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REPETITIVE TRAUMA DISORDERS IN THE GARMENT INDUSTRY

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16. Abstract (Limit: 200 words) The prevalence of repetitive trauma disorders among workers in the garment industry was investigated with the intention of identifying specific sources of ergonomic stress which could be causing these conditions. The prevalence of pain in selected joints and limbs was investigated through a survey of 397 workers, of whom about 25 percent suffered persistent musculoskeletal pain in at least one part of their body. The most frequent location of the pain was the hand, followed by the back and neck. The following tests were also administered: Phalen's Test used to diagnose carpal tunnel syndrome; Tinel's Test used to diagnose carpal tunnel syndrome; Finklestein's Test used to diagnose deQuervain's disease; and Thumb Rotation Test used to diagnose degenerative joint disease. Particularly high rates of strain were noted among stitchers. The authors recommend that: efforts be made to reduce the coefficient of friction between the fabric being sewn and the working surface of the machines; sewing surfaces of the machines should be slanted in order to possibly reduce the tendency to lean forward; and workers should be rotated among different stitching jobs to reduce the amount of exposure each has to the more strenuous of the tasks.

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ABSTRACT

This study was undertaken to determine the prevalence of repetitive trauma disorders among garment workers, and to subsequently identify work tasks associated with increased risk of these disorders.

A survey of 397 garment workers found that approximately 25 percent of the study population suffered persistent musculoskeletal pain in at least one part of the body. The hand was the most frequently cited pain location, followed by the neck and back.

Work methods were analyzed on four garment industry jobs using cinemagraphic and electromyographic techniques. The results of these analyses were used to develop recommendations for changes in equipment and work methods in the garment industry.

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INTRODUCTION

Purpose

The purpose of this study was to determine the prevalence of repetitive trauma disorders among workers in the garment industry, and the relationship between these disorders and ergonomic stresses resulting from job demands.

Background

This study originated in the Fall of 1980 during discussions between safety and health officers from the International Ladies Garment Workers Union (ILGWU) and faculty members from the Occupational Health Program at the Harvard School of Public Health. During these discussions, union officers expressed concern about the growing number of published reports showing a relationship between certain types of upper-extremity musculoskeletal and neural disorders (e.g., tendonitis, tenosynovitis, carpal tunnel syndrome), and the performance of jobs that require repetitive hand motions (Hymovich and Lindholm, 1966; Hadler, 1976; Armstrong and Chaffin, 1979). The officers stated that many garment industry employees were performing jobs that required constant repetitive handwork and questioned if these workers could be experiencing elevated rates of repetitive trauma disorders.

Because of the proximity of the Harvard School of Public Health to the many garment shops in the Boston area, a collaborative study involving the Union, the School, and cooperating garment shops was initiated in 1981. This study was performed in two phases:

> Phase I consisted of a survey of garment industry workers to document the prevalence of localized joint pain. The purpose of this phase was to identify "problem" jobs and to describe the types of complaints associated with these jobs.
>
> Phase II consisted of detailed biomechanical analyses of the "problem" jobs to identify motions and tasks which might be causing the complaints. The purpose of this phase was to develop recommendations for changes in equipment and/or work practices in order to reduce ergonomic stresses.

Phase II was completed in mid-1982.

METHODS

Study Sites and Population

The study population consisted of 397 members of the ILGWU who were employed in eight different garment shops in Massachusetts. Seven of the shops were located in a city in the central part of the state; the eighth shop was located in a city in the eastern part of the state. Table I presents the population sample size and simple descriptive statistics (e.g., age, years of experience in the garment industry) for each of the eight shops. The table shows that workers in central Massachusetts were significantly older (48 years versus 41 years, $p<.01$), and had worked more years (17 versus 13, $p<.05$) than their counterparts in eastern Massachusetts.

The shops in central Massachusetts were considerably smaller than the eastern shop. These shops typically occupied one or two floors of older factory buildings that housed several tenants. The furniture and the equipment in these shops were generally more than 20 years old; however, a few items of newer equipment were observed. The shop in eastern Massachusetts was housed in a modern, single-floor, well-lit, climate-controlled factory building. Most of the equipment and furniture was less than ten years old; a few items were brand new and represented state-of-the-art technology.

Because of their small sizes, none of the shops that were studied had in-house medical facilities or trained personnel. In the unusual event of a work accident, the procedure would be to take the injured worker to a nearby hospital or clinic for treatment. When this occurred, the incident and injury would be recorded on the OSHA log. Non-accident-related health problems were referred to the employee's personal physician, or to one of several union-sponsored medical clinics. Prior to the study, there were no established programs to screen for repetitive trauma disorders.

Table II presents the number of males and females studied in each job title. Of the 397 workers included in the study, only 37 (approximately 9.3 percent) were males. Furthermore, most of the males were assigned to only three job titles: pressers, underpressers, and cutters. Most of the workers studied (266 out of 397) were sewing machine operators, also called stitchers. With the exception of a single male, this job was exclusively performed by females. Descriptions of each of the job titles appearing in Table II are given in the next section.

Job Titles Studied

Most (378 out of 397) of the workers surveyed were assigned to one of the seven designated job titles listed in Table II. These job titles are typically found throughout the garment industry. (Most shops, regardless of size, will have at least one employee assigned to each job in the table.) A brief description of each position is given below:

TABLE I.

EMPLOYEE AGE AND WORK EXPERIENCE BY SHOP

EMPLOYEE AGE AND WORK EXPERIENCE N = 397				
SHOP	MALES	FEMALES	AGE	EXPERIENCE (YRS)
C1	9	52	47±12	14±14
C2	1	10	52±6	25±11
C3	0	15	51±9	19±15
C4	0	12	53±11	28±14
C5	1	28	49±10	18±11
C6	0	10	49±14	20±15
C7	7	45	46±13	16±15
E1	19	188	41±12	13±11

TABLE II.

DISTRIBUTION OF MALES AND FEMALES BY JOB TITLE

DISTRIBUTION OF MALES AND FEMALES BY JOB TITLE		
JOB TITLE	MALES	FEMALES
Stitcher	1	265
Presser	12	15
Floor Help	1	25
Finisher	1	23
Underpresser	6	10
Cutter	11	3
Shipper	1	2
Other	4	17
TOTAL	37	360

Stitcher (n=266) – This is the most common of all garment industry jobs. Basically, the job requires that the worker be seated at a sewing machine, and assemble sections of garments by guiding two or more pieces of fabric through a reciprocating needle. While guiding the fabric with the hands, the machine is cycled on and off under the control of a knee or foot pedal.

Virtually all of the stitchers that were studied specialized in a particular task that was performed repeatedly throughout the workshift. (The degree of specialization, however, was greater in the large shops than in the small shops.) Some of the stitching jobs required relatively low skill levels (e.g., sewing the straight seams on the body of a jacket) while other jobs required high skill levels (e.g., positioning and aligning a sleeve while attaching it to a jacket body). Although several different types of machines were observed in use, the basic work postures and hand motions were similar across the stitching jobs.

A piece-rate incentive system for stitchers was in place at each of the participating shops.

Presser (n=27) – The presser operates the utility steam press, a machine which is used to remove wrinkles from a finished garment and to give the garment its final shape. The machine is operated while standing, and both hand and foot controls are used either to draw a vacuum or to release steam.

All of the pressers studied were required to perform frequent extended arm reaches while operating their machines and when hanging finished garments. In many instances these reaches resulted in significant flexion angles at the shoulder.

In addition to stresses resulting from repetitive motions, several of the pressers were also exposed to hot and humid environmental conditions.

Underpresser (n=16) – The underpresser uses a household type of iron for pressing linings, facings, and other supportive sections of partially completed garments. This activity is performed at a workbench that is similar to a household ironing board.

Work practices were observed to vary from shop to shop for this job title. In some shops underpressers were seated while in other shops, they stood. The exposures to heat and humidity for the underpressers were moderate compared to the exposures for the pressers.

Floor Help (n=26) – Employees assigned to this job are responsible for maintaining the flow of materials and in-process inventory throughout the shop. The job requires the worker to pick up bundles of cloth and/or partially completed garments at one workstation and to carry these materials to the next workstation.

In studying the floor help job, it was observed that most of the bundles were quite light, and that only on rare occasions were loads weighing more than 10 kg. handled. Employees assigned to this position spent virtually 100 percent of the day on their feet, walking and carrying light bundles.

Finisher (n=24) – Prior to final pressing, the finisher uses conventional scissors to remove extraneous threads from completed garments, and folds the garment into its final shape. While inspecting the garment, it is necessary to regrasp it several times so that it can be examined from different angles.

In the shops studied, finishers were positioned at large work tables. Bundles of completed garments were stocked there on tables awaiting inspection. While performing their jobs, the finishers were observed to alternate between standing and seated postures.

Cutter (n=14) – The cutter generates shaped pieces of fabric which are later sewn together to form the final garment. One of the basic tasks performed by the cutter is spreading. Spreading involves lifting a bolt of cloth to a movable rack, and then using the rack to lay multiple plies of cloth on the cutting table. Spreading requires reasonably high physical strength (the bolts of cloth may weigh over 25 kg.) and a high level of skill since any wrinkling of the cloth would distort the pieces which are cut.

After the material is spread, the cutting operation begins. A paper pattern is placed over the top layer of material, and a cutting tool (resembling a jigsaw) is used to cut the cloth. As with spreading, the operation of the cutting tool requires highly developed skills.

In several of the shops visited, different individuals performed the cutting and spreading functions.

Shipper (n=3) – The shipper assembles lots of finished garments according to buyers' orders. The job involves light to moderate manual materials handling and some dock work (shipping and receiving).

Measuring the Outcomes of Interest

It was mentioned previously that none of the eight shops was large enough to have an in-house medical clinic for treating work injuries and disorders, or for maintaining employee health records. The only readily available records of work-related injuries and illnesses were the OSHA logs maintained at each shop. Unfortunately, these logs were much better at recording injuries that resulted from overt accidents (e.g., burns from pressing machines, needle pricks, cuts) than they were at recording the more subtle injuries that resulted from repetitive trauma. As a result of these practices, it was impossible for the investigators to systematically review existing records to determine the prevalence and severity of repetitive trauma problems.

To overcome this problem, a survey was conducted among the employees in the eight shops. The purpose of the survey was to determine the prevalence of symptoms (e.g., pain, numbness, tingling, swelling, stiffness) that have been attributed to recognized repetitive trauma disorders (e.g., tendonitis, tenosynovitis, carpal tunnel syndrome, degenerative joint disease). It must be mentioned that a worker could report any (or all) of the above symptoms and still be 100 percent functional in his/her job. For this reason, a positive response to a survey question did not necessarily mean that a worker was disabled. Instead, a positive response implied that the person worked with noticeable discomfort in at least one joint.

