	p=0.32

4 Discussion

Health surveillance of this work population revealed that this ergonomics control program may have had some impact on reducing occupational CTD's (see Tables 1-6). However, because of the limitations in the study design, (i.e., low number of exposed workers over time), worker mobility, difficulty in precise health measures, the lack of medical diagnosis, and changing CTD symptoms over time (possibly related to changing job risk factors), it was difficult to evaluate the true health impact. On the other hand, this health surveillance approach did show some promise as a viable instrument from which meaningful data could be used to identify job risk factors, especially if it is used as a sentinel for providing information on changes in job risk factors.

The thrust of this research was to demonstrate if the approach of an ergonomic control program was feasible. Health surveillance using a prospective cohort design shows some promise in identifying CTD injury patterns among workers and subsequent changes in CTD morbidity as job risk factors changed. However, such an approach is not without limitations. The following sections will qualify the health surveillance findings taking into account the methodological limitations cited above.

4.1 Study Design

The original study design was a prospective study to compare the prevalence and incidence of the more highly-exposed versus lower-exposed workers to job risk factors related to CTD's. Unfortunately, within this plant there were not enough low exposed workers, particularly after one of the lower exposed departments was eliminated during the course of the study. This reduced the number of available controls and the study design had to be changed. The result was a prospective design which would focus on the changes in CTD reporting for employees who did not

change jobs. This new design was based on the premise that job risk factors for CTD's were present and that changes in job risk factors would reduce CTD morbidity.

4.2 Worker Mobility

Worker mobility was not expected to be a problem at the beginning of this study. Worker selection criteria included: (1) the number of workers in each department should equal 25 or more; (2) health surveillance would be conducted where job analysis was also performed; (3) study jobs had to exist over the course of the control program; and (4) workers had at least two-years seniority prior to the initial health surveillance screening. The advantage to this approach was not only to offer enough statistical power to see significant changes in CTD reporting rates for the work population as a whole, but also at the department and job level. The disadvantage is that if there was worker mobility some statistical power would be lost and the associations between job and health effects would be obscured. There was not enough data to statistically support morbidity changes at the department level after analyzing the data and noting the high rate of worker mobility from the first to last surveys. Therefore, analysis and interpretation was done for the plant as a whole. While this approach increased the statistical power, it left limited opportunity to evaluate changes at the department level.

4.3 Job Selection and Health Surveillance

Another problem of an analysis scheme based on departments and jobs was the study observation that exposures could vary depending on the specific nature of the job, such as large versus small press operators, or paced assembly lines versus nonpaced individual assembly work stations.

4.4 Subject Selection and Survivor Bias

Initially, we interviewed all non-furloughed workers in study jobs. Because employment depended on seniority, all available workers interviewed had two or more years of service with this company. Prior to the second interview (May, 1982) several of these furloughed workers were called back to work. Because many of these workers were in study jobs, they were interviewed along with the workers interviewed on the first survey. Only workers interviewed on the first and second interview were interviewed on the third and final survey (December 1982).

Furloughed workers who were returning to work before the second surveys may have experienced transient physical difficulty in adjustment to their work routine after their long absence from the workforce. This may explain in part the higher rates of symptom reporting noted during the second survey. This potential bias could overestimate the CTD prevalence for returning workers. In addition, we could have underestimated the CTD prevalence for workers in the Subcore group, since this group by definition had stayed on the job over the control program period. Because of this concern, analysis was performed on the three groups of workers (All, Core, and Subcore) as mentioned in section 1.2. It is interesting that the prevalence of "All" worker reporting is slightly higher than "Core" and "Subcore" workers. This may suggest some survivor effect for first survey workers, or perhaps some transient physical difficulty for workers returning to work before the second interview. These differences between study groups were not significant, even though there was variation in responses for "All" workers compared to "Core" and "Subcore" cohorts.

4.5 Variation of Job Risk Factors Within Job

Where possible, up to three representative workers were videotaped for job analysis. From the videotaped workers, a representative worker

for each study job was selected for detailed job risk factor analysis at the beginning and end of the control program. Within some jobs there was considerable variability in exposure assessment. This was further compounded by the "transient" nature of the job risk factors for the same job from week-to-week over the course of the control program. There was evidence of changes in job stresses from week-to-week and possibly from day-to-day, even when the job stayed the same. This variance may have played a role in the changes in CTD rates simply on the basis of coincidence between a bad or good week with regard to job risk factors and when the health surveillance information was taken. The evidence of changes in job stresses is explained in the job anlaysis section (paper 2) of this report.