It should be pointed out that the response measure used in this study was considerably more sensitive that the response measures used in other studies (e.g., lost days, medical payments, etc.). The results of the survey, however, were *only* used to identify jobs for biomechanical analyses; the results were not used to classify a job as either safe or hazardous.

The Employee Survey

To collect the survey information, a special questionnaire was developed and distributed to ILGWU members in the eight shops. A copy of the questionnaire is included in the Appendix to this report. (Note: The questionnaire in Appendix A represents the final revision that was used at the eastern Massachusetts shop. A form with a slightly different format was distributed at the seven shops in central Massachusetts.)

The survey was designed to determine the prevalence of symptoms at specific body locations (e.g., back/neck, shoulders, elbows, wrists, hands, hip, knee, feet). For each location, employees were asked if they had experienced persistent feelings of pain, tingling, stiffness or swelling. To help employees interpret the questions, persistent was defined as "most days for at least one month". If the employee gave a positive response, he/she was asked more specific questions concerning the location of the discomfort and the time since the most recent episode.

To minmize interference with the workers' productivity, the questionnaire was distributed during lunchbreaks. Participation in the study was on a voluntary basis; approximately 65% of the potential participants (based on union membership lists) elected to complete the survey form. Following distribution of the forms, investigators remained in the shops to answer questions and to assist employees.

Because many members of the study population were not fluent in the English language, the questionnaire was translated into Spanish, Italian, Greek, and Polish. In instances where a language barrier existed between investigator and subject, a bilingual co-worker was used as an interpreter.

(Note: The questionnaire was designed by Ms. Laura Punnett, a graduate student in Occupational Health at the Harvard School of Public Health. Specifically, the questionnaire was used as part of her Master's thesis which compared positive reports of pain symptoms to positive findings on a battery of clinical tests used to diagnose repetitive trauma disorders (e.g., Tinel's, Finklestein's, Phalen's). The questionnaire and the test battery were based on an extensive review of the literature and consultations with medical specialists. Some of the findings of this thesis research will be presented in the RESULTS section below.)

Preliminary Job Analyses

During the initial visits to the study shops, preliminary job analyses were performed for each of the seven positions discussed in the above "Job Titles

Studied" section. These analyses were performed on a walk-through basis and relied upon direct observation of the job being performed and 35 mm photographs of selected tasks. The goals of the preliminary analyses were: 1) to develop a brief description of the requirements of the job and 2) to identify specific tasks and postures which might be related to the development of repetitive trauma disorders.

The results of the preliminary analyses were used to develop a summary of the job which included the following items:

1. A description of the body postures maintained while performing the job and the percentage of the workday spent in each posture.
2. A description of the major tasks performed with the upper and lower extremities.
3. A description of significant materials handling (e.g., lifting, carrying, etc.).
4. A description of any environmental stresses at the workstation.

Results of the preliminary analyses for the Presser and Floor Help positions are presented in Figure 1. The postural analysis revealed that workers in both of these jobs were required to stand for virtually 100 percent of the workday.

Upper extremity tasks varied considerably between the two jobs. The shoulders, arms, and hands of the presser were in constant motion while operating the pressing machine in a highly repetitive task. On the other hand, the Floor Help position placed considerably less stress on the upper extremities. In this job, workers performed whole-body work (lifting light bundles, typically less than 10 kg.), and static arm work (while carrying the bundles between workstation).

Both Pressers and Floor Help performed some tasks with the lower extremities. The Presser operated foot pedals controlling steam and vacuum while the Floor Help walked between workstations.

Neither job had significant lifting requirements. On occasion, Pressers were exposed to uncomfortable levels of heat and humidity. Environmental conditions for Floor Help were nominally comfortable.

Detailed Job (Work Methods) Analyses

A detailed analysis of work postures, work motions, and hand forces was performed on selected jobs using a cinemagraphic-electromyographic (EMG) methodology developed by Armstrong and his co-workers (1979a,1979b). Major equipment required for this analysis included a Canon 514-XLS Super 8 movie camera and a portable EMG monitor system borrowed from NIOSH (Property Control No. NIOSH-14697).

The central unit of the portable EMG system included a 2-channel amplifier, and an intervalometer for controlling the rate of filming. The output unit featured two ten-position light emitting diode displays (LEDs) for presenting the amplitude of the rectified EMG signal (one display for each channel), and a digital LED display for presenting the frame number (this display was controlled by the intervalometer). By placing the output display within the camera field at the

PRELIMINARY ANALYSIS

PRESSER

POSTURE	-	Standing (100%)
UPPER LIMBS	-	Reach for garment (Shoul. Abd.) Reack for buck (Shoul. Abd.) Operate hand controls Hang garment (Shoul. Abd.)
LOWER LIMBS	-	Operate foot pedals
LIFTING	-	N.S.
ENVIRONMENT	-	Hot and humid at times

FLOOR HELP

POSTURE	-	Standing (100%) -Walking, carrying
UPPER LIMBS	-	Lift, carry bundles of material
LOWER LIMBS	-	Walk
LIFTING	-	Up to 20 lbs.
ENVIRONMENT	-	N.S.

Figure 1: Preliminary Analysis - Presser and Floor Help

workstation, it was possible to simultaneously film the work element, the work position, the rectified and amplified EMG signal, and the frame number. The EMG field monitor system is described in greater detail elsewhere (Armstrong, et.al., 1980).

A three electrode system was used to record EMG signals at the surface of the skin for each arm. The active electrode was placed on the forearm above the extrinsic finger flexor muscles. The reference and ground electrodes were placed over the lateral and medial epicondyles respectively. For each arm, the three electrodes were connected to a pre-amplifier, which in turn was connected to one channel of the EMG monitor.

Prior to filming a work sequence, the system was calibrated by asking the worker to exert a series of different hand forces while recording the corresponding output level on the ten position display. These data were used to develop calibration curves relating hand forces to the recorded EMG signal.

After processing, the film was analyzed on a frame by frame basis in order to simultaneously determine the position of the limbs and joints of the upper extremities and the forces exerted with the hands. This information was used to identify particular tasks and/or work motions which could cause or precipitate repetitive trauma disorders. Additional details on the job analysis procedures may be found elsewhere (Armstrong, et. al., 1982).

RESULTS AND DISCUSSION

Results of the Employee Survey

The purpose of the employee survey was to determine the prevalence of musculoskeletal pain among workers in the garment industry, and to determine if employees working on certain jobs were more likely to experience pain than employees working at other jobs. In order to do this, it was necessary to compute the prevalence of reported pain on each job that was studied.

Table III presents the number of subjects working at each job, broken down by shop. Several of the shops in central Massachusetts were quite small, and had no full-time employees assigned to some of the jobs. (In such an instance, several employees would perform more than one job. For example, a presser might also perform underpressing tasks, or a stitcher might function as floor help by carrying in-process work to the next workstation.) In other job titles, the total population was only one or two employees. Such small numbers made it infeasible to compute prevalence rates on a shopwise basis. For example, suppose that the lone presser in Shop 4 reported hand pain. The computed prevalence of hand pain among pressers would be 100 percent, a rather incredible statistic. Such an extreme statistic would probably never occur with a larger population.

To overcome this problem and to stabilize the prevalence rates, it was decided to pool the data into two groups; one group from central Massachusetts and the other group from eastern Massachusetts. Justification for organizing the data in this manner was based on the following points:

- Analysis of variance disclosed no significant differences in either age or work experience among the workers in the seven central Massachusetts shops. When the "central" data were pooled, it was discovered that the "central" workers were significantly older and had worked more years than the "eastern" workers (This was previously discussed in the METHODS section).
- The shops in central Massachusetts were in older buildings and contained older equipment than the shop in eastern Massachusetts.
- Several of the "long-time" employees in central Massachusetts had worked in several of the study shops during their careers. These individuals would have been exposed to conditions in more than one shop. (Note: Several "eastern" subjects had also worked in other shops in and around the city of Boston. However, none of these shops was studied.)
- Although similar survey methods were used in both locations, the form used in the eastern shop was slightly different than the form used in the central shops.

Because of small population samples within certain job titles, it was necessary to organize the survey data into five job categories: stitcher, presser, floor help, cutter and other. This pooling scheme was based on the following reasoning:

TABLE III.

DISTRIBUTION OF EMPLOYEES BY SHOP LOCATION

DISTRIBUTION OF EMPLOYEES BY SHOP LOCATION			
JOB TITLE	CENTRAL MASS.	EASTERN MASS.	TOTAL
Stitcher	125	141	266
Presser	17	10	27
Floor Help	15	11	26
Finisher	4	20	24
Underpresser	2	14	16
Cutter	11	3	14
Shipper	2	1	3
Other	14	7	21

- There were only three shippers (two from central shops, one from the eastern shop) in the entire study population; any prevalence statistic computed for this sample would not be stable.
- There were only two underpressers from the central shops; again, any prevalence statistic would be unstable.
- There were only four finishers from the central shops; any prevalence statistic would not be stable.

Using the above logic, cutters should have also been pooled into the job category "other" because there were only three cutters from the eastern shop. This was not done for the following reasons:

- The preliminary biomechanical analysis showed that this job involved constant work with the arms and hands, sometimes in extreme postures.
- Comments made by cutters during the survey interviews suggested that this group was experiencing abnormally high rates of pain in the hands and wrists.

Table IV summarizes the results of the employee surveys conducted at the central Massachusetts shops. A matrix format is used to show the number of workers in each of the five job classifications who reported pain in any of six body locations. Prevalence statistics (i.e., the number of employees reporting pain divided by the total number of employees on the job) are presented in parentheses.

Perhaps the most noteworthy aspect of Table IV is the high prevalence of musculoskeletal pain that was reported by the subjects. Looking at the total sample (n=190, extreme right column), it is seen that roughly one-third of the population reported hand pain. Stitchers (who comprised almost 66 percent of the study population) had the highest prevalence of hand pain (0.376). The prevalence of hand pain was also high among pressers (0.294) and cutters (0.273) when compared to floor help (0.133) and others (0.182). The differences among prevalence rates was found to be marginally significant ($p<0.10$) using a Chi-square analysis.

Next to hand pain, back pain was the most common complaint with a total population prevalence of 0.226. A Chi-square analysis failed to show any differences in the pain reported by the five occupational groupings.

Significant ($p<0.05$) differences were observed in the prevalence of hip pain reported by the different occupational groups. Stitchers experienced a prevalence rate of 0.232, more than twice the rate experienced by any other group.

There were no significant differences among the occupational groups in the reported prevalence of knee, hip and foot pain.

Table V presents the results of the employee survey conducted at the eastern Massachusetts shop. It is interesting to note that these employees reported considerably lower rates of pain than the employees from central Massachusetts. Chi-square analyses showed that the differences were significant ($p<0.05$) for knee, leg, foot and hand pain.

TABLE IV.

RESULTS OF EMPLOYEE SURVEY - CENTRAL MASSACHUSETTS

BODY PART	JOB TITLE					
	STITCHER (n=125)	PRESSER (n=17)	FLOOR (n=15)	CUTTER (n=11)	OTHER (n=22)	TOTAL (n=190)
BACK/NECK	30 (0.240)	4 (0.235)	2 (0.133)	1 (0.091)	6 (0.273)	43 (0.226)
HIP	29 (0.232)	1 (0.059)	1 (0.067)	1 (0.091)	2 (0.091)	34** (0.179)
KNEE	22 (0.176)	3 (0.176)	3 (0.200)	2 (0.182)	4 (0.182)	34 (0.179)
LEG	19 (0.152)	5 (0.294)	2 (0.133)	1 (0.091)	4 (0.182)	31 (0.163)
FEET	20 (0.160)	3 (0.176)	4 (0.267)	1 (0.091)	4 (0.182)	32 (0.168)
HANDS/WRIST	47 (0.376)	5 (0.294)	2 (0.133)	3 (0.273)	4 (0.182)	61** (0.321)

*$p < 0.10$
**$p < 0.05$

TABLE V.

RESULTS OF EMPLOYEE SURVEY - EASTERN MASSACHUSETTS

BODY PART	JOB TITLE					
	STITCHER (n=141)	PRESSER (n=10)	FLOOR (n=11)	CUTTER (n=3)	OTHER (n=42)	TOTAL (n=207)
BACK/NECK	21 (0.149)	3 (0.300)	3 (0.273)	0 (0.000)	10 (0.238)	37 (0.179)
HIP	14 (0.099)	1 (0.100)	2 (0.189)	0 (0.000)	6 (0.143)	23 (0.111)
KNEE	10 (0.071)	0 (0.000)	3 (0.273)	1 (0.333)	8 (0.190)	22 (0.106)
LEG	9 (0.064)	1 (0.100)	3 (0.273)	0 (0.000)	6 (0.143)	19 (0.092)
FEET	11 (0.078)	0 (0.000)	3 (0.273)	0 (0.000)	3 (0.071)	17 (0.082)
HANDS/WRIST	20 (0.142)	0 (0.000)	4 (0.367)	2 (0.667)	10 (0.238)	38 (0.183)

Similar to the central group, hand pain was the most common complaint among the eastern group with an overall prevalence rate of 0.183. Cutters experienced the highest prevalence of hand pain (0.667), followed by floor help (0.367) and others (0.142). Stitchers reported a relatively low prevalence of hand pain (0.142). Because of the small sample sizes in the cutter, floor help and presser classifications, the Chi-square test could not be used to evaluate differences in rates.

As with the central group, back pain was the second most common complaint among the eastern group (prevalence = 0.179). Complaints of back pain were most common among pressers, floor help and others. No statistical tests could be performed, however, because of the limited sample size in several of the job titles.

The prevalence of hip,knee, leg and foot pain is also presented in Table V for the five occupational groups. In general, the floor help reported the highest rates of pain in these body parts. Again, however, sample size limitations precluded the use of statistical tests.

Discussion of Survey Results

Table VI summarizes the results of the employee survey for the entire study population (n=397). The most noteworthy feature of this table is that a substantial fraction (approximately 25 percent) of the workers surveyed reported persistent musculoskeletal pain in at least one part of the body. It is important to note that these pains *were not disabling;* all of the workers that were surveyed performed normal job functions with no certified medical restrictions. Furthermore, many of the workers who reported pain seemed willing to accept their discomfort as part of the job.

Given the above information, one might conclude that there are no serious repetitive trauma problems in the garment industry, and that no ergonomic intervention is needed. Such a conclusion might be premature, and could be challenged on the following points:

-- The study design was probably biased by the "healthy worker effect" since all of the subjects were actively employed in the garment industry at the time of the survey. There was no mechanism in the study design for surveying individuals who may have "retired" from working in the industry because they could not accept pain as part of the job.
-- Pain may be a precursor to future potentially disabling conditions. If pain is caused by poor job design, reports of pain can be used in conjunction with ergonomic analyses to identify (and hopefully correct) stressful conditions before disabling injuries occur.
-- Persons who experience pain may not be as productive as they would be if they could work pain-free. Although no workers were medically restricted, their pains may have prevented them from realizing their full potential and productivity.

An interesting aspect of Table VI is that the most frequently cited location for pain was the hand. With the exception of floor help, all of the jobs that were

TABLE VI.

RESULTS OF EMPLOYEE SURVEY - ALL SUBJECTS

BODY PART	JOB TITLE					
	STITCHER (n=266)	PRESSER (n=27)	FLOOR (n=26)	CUTTER (n=14)	OTHER (n=64)	TOTAL (n=397)
BACK/NECK	51 (0.192)	7 (0.259)	5 (0.192)	1 (0.071)	16 (0.250)	80 (0.201)
HIP	43 (0.162)	2 (0.074)	3 (0.115)	1 (0.071)	8 (0.125)	57 (0.143)**
KNEE	32 (0.120)	3 (0.111)	6 (0.231)	3 (0.214)	12 (0.186)	56 (0.141)*
LEG	28 (0.105)	6 (0.222)	5 (0.192)	1 (0.071)	10 (0.156)	50 (0.126)*
FEET	31 (0.117)	3 (0.111)	7 (0.269)	1 (0.071)	7 (0.109)	49 (0.123)
HANDS/WRIST	67 (0.252)	5 (0.185)	6 (0.231)	5 (0.357)	14 (0.219)	99 (0.249)

*$p < 0.10$
**$p < 0.05$

studied involved continuous and repetitive hand motions. Complaints of hand pain were greatest among stitchers and cutters. Both of these jobs required precise and sometimes forceful positioning of fabric as the material was being sewn or cut. Previous studies have shown that repetitive hand motions of this nature may cause or precipitate inflammatory and/or degenerative disorders in the hand and wrist (Hymovich and Lindholm, 1966; Tichauer, 1978; Armstrong and Chaffin, 1979).

Ergonomic evaluations of these jobs could provide solutions to the repetitive motion problems. (The results of several ergonomic analyses are presented later in this report.)

The second most common pain site was the back/neck region with an overall prevalence of 0.201. Initially, this result was unexpected since most garment industry jobs do not require significant manual lifting, an accepted risk factor in the development of back pain (NIOSH, 1981). (The only "heavy" job in the shops studied was the cutter position, where it was necessary to occasionally lift a full bolt of fabric. Cutters, however, reported the lowest rate of back/neck pain among the groups studied.)

Lifting is not the only known risk factor in back/neck pain. Magora (1969) reported that prolonged sitting may result in lower back pain. Tichauer (1978) reported that continuous neck flexion may result in upper back and neck fatigue. These previous studies may explain the high complaint rate among stitchers who were seated continuously and frequently flexed their necks while sewing. When stitchers who responded "yes" to the back/neck question were asked to precisely locate their pain, 56 percent reported pain in the neck, upper back or shoulders, while 25 percent reported pain in the lower back.

Considering the total study population (n=397), the prevalence of pain at other body locations was surprisingly consistent (hip=0.143, leg= 0.126, foot=0.123). Whether these rates reflect a "background" rate of musculoskeletal pain for a population with the demographic characteristics of the study sample, or if these rates are elevated due to the results of repetitive trauma could not be determined from the available data.

Discussion of Punnett's Study

The employee survey was not designed to provide specific diagnoses of repetitive trauma disease entities. Instead, it was intended to measure the prevalence of local pain and discomfort that could be caused by repetitive occupational activities. A positive response to a survey question was non-specific (in terms of diagnosis) and could result from several classes of disorders: soft tissue inflammation (e.g., tendonitis, tenosynovitis), joint degeneration (e.g., osteoarthritis), nerve entrapment (e.g. carpal tunnel syndrome), or idiopathic joint pain.

As part of her Master's degree research at Harvard, Ms. Laura Punnett evaluated the relationship between reports of subject hand and wrist pain, and the results of several clinical tests that are used to diagnose repetitive motion disorders of the upper extremities (Punnett, 1982). Some of the results of her research are summarized and briefly discussed below.

A total of 294 subjects participitated in the Punnett study (207 of the subjects were the group from the garment shop in eastern Massachusetts; 87 of the subjects were employed at a hospital). Each subject was administered the questionnaire shown in Appendix A. In addition to the questionnaire, each subject was given a battery of clinical tests often used to diagnose repetitive trauma disorders. The following tests were included:

1. Phalen's Test - A wrist-flexion test used to diagnose carpal tunnel syndrome (entrapment of the median nerve).
2. Tinel's Test - A wrist-tap test also used to diagnose carpal tunnel syndrome.
3. Finklestein's Test - A wrist manipulation used to diagnose deQuervain's disease.
4. Thumb Rotation Test - A thumb manipulation used to diagnose degenerative joint disease.

The testing methods were standardized based on consultations with a neurologist, a hand surgeon, a rheumatologist, and other specialists (Punnett, 1982).

Sensitivity and specificity statistics were computed for each test and are presented in Table VII. (Please refer to Figure 2 for a definition of these statistics.)

Sensitivity ranged from a low value of 0.08 (Tinel's test as a predictor of hand pain) to a high value of 0.56 (Finklestein's test as a predictor of wrist pain). Specificity ranged between 0.87 (Phalen's test as a predictor of hand pain) and 0.98 (Tinel's test as a predictor of hand pain). The high specificity scores indicate that the tests were unlikely to produce false positives (i.e., positive test finding with no pain).

The high sensitivity and specificity of Finklestein's test do not necessarily mean that it is a better diagnostic tool than the other tests. A reasonable explanation of this finding is that most of the pain complaints in the population studied were caused by soft-tissue inflammation. Finklestein's test is useful in the diagnosis of deQuervain's disease (tendonitis of the thumb extensors and abductors), a soft-tissue disorder. The other tests are specifically designed to diagnose nerve entrapment or joint degeneration. If these conditions were rare in the population studied, low sensitivity would be expected.

An important finding of the Punnett study is that traditional tests that are used to diagnose repetitive trauma disorders of the hand and wrist may not be particularly useful in detecting the presence of pain, particularly when the pain is due to non-specific soft-tissue inflammation. New tests should be developed for diagnosing this condition.