4.6 Variation in Worker Behavior and Work Practices

Because of the repeated surveillance and videotaping of jobs in this plant over the control program period, there was a "heightened" awareness by the workers about ways to control and reduce occupationally induced CTD's. Such awareness may have caused workers to modify their work practices and thereby reduce awkward postures, unnecessary repetition, or extraneous force. Such changes may have been too subtle to identify through job analysis techniques, but sensitive enough to be recorded through health surveillance. These worker-initiated changes may have resulted in the lower reporting of worker symptoms at the end of the program.

4.7 Health Status Misclassification and Subject Error

Information bias between workers and interviewers, measurement error during physical examination, and subject recall could have affected CTD reporting. The skill of interviewers, while enhanced by training, was not at the level exhibited experienced occupational nurses or physicians. Workers were randomly assigned to interviewers, and

interviewers were blinded to the specific jobs of the workers. This health and exposure misclassification would most likely obscure a true treatment effect.

4.8 Comparison with Other Health Surveillance Studies

Health surveillance work from Silverstein (1985), Armstrong and Associates (1982)[7], Kourinka and Koskinen (1979)[8], Luopajarvi (1979)[9], and Viikari-Juntura (1983)[10] has identified work populations with various prevalences of upper extremity disorders. In Silverstein's work, the overall prevalence of tendinitis of the hand and wrist among 652 workers selected from 7 hand-intensive industries was 5.1 percent. The results are similar to Viikari-Juntura (1983) who reported a 4.4 percent overall prevalence of tendinitis among slaughter house workers. Kourinka and Koskinen (1979) reported an 18 percent prevalence among workers in a scissor manufacturing industry, and Luopajarvi (1979) reported a hand disorder prevalence of 56 percent among assembly-line packers and 14 percent among show assistants.

Other epidemiological studies presented similar results for populations at risk such as Hymovich and Lindholm (1966)[11] reported upper extremity rates at 6.6 cases per 200,000 work hours for electronics workers; Wasserman and Badger (1977)[12] reported 7.0 cases per 200,000 work hours for film products workers; and Armstrong for poultry processing plants, reported 17.4 cases per 200,000 work hours; Jensen et al., (1983)[13] examined Workers' Compensation claims for inflammation or irritation injuries to the upper extremities and found a prevalence of 6 percent.

When the present study is compared to the work cited above, one notes that the overall prevalence is slightly higher (about 5 percent) than those of Silverstein's (1985)[14] and Viikari-Juntura (1983), but lower than Luoprjarvi (1979) for most categories in this study. For recurrent disorders the reporting rates were approximately one-third

that of nonrecurrent disorder reporting (Table 5), and for Range of Motion Physical Pain Scores the percentage was lower still (Table 4). Because of the relatively low prevalence rate in this study, one would not expect much change in incidence rate reporting between the beginning and end of the control program. Such was the case here. There was not enough statistical power to show "real" change beyond background levels.

5 Conclusions

Health surveillance showed that workers reported CTD symptoms 10-20 percent less often at the end of the control program than at the beginning. More workers reported occassional CTD symptoms (25 percent for the neck to 45 percent for the wrist and hands) than those who reported recurrent CTD symptoms (10 percent for the neck to 35 percent for the wrists and hands). The largest reduction for both occassional and recurrent CTD symptom reporting was for the wrists and hands. The range of motion (ROM) examinations showed 10 to 15 percent of the workers reporting discomfort or pain on examination. At the end of the program there was a slight decrease ROM discomfort and pain reporting, however, the pattern was not consistent for all joints measured. Proportional analysis of quantitative data showed that workers who had persistent CTD's at the beginning of the program did not significantly improve at the end.

These health surveillance results suggest that workers may be exposed to job stresses which change on a week-to-week and possibly day-to-day basis even though the basic job remains the same. This variance in exposure may be a limitation to this type of study in which information is gathered at pre-scheduled intervals over the program period. Worker mobility and changing work assignments also make it difficult to establish a correlation between changes in health-status and changes in job CTD risk factors. Perhaps the maintenance of a

day-to-day log of CTD injury reporting at the plant medical dispensary would more directly address the limitation observed for active health surveillance.

Despite these limitations, the surveillance effort helped to provide the task force with justification to apply ergonomic principles to workplace and process design. Such instruments can be used to establish baselines and identify jobs with high rates of disorders so that an effective control program can be developed. While such an approach may be limited on a plant-wide basis, other researchers have found that larger surveillance programs involving several plants may be used to determine the effectiveness of control programs in reducing the number, severity, and cost of CTD's (Fine et. al., 1986).[15]

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