Selection of Jobs for Detailed Analyses

Observations made during the preliminary job analyses and responses to questions on the employee survey were used to select four jobs for detailed work methods and electromyographic analyses. Reasons for selecting the four jobs are discussed briefly below:

TABLE VII.

SENSITIVITY AND SPECIFICITY OF
DIAGNOSTIC TESTS (PUNNETT,1982)

SENSITIVITY AND SPECIFICITY
OF DIAGNOSTIC TESTS (Punnett, 1982)

	Sensitivity	Specificity	Prevalence
Hand			(0.20)
Phalen's	0.32	0.87	
Tinel's	0.08	0.98	
Thumb Rotation	0.12	0.95	
Wrist			(0.13)
Thumb Rotation	0.25	0.96	
Finkelstein's	0.56	0.91	

SYMPTOMS	TEST RESULTS		
	Positive	Negative	TOTAL
Present	a	b	a+b
Absent	c	d	c+d
TOTAL	a+c	b+d	N

Sensitivity: a/a+b
Specificity: d/c+d
Prevalence : a+b/N

Figure 2: Definition of Statistics (Punnett,1982)

1. *Pressers* – Pressers (n=27) were the second largest occupational group in the study, and reported the highest prevalence of back and neck pain. During the preliminary job analysis, it was observed that the shoulders, arms, and hands of the presser were in constant motion; reaching for a garment, placing it on the pressing machine, pulling down the press head, operating the steam control, releasing the press head, repositioning the garment (followed by another cycle of the press head), and hanging the garment on an overhead rack. These actions required repeated shoulder flexions and repeated pressing actions with the fingers and palms. Although the prevalence of hand and wrist pain was the lowest of all groups studied (0.185), it was considered sufficiently high to justify further analysis.

2. *Cutters* – The employee survey disclosed an interesting pattern of pain complaints among the cutters. In four areas of the body (back/neck, hips, legs, feet), cutters experienced the lowest prevalence of pain among all occupational groups. In the hand and wrist however, cutters experienced the highest incidence of pain (0.357).

   The preliminary job analysis disclosed that the cutting job required sustained gripping forces to be exerted by the right hand (while holding and guiding the cutting machine) and intermittent pressing forces to be exerted by the left hand (while holding down fabric in the vicinity of the blade).

3. *Stitchers* -- This job was studied because it is the most common job in the garment industry and because the employee survey disclosed that over one-fourth of the stitchers experienced persistent pain in their hands and wrists (Stitchers were second only to cutters in hand/wrist complaints). The preliminary job analysis indicated that stitchers constantly worked with their hands while positioning and guiding fabric through their sewing machines.

   Two different stitching jobs were studied. The first job involved the assembly of the main body of a woman's blazer by sewing long, straight seams to connect different sections. The second job involved matching and aligning the collar to the blazer body, and attaching it with a precise curved seam. The preliminary analysis suggested that ergonomic stresses could differ considerably between the two jobs.

Findings of the Detailed Analyses

Results - Presser

Films were taken of one subject (male, 170 cm, 74 kg.) performing several cycles of the final steam pressing required for a woman's blazer. The subject was employed in the eastern Massachusetts shop and performed tasks similar to those performed by other pressers in the sample study population. An anthropologic summary for the subject is given in Table VIII.

The final pressing operation was performed on a Hoffman Utility Steam Press Model No. 42-C05. The fixed, lower pressing surface (called the "saddle") was located at a height of 107 cm above the floor. This surface was slightly curved, and had a horizontal (i.e., parallel to the floor) orientation. Most of the basic pressing tasks (e.g., positioning, repositioning, and smoothing the blazer) were performed on this surface. The movable, upper pressing surface (called the "head") was attached to the saddle with a hinged-mechanism. When fully

TABLE VIII.

ANTHROPOLOGIC SUMMARY OF CASE-STUDY SUBJECTS

	JOB TITLE			
	Presser	Cutter	Straight Stitcher	Collar Stitcher
Age (years)	42	66	60	45
Sex	male	male	female	female
Height (inches)	67	64½	63	64
Weight (pounds)	163	165	138	135
Elbow Height Standing (inches)	41	41		
Elbow Height Seated (inches)			31	29
Shoulder Height Standing (inches)	55	53		
Shoulder Height Seated (inches)			40	44
Dominant Hand	right	right	right	right
Muscle Group Studied	FDS/FDP	FDS/FDP	FDS/FDP	FDS/FDP

extended to its upper position, the handle of the press head was located 142 cm above the floor. It was necessary for the operator to reach to this height and grab the handle in order to lower the head and activate the steam controls.

The right hand was calibrated for the EMG analysis in three positions: finger press, palm press, and finger pinch (pulp pinch). (Refer to Armstrong, et. al., (1982) for a more complete definition of these positions.) Each of these positions was used in positioning and smoothing the fabric. All calibrations were performed at the saddle height of 107 cm.

The left hand was calibrated in four positions, three of which were mirror images of the right hand calibration. These three positions were typical of the hand postures used while positioning and smoothing the material. The fourth calibration was performed at the height of the handle and steam controls (142 cm) to simulate the head lowering motion and release of the steam.

The long time (100 seconds) required to press one blazer limited the EMG analysis to only one cycle. Based on observation and filming of several cycles, it is felt that the results presented below are representative for a typical pressing cycle.

The results of the biomechanical and EMG analyses of the press operator are presented in detail in Appendix B. Table B-1 presents a detailed, time-based activity summary for the tasks performed by the left and right hand during the studied cycle. Figures B-1 through B-9 present a time chart of the positions of the shoulders, elbows, wrists, hands, neck and back during the studied cycle.

As mentioned above, the time required to complete one cycle of the pressing operation was approximately 100 seconds. Assuming an eight-hour workday (with 30 minutes for rest breaks), approximately 270 blazers were pressed per day. The job was highly dynamic and required the operator to perform three tasks on a repetitive basis. The first task required the operator to position and smoothe a section of the blazer on the surface of the saddle. This task was done 17 times during a typical cycle or about 4600 times per day. The second task involved lowering the press head (done with the left hand) and operating a steam control (also done with the left hand) to apply steam. This task was also done approximately 4600 times per day. The third task was to remove wrinkles from the blazer by holding (with the right hand) a section of material against the extended press head, and activating the steam control (with the left hand) to "shoot" steam through the material. This was done three times during a typical cycle, or 810 times per day. In addition to these major tasks, the operator was required to hang the finished blazer on a coat rack when the pressing cycle was completed (270 times per day).

One method for evaluating postural stress is to examine the EMG films to determine limb angles at the joints of the upper extremities, and to determine the percentage of time spent in each posture during the work cycle. This has been done for the presser job and the results are presented in Table IX. The system used for defining joint positions was developed by Armstrong, et.al. (1981). The information contained in this table along with the time graphs in Appendix B has led to the following observations about the presser job.

The height of the press head and steam controls (142 cm in the extended position) required the operator to repeatedly flex the left shoulder when reaching for the handle or the controls. This is shown in Table IX; the left shoulder was

TABLE IX.

UPPER EXTREMITY POSTURES

PRESSER

Total time: 99.5 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND	BODY	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	Neck	Trunk
Flx 0.5	Add 8.5	Lat 4.0	Flx 5.0	Sup 2.5	Rad 5.0	Ext 9.0	PPr 13.6	Neu 22.6	Neu 89.7
45 2.0	Neu 58.8	Neu 40.7	90 29.2	Neu 25.6	Neu 49.7	45E 46.8	PP 37.7	30 54.8	Flx 10.3
90 13.1	45 27.2	45 23.6	45 42.2	Pro 60.3	Uln 27.1	Neu 22.6	FP 11.6	60 22.6	
135 42.7	Abd 5.0	Med 31.7	Ext 23.1	Oth 11.6	Oth 18.2	45F 8.0	HG 3.5		
Neu 38.7	Oth 0.5	Oth 0.0	Oth 0.5			Flx 0.0	Oth 33.6		
Ext 3.0						Oth 13.6			
Oth 0.0									

LEFT

SHOULDER			ELBOW		WRIST		HAND	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	
Flx 0.0	Add 20.1	Lat 5.7	Flx 21.6	Sup 0.0	Rad 26.8	Ext 11.9	PPr 19.1	
45 2.6	Neu 41.2	Neu 19.6	90 37.7	Neu 4.6	Neu 27.8	45E 45.9	PPS 19.1	
90 21.6	45 29.4	45 19.1	45 21.6	Pro 80.9	Uln 19.1	Neu 11.9	PPH 26.8	
135 51.6	Abd 3.6	Med 48.4	Ext 12.4	Oth 14.5	Oth 26.3	45F 7.7	FP 7.7	
Neu 20.6	Oth 5.7	Oth 7.2	Oth 6.7			Flx 4.6	Oth 27.3	
Ext 0.5						Oth 18.0		
Oth 3.1								

TABLE IX. (cont.)

LEGEND

Flx................Flexion

Ext................Extension

Neu................Neutral

Add................Adduction

Abd................Abduction

Lat................Lateral

Med................Medial

Sup................Supination

Pro................Pronation

Rad................Radial

Uln................Ulnar

45E................45 Extension

45F................45 Flexion

HAND POSITION ABBREVIATIONS

PPr..........Palm Press

PP ....Finger Pinch (Pulp Pinch)

FP ....Finger Press

HG ....Handle Grip

PPS..........Finger Pinch Saddle

PPH..........Finger Pinch Handle

FPM..........Finger Press Medial

FPN..........Finger Press Neutral

flexed 75.8 percent of the cycle while the right shoulder was flexed only 58.3 percent of the cycle. The high frequency of the flexion motion (approximately 5400 times per day) could be a cause of shoulder fatigue, and may lead to inflammatory disorders (e.g., bursitis) in some individuals. It should be pointed out that the subject for the analysis was 170 cm tall, slightly shorter than the average male. The problem of shoulder flexion of this job is not independent of the operator's height; a shorter individual would be more likely to suffer problems than a taller individual.

The right arm did not make any extended reaches except when hanging the blazer at the end of the cycle. Because of the height of the rack (188 cm) it was necessary to flex the shoulder while performing this task. Fortunately, the frequency of this activity was only 270 times per day.

The design of the workstation did not cause any frequent or sustained awkward postures for either elbow. For most of the task cycle, the elbows were kept near the middle of the range of motion. The design of the press saddle, and the need to continuously smoothe the material resulted in forearm pronation for a large fraction of the cycle (left=80.9 percent, right=60.3 percent).

The location (107 cm above the floor) and orientation (horizontal) of the press saddle created a potential problem for the wrists and hands while performing the positioning and smoothing tasks. Because the operator's elbows were held higher than the saddle, the forearms were positioned slightly downward during this task. Because the surface of the saddle was horizontal, it was necessary to extend the wrists as shown in Figure 3. Table IX shows that the wrists are maintained in this position for a large fraction of the cycle time (left=57.8 percent, right=55.8 percent).

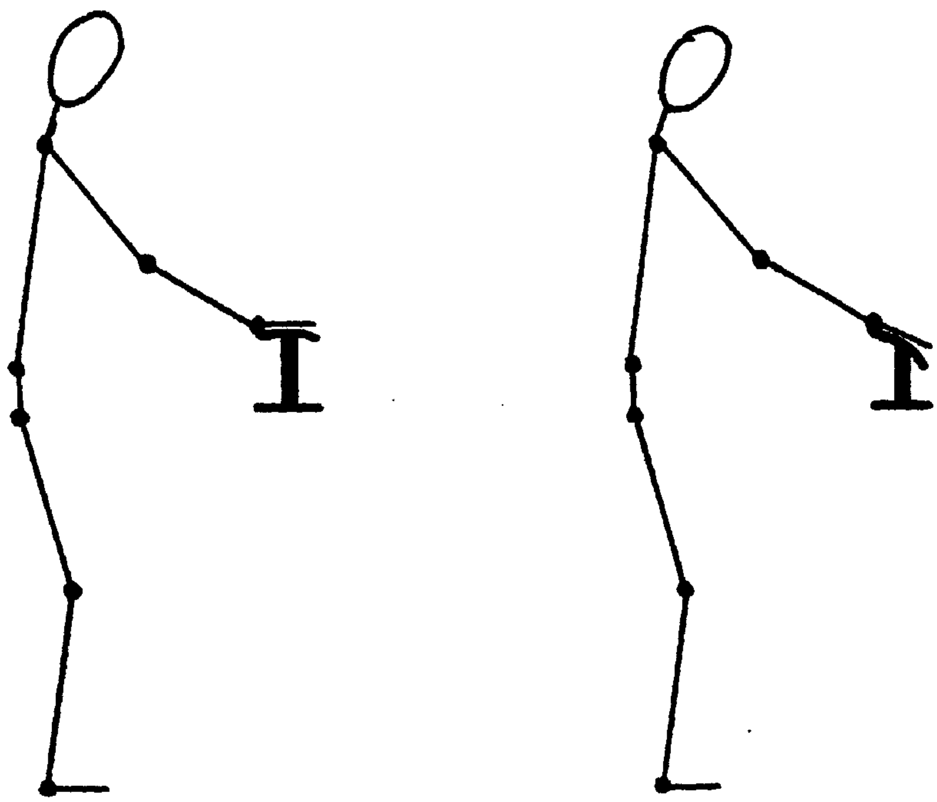
Sustained wrist extension was only part of the problem on this job. An examination of the time graphs in Appendix B reveals that the most forceful (greater than 4 kg) right hand exertions were finger pinches (pulp pinches) performed with an extended wrist. The most forceful left hand exertions (lowering the press head and operating the steam controls) were also performed with an extended wrist. Previous studies (Armstrong and Chaffin, 1979) have shown that forceful hand exertions with deviated wrists may be a factor in the development of carpal tunnel syndrome.

The position of the work surface relative to the operator's eyes required the operator to look downward through most of the work cycle. This may have been the reason that the operator worked with a noticeably flexed neck for 77.4 percent of the cycle. It is possible that continuous neck flexion could lead to fatigue and/or discomfort in the upper back, neck, and shoulders.

In addition to hand controls, there were three foot controls for activating steam release, drawing a vacuum on the press saddle, and lowering the press head. Operation of these controls were not studied during the EMG analyses.

Suggestions for Job Redesign - Presser

The following changes in the design of the operation would reduce the ergonomic stresses of the pressing job:



Current Design Proposed Design

Figure 3: Horizontal orientation of press saddle forces operator to extend wrist while smoothing fabric (current design). Slanted saddle in the proposed design would allow operator to perform the smoothing task with a neutral wrist.

1. *Develop an alternative method for lowering the press head.* The high frequency and duration of shoulder flexion for the left arm is due to the requirement to reach for the handle and steam controls on the press head. This stress could be reduced by developing an automatic mechanism for lowering the press head. Naturally, this mechanism would have to be guarded (e.g., a two-handled trip mechanism located on the bench below the press saddle) to prevent either of the hands from being accidently caught in the press.
2. *Slant the surface of the press saddle.* By slanting the surface of the press saddle away from the operator (see Figure 3), many of the wrist extension problems discussed above could be alleviated. A potential problem with slanting the saddle would be an increased tendency for material to slide off if it is not held. This problem could be prevented by drawing a slight vacuum on the press saddle at all times.
3. *Lower the height of the clothing rack for finished garments.* This would reduce the extended reach and shoulder flexion while hanging the garment.
4. *Provide a high stool to allow press operators to alternate between standing and sitting.* This change would reduce the load on the operators' legs, and may be helpful in the prevention of back pain.

Results - Cutter

Films were taken of one subject (male, 164 cm, 75 kg) performing the cutting operation at the eastern Massachusetts shop. The tasks analyzed during the EMG analysis were similar to cutting tasks performed by other study subjects. An anthropologic summary of the subject was presented earlier in Table VIII.

The cutting operation was performed on a flat table located at a height of 99 cm above the floor. Typically, several centimeters of cloth material would be spread onto this surface; a thickness of approximately 12 cm was being cut at the time of the analysis, bringing the working height to 111 cm.

The cutting machine was a Maimin Powertron, a device that operates much like a jig saw. A cylindrically-shaped handle (used to hold and guide the tool while cutting) was located 124 cm above the floor, and oriented horizontally.

To prepare for the EMG analyses, the right hand was calibrated in two power grip positions that are used to hold the handle of the cutting tool. The left hand was calibrated in two different finger press positions that are used to "hold down" material to ensure a clean, even cut. The first position involved no humeral rotation at the shoulder, the second position involved humeral rotation of about 90 degrees.

The cutting job was not a perfectly repetitive task because patterns changed as a function of garment design and size; and resistance to the cutting blade changed as a function of the number of layers being cut, and the characteristic of the material being cut. Because of the long cycle time required to cut a complete garment (usually over an hour) four "typical" cutting tasks were selected for EMG analysis:

Task #1 – *Straight Cut* – This cut was performed parallel to the frontal plane, from the operator's right to left.

Task #2 -- *Curved Cut* -- This cut consisted of a counterclockwise arc and was performed in front of the operator (more or less in the sagittal plane).

Task #3 -- *Trimming and Notching* -- This task consisted of short duration cuts to form a pattern in the edge of the fabric.

Task #4 -- *S-Shaped Cut* -- This curved cut was performed in the sagittal plane, moving away from the operator.

For all of the cuts, filming was done at four frames per second. Tasks 1,3, and 4 were analyzed every fourth frame, task 2 was analyzed every second frame.

Detailed results of the biomechanical and EMG analyses are presented in Appendix C. Tables C-I through C-IV give a detailed time-based activity charting of the left and right hands for each of the four tasks. Figures C-1 through C-32 present a time chart of the positions of the shoulders, elbows, wrists and hands during the studied tasks.

Table X summarizes the position of upper extremity limbs and joints (in terms of the percentage of total task time spent in a particular posture) for the straight cut (task #1). Tables XI through XIII provide similar summary information for tasks 2,3, and 4. The information contained in these tables, along with the time graphs in the Appendix have led to the following observations for the cutter job.

An analysis of wrist position showed that the operator's right wrist was held in ulnar deviation during a major fraction of the work cycle while performing three of the cutting tasks (task #1 caused ulnar deviation 78.9 percent of the cycle time, task #2 required 54.9 percent ulnar deviation, and task #3 required 58.3 percent ulnar deviation). On task #1 (the straight cut), high gripping forces (sometimes exceeding the maximum calibration level of 4 kg) were exerted while the wrist was held in ulnar deviation.

An analysis of the workplace layout and tool design suggests that the ulnar deviations resulted from the use of a horizontal handle on the cutting machine that was positioned 124 cm above the floor. The height of the handle dictated that it be held with the forearm in a (nominally) horizontal altitude. With the forearm in this position, it was necessary for the operator to bend the wrist (in the ulnar direction) to grip the horizontal handle (see Figure 4).

Sustained ulnar deviation is a cause for concern because it may lead to tendonitis in the wrist. Tichauer (1978) has shown that repeated ulnar deviations may lead to deQuervain's disease.

It is interesting to note that ulnar deviation was reduced to 16.7 percent on task #4. An analysis of the film suggests that this was accomplished by simultaneously pronating the forearm and extending the wrist. This technique is not without problems; the risk of developing carpal tunnel syndrome may increase with wrist extension. Fortunately, the grip forces used to hold the handle were light (approximately 1-2 kg.) throughout most of the cut.

A less serious problem than ulnar deviation was that of shoulder flexion. On cutting tasks #1 and #2, the left shoulder was held in a neutral position 84.2 and 93.6 percent of the time, respectively. On the same tasks, however, the right shoulder was in flexion 73.7 and 96.8 percent of the time. Both of these tasks were performed at the near (to the operator) edge of the cutting table. The difference in flexion angles was caused by the difference in working heights of the two hands. The left hand was holding down material at a height of 111 cm

TABLE X.

UPPER EXTREMITY POSTURES

CUTTER
Straight Cut - Frontal Plane - Right to Left
Total time: 19.0 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 36.8	Lat 0.0	Flx 10.5	Sup 0.0	Rad 0.0	Ext 0.0	HG 100.0
45 0.0	Neu 31.6	Neu 21.1	90 47.4	Neu 47.4	Neu 21.1	45E 36.8	
90 47.4	45 31.6	45 57.9	45 10.5	Pro 52.6	Uln 78.9	Neu 63.2	
135 26.3	Abd 0.0	Med 21.1	Ext 31.6	Oth 0.0	Oth 0.0	45F 0.0	
Neu 26.3	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 0.0	
Oth 0.0							

LEFT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 31.6	Flx 0.0	Sup 5.3	Rad 21.0	Ext 0.0	FPM 15.8
45 0.0	Neu 100.0	Neu 63.2	90 36.8	Neu 5.3	Neu 5.3	45E 10.5	FPN 10.5
90 5.3	45 0.0	45 5.2	45 63.2	Pro 26.3	Uln 5.3	Neu 21.1	Oth 73.7
135 10.5	Abd 0.0	Med 0.0	Ext 0.0	Oth 63.1	Oth 68.4	45F 0.0	
Neu 84.2	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 68.4	
Oth 0.0							

TABLE XI.

UPPER EXTREMITY POSTURES

CUTTER
Curved Cut - Sagittal Plane - Counterclockwise
Total time: 15.5 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 0.0	Flx 48.4	Sup 0.0	Rad 0.0	Ext 0.0	HG 100.0
45 0.0	Neu 12.9	Neu 0.0	90 32.3	Neu 45.2	Neu 41.9	45E 45.2	
90 22.6	45 74.2	45 45.2	45 6.4	Pro 54.8	Uln 54.9	Neu 54.2	
135 74.2	Abd 12.9	Med 54.8	Ext 12.9	Oth 0.0	Oth 3.2	45F 0.0	
Neu 3.2	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 0.0	
Oth 0.0							

LEFT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 0.0	Flx 0.0	Sup 9.7	Rad 54.9	Ext 0.0	FPM 6.5
45 0.0	Neu 100.0	Neu 87.1	90 90.3	Neu 3.2	Neu 12.9	45E 67.7	FPN 67.7
90 0.0	45 0.0	45 9.7	45 6.5	Pro 77.4	Uln 3.2	Neu 3.2	Oth 25.8
135 6.4	Abd 0.0	Med 3.2	Ext 3.2	Oth 9.7	Oth 29.0	45F 0.0	
Neu 93.6	Oth 0.0	Oth 0.0	Oth 0.0			Flx 6.5	
Ext 0.0						Oth 22.6	
Oth 0.0							

TABLE XII.

UPPER EXTREMITY POSTURES

CUTTER
Trimming and Notching
Total time: 36.0 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 0.0	Flx 22.2	Sup 0.0	Rad 2.8	Ext 5.6	HG 100.0
45 0.0	Neu 41.7	Neu 30.6	90 77.8	Neu 11.1	Neu 30.8	45E 44.4	
90 11.1	45 58.3	45 58.3	45 0.0	Pro 88.9	Uln 58.3	Neu 44.4	
135 27.8	Abd 0.0	Med 8.3	Ext 0.0	Oth 0.0	Oth 8.3	45F 0.0	
Neu 61.1	Oth 0.0	Oth 2.8	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 5.6	
Oth 0.0							

LEFT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 2.8	Flx 2.8	Sup 2.8	Rad 16.7	Ext 0.0	FPM 8.3
45 0.0	Neu 83.3	Neu 55.6	90 25.0	Neu 2.8	Neu 41.7	45E 22.2	FPN 44.5
90 8.3	45 16.7	45 5.5	45 13.9	Pro 80.5	Uln 5.5	Neu 44.4	Oth 47.2
135 44.5	Abd 0.0	Med 36.1	Ext 58.3	Oth 13.9	Oth 36.1	45F 5.6	
Neu 47.2	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 2.8	
Oth 0.0							

TABLE XIII.

UPPER EXTREMITY POSTURES

CUTTER
S-Shaped Cut - Sagittal Plane
Total time: 24.0 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 37.5	Lat 0.0	Flx 0.0	Sup 0.0	Rad 0.0	Ext 0.0	HG 100.0
45 0.0	Neu 62.5	Neu 8.3	90 54.2	Neu 20.8	Neu 79.2	45E 75.0	Oth 0.0
90 54.2	45 0.0	45 16.7	45 20.8	Pro 79.2	Uln 16.7	Neu 20.9	
135 20.8	Abd 0.0	Med 75.0	Ext 25.0	Oth 0.0	Oth 4.1	45F 0.0	
Neu 25.0	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 4.2	
Oth 0.0							

LEFT

SHOULDER			ELBOW		WRIST		HAND
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position
Flx 0.0	Add 0.0	Lat 0.0	Flx 0.0	Sup 0.0	Rad 12.5	Ext 0.0	FPM 12.5
45 0.0	Neu 83.3	Neu 54.2	90 33.3	Neu 0.0	Neu 66.7	45E 37.5	FPN 87.5
90 37.5	45 16.7	45 8.3	45 8.3	Pro 100.0	Uln 4.1	Neu 25.0	Oth 0.0
135 50.0	Abd 0.0	Med 37.5	Ext 58.4	Oth 0.0	Oth 16.7	45F 0.0	
Neu 12.5	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0	
Ext 0.0						Oth 33.3	
Oth 0.0							

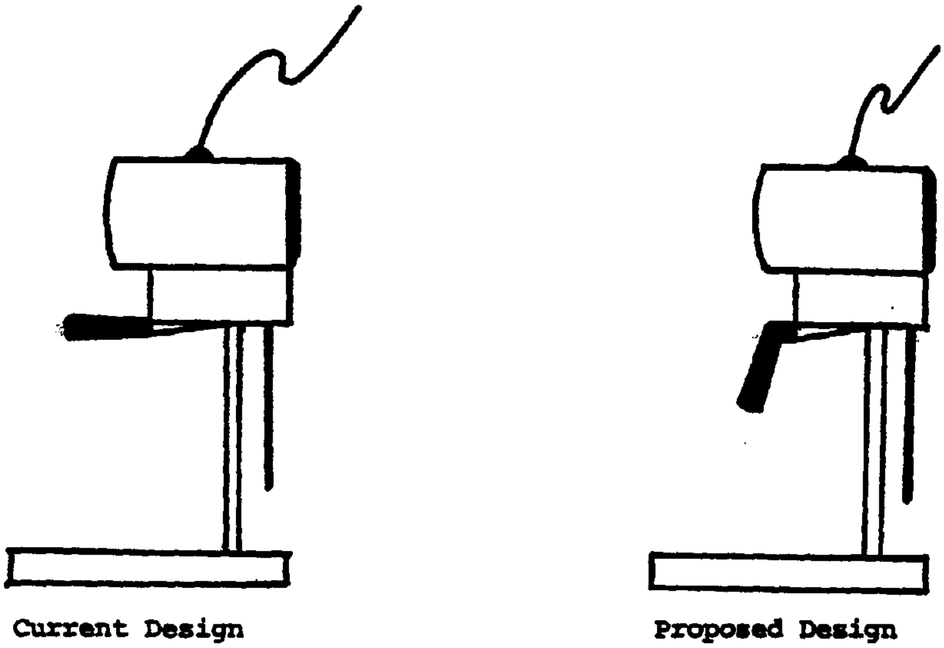


Figure 4: Horizontal orientation of cutting tool handle causes ulnar deviation of the wrist. Near-vertical handle in the proposed design would allow operation of tool with neutral wrist.

while the right hand was gripping the handle at 124 cm. Differences in shoulder flexion for the right and left arms were less on tasks #3 and #4. This was due to the fact that these tasks were performed toward the center of the table with both arms extended.

Back and neck angles were not studied for the cutter. Because this job was performed while standing and walking, it was usually possible for the operator to move to locations where back and neck angles could be held in their neutral positions.

Suggestions for Job Redesign - Cutter

The following changes in the design of the operation would reduce ergonomic stresses on the cutting job:

1. *Reorient the handle of the cutting machine.* The handle used to guide the cutting machine should be changed from a horizontal orientation to a vertical or near-vertical orientation as shown in Figure 4. This would allow the machine to be held with the wrist in a neutral posture. An alternative to this suggestion would be to design the handle to be fully adjustable. This would allow the operator to change the handle orientation for different types of cuts.
2. *Use a cutting table of adjustable height.* Cutting is an activity that is always performed while standing; therefore, the operator's stature will determine the position of his/her shoulders, elbows, and hands. A short operator may be forced to continuously flex and abduct the shoulders if the table is too high. On the other hand, a tall operator may be required to continuously flex the trunk while bending to reach a table that is too low. In either case, muscle fatigue may result, and the potential for more serious disorders is increased.

Results - Stitchers

EMG analyses were performed on two stitching jobs at the eastern Massachusetts shop. The first analysis was performed on the body stitcher. This employee assembled the major body panels of a woman's blazer by sewing long, straight seams. This position will be called the "straight stitcher" in the discussions which follow. The second analysis was performed on the collar setter. This employee attached the collar section to the body of a woman's blazer. This job differed from the straight stitcher because the seam followed a curve, and the two parts required precise alignment during the stitch.

Straight Stitcher

Films were taken of one subject (female, 160 cm, 63 kg.) performing the basic body stitching on a woman's blazer. An anthropologic summary of the subject was presented earlier in Table VIII. Although the tasks analyzed were not identical to body stitching tasks in other study shops, the motion patterns and work posture were quite similar to those observed in other locations.

The sewing machine used in the analysis was a Mitsubishi Model No. DB-189. The height of the work table was 75 cm, and the subject was seated in a cushioned chair with a seat height of 51 cm.

The calibration sequence was designed to simulate hand postures used while pushing and guiding fabric through the machine. The right hand was calibrated in two postures; a finger press and a pulp pinch. The left hand calibration sequence was a mirror image of the right hand.

Two sequences were selected for EMG analysis. The first sequence, typical of the motions required for stitching a straight body seam, lasted 35 seconds and was filmed at two frames per second. The second sequence (also filmed at two frames per second) lasted 20 seconds. In this sequence the operator sewed a ribbon along a straight seam. Although the selected sequences did not describe a complete cycle (which lasted approximately 4 minutes), they were representative of the hand activities required to perform this job.

Detailed results of the biomechanical and EMG analyses are presented in Appendix D. Tables D-1 and D-2 present a detailed time-based activity charting of the left and right hands for each of the two sequences. Figures D-1 through D-18 present a time chart of the positions of the shoulders, elbows, wrists, hands, neck, and back.

Table XIV summarizes the position of upper extremity limbs and joints (in terms of the percentage of total sequence time spent in a particular posture) for the body-seam stitching sequence. Table XV provides similar summary information for the ribbon stitch. The information contained in these tables, along with the time graphs in Appendix D have led to the following observations for this job.

Workstation layout and work practices allowed the joints and limbs at the shoulders and elbows to be held in neutral or near-neutral postures throughout most of the duration of both stitching sequences. The height of the sewing table relative to the height of the operator's shoulders allowed the upper arms to be held in a neutral or slightly-flexed position. This also permitted the operator to maintain the elbows in a comfortably flexed posture. Both of the sequences involved stitching basically straight seams, therefore it was possible for the operator to guide the fabric through the machine by simply moving both hands forward in the sagittal plane. This was not done by flexing the shoulders; instead, the operator slowly leaned forward by flexing the trunk in a smooth, fluid-like motion (Tables XIV and XV show that the back was flexed 73.2 percent of the time for the body seam stitch and 67.5 percent of the time for the ribbon stitch).

The above practice reduced the need to repeatedly flex the shoulders. It also increased the speed and accuracy of the stitching task by reducing body movements to a simple trunk flexion. A potential problem with this practice was that it may have been a contributing factor to the high prevalence of back complaints among the stitchers as reported in the previous section.

There were no major differences in wrist positions and hand forces between the two sequences studied; however, stresses differed considerably between the left and right side. The right wrist was held in slightly extended (45E), neutral, and slightly flexed (45F) positions for approximately equal periods of time during the

TABLE XIV.

UPPER EXTREMITY POSTURES

STRAIGHT STITCHER
Body Stitch
Total time: 35.5 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND	BODY	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	Neck	Back
Flx 0.0	Add 0.0	Lat 0.0	Flx 43.7	Sup 0.0	Rad 9.9	Ext 1.4	PP 26.8	Neu 73.2	Neu 26.8
45 0.0	Neu 93.0	Neu 74.7	90 54.9	Neu 9.9	Neu 69.0	45E 39.4	FP 59.1	30 25.4	Flx 73.2
90 0.0	45 5.6	45 19.7	45 1.4	Pro 90.1	Uln 19.7	Neu 31.0	Oth 14.1	60 1.4	
135 38.0	Abd 1.4	Med 5.6	Ext 0.0	Oth 0.0	Oth 1.4	45F 25.4			
Neu 59.2	Oth 0.0	Oth 0.0	Oth 0.0			Flx 2.8			
Ext 2.8						Oth 0.0			
Oth 0.0									

LEFT

SHOULDER			ELBOW		WRIST		HAND	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	
Flx 0.0	Add 32.4	Lat 0.0	Flx 42.3	Sup 1.4	Rad 23.9	Ext 12.7	PP 28.2	
45 0.0	Neu 54.9	Neu 7.0	90 35.2	Neu 18.3	Neu 43.7	45E 39.5	FP 47.9	
90 16.9	45 11.3	45 26.8	45 8.4	Pro 69.0	Uln 14.1	Neu 23.9	Oth 23.9	
135 49.3	Abd 0.0	Med 64.8	Ext 12.7	Oth 11.3	Oth 18.3	45F 4.2		
Neu 31.0	Oth 1.4	Oth 1.4	Oth 1.4			Flx 1.4		
Ext 0.0						Oth 18.3		
Oth 2.8								

TABLE XV.

UPPER EXTREMITY POSTURES

STRAIGHT STITCHER
Ribbon Stitch
Total time: 20.0 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND	BODY	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	Neck	Back
Flx 0.0	Add 0.0	Lat 5.0	Flx 27.5	Sup 2.5	Rad 0.0	Ext 2.5	PP 90.0	Neu 85.0	Neu 2.5
45 0.0	Neu 35.0	Neu 60.0	90 72.5	Neu 37.5	Neu 47.5	45E 37.5	FP 7.5	30 15.0	Flx 97.5
90 0.0	45 47.5	45 32.5	45 0.0	Pro 60.0	Uln 52.5	Neu 37.5	Oth 2.5	60 0.0	
135 65.0	Abd 17.5	Med 2.5	Ext 0.0	Oth 0.0	Oth 0.0	45F 22.5			
Neu 35.0	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0			
Ext 0.0						Oth 0.0			
Oth 0.0									

LEFT

SHOULDER			ELBOW		WRIST		HAND	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	
Flx 0.0	Add 27.5	Lat 0.0	Flx 7.5	Sup 0.0	Rad 17.5	Ext 7.5	PP 20.0	
45 0.0	Neu 67.5	Neu 2.5	90 65.0	Neu 15.0	Neu 45.0	45E 65.0	FP 77.5	
90 20.0	45 5.0	45 15.0	45 25.0	Pro 85.0	Uln 17.5	Neu 12.5	Oth 2.5	
135 70.0	Abd 0.0	Med 82.5	Ext 2.5	Oth 0.0	Oth 20.0	45F 7.5		
Neu 10.0	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0		
Ext 0.0						Oth 7.5		
Oth 0.0								

two sequences. Wrist deviation differed slightly between the two sequences. For the body seam stitch, the right wrist was neutral 69 percent of the time, in ulnar deviation 19.7 percent of the time, and in radial deviation 9.7 percent of the time. For the ribbon stitch the right hand spent approximately equal amounts of time in ulnar deviation or in the neutral position. For both sequences, forces exerted by the right hand were quite low, often below the minimum calibration level of 1.1 kg.

For this job, the left hand and wrist were more highly stressed than the right. Both sequences required that the left wrist be held in an extended position for more than 50 percent of the work cycle. Radial deviations were more common on the left arm than the right. Combining the observations from both sequences, radial deviation occured about 20 percent of the work cycle, while ulnar deviations occured about 15 percent of the cycle. Hand forces were higher on the left side. For the body seam stitch, forces of approximately 2 kg. were exerted as the hand alternated between a finger press and a pulp pinch. For the ribbon stitch hand forces were considerably higher (exceeding the maximum calibration level of 4 kg. on several occasions). The most forceful exertions during this sequence were finger presses exerted with an extended wrist. Such exertions would certainly be possible contributing factors to the development of repetitive motion disorders among workers assigned to this job.

Collar Setter

Films were taken of one subject (female, 163 cm, 61 kg) setting collars on womens' blazers at the eastern Massachusetts shop. An anthropologic summary of the subject was presented earlier in Table VIII. This job was similar (but certainly not identical) to many of the complex stitching jobs (e.g., sleeve setting, pocket setting, top stitching) that were observed in all eight shops. (In this context, the adjective "complex" refers to seams that follow curves on angles instead of straight lines, and where precise alignment of the fabric panels is required

The sewing machine used on the job analyzed was a Pfaff Model No. 418475. The height of the sewing table was 76 cm, and the operator was seated on a cushioned chair with a height of 46 cm.

The calibration sequence was designed to simulate hand postures used while pushing and guiding fabric through the machine. Four postures were calibrated, identical to the ones used to calibrate the straight stitcher.

Two sequences were selected for EMG analysis. In the first sequence, which lasted about 60 seconds, the operator sewed a long, curved, preparatory stitch into the body of the blazer. This sequence was filmed at two frames per second, but analyzed at one frame per second because postural changes were infrequent throughout the task. In the second sequence, which lasted about 50 seconds, the operator mated the collar to the blazer body. This sequence was analyzed at two frames per second. Due to the long cycle time required to complete the collar setting process (approximately four minutes), other aspects of this job were not analyzed.

Detailed results of the biomechanical and EMG analyses are presented in Appendix E. Tables E-1 and E-2 present a detailed time-based activity chart of the left and right hands for each of the two sequences. Figures E-1 through E-18 present a time chart of the positions of the shoulders, elbows, wrists, hands, neck, and back.

Table XVI summarizes the position of upper extremity limbs and joints (in terms of the percentage of the total sequence time spent in a particular posture) for the preparatory stitch sequence. Table XVII provides similar summary information for the collar setting stitch sequence. The information contained in these tables, along with the time graphs in Appendix E have led to the following observations for this job.

Substantial differences in ergonomic stresses were found between the two stitching jobs. As discussed above, the straight stitcher did not have to forcefully align fabric while guiding it through the machine. This allowed her to use fluid and continuous motions while performing her job. On the other hand, the collar stitcher had to precisely match collars to blazer bodies and then carefully guide the mated units through her machine. Instead of using the sewing machine to create long, straight runs, the collar setter had to alternate between operating the machine for a short run and stopping the machine while aligning the next section of the seam. During the alignment sub-task, it was necessary to change the relative position of the shoulders, elbows, wrists, and hands in order to pivot the fabric about the needle of the machine.

In order to have more degrees of freedom to execute the pivot, the operator lifted her elbows from the sewing table. In lifting the elbows, it was necessary to flex her shoulders away from the neutral position. Shoulder flexion angles (particularly for the right arm) were considerably more pronounced in the collar setter than in the straight stitcher.

The left and right elbows were held in comfortably flexed positions throughout both stitching sequences. The forearms were pronated for most of the cycle time in both sequences.

Several data points describing the wrist position were lost when the operator's hands were either covered by the fabric or obscured by the body (these conditions occurred in about 25 percent of the film frames examined for the left hand and in about 40 percent of the frames examined for the right hand; see Table XVII). During the preparatory stitch the left wrist alternated between a neutral position and a radial deviation, while the right wrist alternated between a neutral position and an ulnar deviation. Both wrists were periodically flexed, extended, or neutral. During the collar setting stitch both wrists alternated between a neutral position and a radial deviation, with an occasional ulnar deviation. Similar to the preparatory stitch, the wrist was periodically flexed, extended, or neutral during the collar setting stitch.

Table XVII only partially describes the wrist stresses associated with the collar setting job. Referring to Figures E-1 through E-18 in Appendix E, it is immediately seen that the changes in posture occur very frequently (these changes are necessary to pivot the fabric around the needle, as discussed above).

In general, the forces exerted by the right hand were low (less than the minimum calibration level of 1.1 kg.) throughout the preparatory stitch sequence. Occasionally, these forces reached as high as 2 kg. (A few readings of the EMG monitor indicated that hand forces exceeded the maximum calibration level of 4 kg.; however, these readings were believed to be spurious.) Throughout

TABLE XVI.

UPPER EXTREMITY POSTURES

COLLAR STITCHER

Preparatory Stitch
Total time: 60.5 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND	BODY	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	Neck	Back
Flx 0.0	Add 0.8	Lat 3.3	Flx 49.6	Sup 0.8	Rad 2.5	Ext 1.7	PP 24.0	Neu 2.5	Neu 21.5
45 0.0	Neu 14.1	Neu 21.5	90 48.8	Neu 12.4	Neu 32.2	45E 37.2	FP 59.5	30 13.2	Flx 78.5
90 66.1	45 84.3	45 10.7	45 1.6	Pro 83.5	Uln 26.5	Neu 19.0	Oth 16.5	60 84.3	
135 18.2	Abd 0.8	Med 64.5	Ext 0.0	Oth 3.3	Oth 38.8	45F 10.7			
Neu 15.7	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0			
Ext 0.0						Oth 31.4			
Oth 0.0									

LEFT

SHOULDER			ELBOW		WRIST		HAND	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	
Flx 0.0	Add 1.7	Lat 0.8	Flx 29.7	Sup 0.0	Rad 26.4	Ext 1.7	PP 32.2	
45 1.7	Neu 34.3	Neu 8.3	90 62.0	Neu 8.3	Neu 40.5	45E 47.9	FP 52.9	
90 22.3	45 62.3	45 24.0	45 4.9	Pro 87.6	Uln 5.8	Neu 18.2	Oth 14.9	
135 59.5	Abd 0.0	Med 65.2	Ext 1.7	Oth 4.1	Oth 27.3	45F 19.0		
Neu 14.8	Oth 1.7	Oth 1.7	Oth 1.7			Flx 0.8		
Ext 0.0						Oth 12.4		
Oth 1.7								

TABLE XVII.

UPPER EXTREMITY POSTURES

COLLAR STITCHER
Setting Collar
Total time: 50.5 seconds

RIGHT

SHOULDER			ELBOW		WRIST		HAND	BODY	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	Neck	Back
Flx 0.0	Add 0.0	Lat 5.0	Flx 48.5	Sup 0.0	Rad 12.9	Ext 1.0	PP 5.0	Neu 2.0	Neu 7.0
45 0.0	Neu 1.0	Neu 2.0	90 49.5	Neu 4.0	Neu 38.6	45E 20.8	FP 86.1	30 0.0	Flx 93.0
90 89.1	45 98.0	45 16.8	45 2.0	Pro 64.4	Uln 2.0	Neu 16.8	Oth 8.9	60 98.0	
135 6.9	Abd 1.0	Med 76.2	Ext 0.0	Oth 31.6	Oth 46.5	45F 17.8			
Neu 4.0	Oth 0.0	Oth 0.0	Oth 0.0			Flx 0.0			
Ext 0.0						Oth 43.6			
Oth 0.0									

LEFT

SHOULDER			ELBOW		WRIST		HAND	
Extension Flexion	Adduction Abduction	Lateral Medial	Angle	Forearm Rotation	Deviation	Angle	Hand Position	
Flx 0.0	Add 1.0	Lat 0.0	Flx 17.0	Sup 0.0	Rad 26.0	Ext 4.0	PP 20.0	
45 0.0	Neu 44.0	Neu 4.0	90 76.0	Neu 11.0	Neu 44.0	45E 51.0	FP 59.0	
90 24.0	45 49.0	45 6.0	45 0.0	Pro 72.0	Uln 5.0	Neu 12.0	Oth 21.0	
135 69.0	Abd 0.0	Med 84.0	Ext 0.0	Oth 17.0	Oth 25.0	45F 4.0		
Neu 1.0	Oth 6.0	Oth 6.0	Oth 7.0			Flx 1.0		
Ext 0.0						Oth 28.0		
Oth 6.0								

the sequence, the right hand was in a finger press position (59.5 percent of the non-obscured frames) or in a pulp pinch position (24.0 percent of the non-obscured frames). Forces exerted by the left hand were considerably more variable than the forces exerted by the right hand (see Figures E-5 and E-9). Although most of the EMG readings were below the minimum calibration level of 1.1 kg., sporadic readings up to and exceeding 4 kg. were recorded. These high exertions usually occurred with the hands in the pulp pinch position, and probably occurred during precise fabric alignment.

During the collar setting sequence, forces exerted by the right hand were greater than during the preparatory stitch sequence. Finger press forces of approximately 2 kg. were exerted about 50 percent of the sequence. The balance of the sequence was at or below the minimum calibration level of 1.1 kg. (A few spurious readings exceeding 4 kg. were again ignored). At the very beginning of the sequence (seconds 1-10) and midway through the sequence (seconds 32-36), left hand forces ranged between 2.5 and 4 kg. with the hand in the pulp pinch position. Forces in the left hand decreased to much lower levels (less than 1.1 kg.) when the hand position changed to a finger press.

During both sequences, the operator flexed her neck throughout the work cycle to have a better view of the needle on her sewing machine (In Tables XVI and XVII, the designation "60" under the NECK heading means that the neck was fully flexed). Although most of the operators did not flex their necks to the same degree as the subject studied, prolonged neck flexion was common among collar setters and other "complex" stitchers. Moderate back flexion was also quite common in the "complex" stitching jobs.

Recommendations - Stitchers

The following changes are suggested to reduce the ergonomic stresses on the stitching jobs:

1. *Reduce the coefficient of friction between the fabric being sewn and the working surface of the machine*. Many of the high hand forces discussed above are associated with the activity of pushing fabric through the sewing machine. These forces could be reduced if the resistance to fabric movement was decreased. Several operators commented that certain fabrics tended to "stick" to the metal base plate (located below the machine needle) and that this occurance increased the level of difficulty of the sewing task. New materials and/or treatments for the base plate may reduce resistance to fabric movement, lowering the forces required to perform the job.
2. *Slant the sewing surface*. The high prevalence of back complaints among stitchers may be due to prolonged flexion of the neck and back. It may be possible to reduce the tendency to lean forward by slanting the sewing table in a manner similar to a drafting table. Changes would also have to be implemented to the design and height of the sewing chair to ensure that the resulting changes in shoulder and hand postures are not deleterious.
3. *Rotate workers among different stitching jobs*. Rotation of worker's among straight stitching and complex stitching would reduce the amount of exposure to the most strenuous stitching tasks. The principal problem with job rotation would be the reduction in productivity associated with the need to

learn several different stitches. Because most of the garment industry operates on a piece-rate system, any reduction in productivity would be challenged by both managers and employees.

SUMMARY

The purpose of this study was to determine the prevalence of repetitive trauma disorders among garment workers, and to identify sources of ergonomic stress which could be causing these disorders to occur.

A survey of 397 garment workers was conducted to determine the prevalence of pain in selected joints and limbs. This survey found that approximately 25 percent of the study population suffered persistent musculoskeletal pain in at least one part of the body. The hand was the most frequently reported location for pain, followed by the neck and back.

Detailed biomechanical analyses were performed on four common garment industry jobs. The purpose of these analyses was to identify equipment and/or work practices which could be causing the high rates of reported pain. Specific recommendations were developed for changes in equipment and practices on the studied jobs.

Although the pain disorders reported in the employee survey were not disabling, it was concluded that repetitive trauma problems are quite common in the garment industry. Changes in equipment and work practices (such as the ones suggested in this report) should be developed and evaluated. If found to be successful, the modifications should be implemented on a large scale.

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July 29, 1982

Dan Habes
NIOSH
Physiology and Ergonomics Branch
Robert A. Taft Center
Room 417
4676 Columbia Parkway
Cincinnati, OH 45226

Dear Dan:

Enclosed are copies of my slides presented during my AIHC paper on the Garment Workers Study. I have also enclosed a set of brief captions for the slides.

I hope that you find these materials satisfactory. If you have any questions please call me.

Sincerely,

Monroe

W. Monroe Keyserling, Ph.D.
Assistant Professor of
Occupational Safety

WMK:AH
Encl.

SLIDE 1: No comments.

SLIDE 2: No comments.

SLIDE 3: Shops with "C" code are located in Worcester, Ma while shop with "E" code is located in Lynn, MA. The Lynn shop is considerably newer than the Worcester shops and features a much better general work environment (better lighting, air conditioning). In addition, the Lynn subjects were significantly younger and had less experience in the garment industry than the Worcester workers.

For many of the analyses below, data from the Worcester shops were pooled.

SLIDE 4: Stitcher, presser, and floor help were the only job titles where the sample sizes were sufficiently large at both Worcester and Lynn to perform Chi-Square analyses of the prevalence of musculoskeletal complaints.

SLIDE 5: No comments.

SLIDE 6: This slide presents the results of a preliminary analysis of the cutter job. Although the sample size of the cutter was too small to justify statistical analyses, the rate of musculoskeletal complaints made this an interesting job for detailed biomechanical and EMG analyses. The results of the detailed final analyses will be included in the final report.

SLIDE 7: This slide presents the preliminary analysis of the floor help job. Because this job did not appear to have localized musculoskeletal stresses it was not selected for follow-up analyses.

SLIDE 8: Two stitching tasks were selected for EMG analysis (straight seam stitching, collar setting stitching). The results of these analyses will appear in the final report.

SLIDE 9: The presser job was selected for EMG analyses and will be presented in the final report.

SLIDE 10: This slide presents the prevalence of musculoskeletal complaints at Worcester and Lynn for six body parts. It should be noted that the prevalence of complaints at Lynn was considerably lower than at Worcester. Furthermore, the back and the hand are the most frequently reported areas of pain.

SLIDE 11: This slide presents the prevalence of musculoskeletal pain in the Worcester shops, broken down by job title and by body part. Stitchers were observed to have significantly higher rates of hand pain and hip pain than the other job titles.

SLIDE 12: This slide presents the prevalence of musculoskeletal pain in the Lynn shop, broken down by body part and job title. No significant differences were observed among the job titles.

SLIDE 13: Workers who reported pain at a general body location were asked to describe the specific location of their pain. This slide presents the results of the "follow-up" questions for the pressers. The numbers describe prevalence (in percent) of pain at specific locations.

SLIDE 14: This slide presents "follow-up" results for the stitchers. It is interesting to note that knee and hip complaints were more prevalent on the right side than on the left. This observation may result from the fact that stitchers operate a pedal with the right knee.

SLIDE 15 These recommendations may be revised depending on the outcome of the EMG study.

SLIDE 16: See comment for slide 14.

SLIDE 17: Workers in the Lynn shop were given a battery of "objective" tests that are sometimes used to diagnose specific hand/wrist disorders. The purpose of these tests was to evaluate the relationship between presence of subjective pain and positive findings on the objective tests. The results of this experiment are given in the final two slides.

SLIDE 18: No comments.

SLIDE 19: No comments.

QUESTIONS ADDRESSED

1. What is the prevalence of musculoskeletal pain and disorders among workers in the garment industry?

2. What is the relationship between reported disorders and ergonomic stresses?

3. What is the relationship between subjective reports of pain and "objective" diagnostic tests?

②

STUDY PHASES

1. Gain access to cooperating garment shops.
2. Perform preliminary job analyses.
3. Survey employees in participating shops.
4. Use survey results to identify "problem" jobs.
5. Perform detailed analysis of "problem" jobs.
6. Recommend changes in equipment, tools, work methods, etc.

PARTICIPATION IN STUDY

N = 397

SHOP	MALES	FEMALES	AGE	EXPERIENCE (YRS)
C1	9	52	47±12	14±14
C2	1	10	52±6	25±11
C3	0	15	51±9	19±15
C4	0	12	53±11	28±14
C5	1	28	49±10	18±11
C6	0	10	49±14	20±15
C7	7	45	46±13	16±15
E1	19	188	41±12	13±11

DISTRIBUTION OF STUDY POPULATION BY JOB TITLE

JOB TITLE	CENTRAL MASS.	EASTERN MASS.	TOTAL
STITCHER	125	141	266
PRESSER	17	10	27
FLOOR HELP	15	11	26
FINISHER	4	20	24
UNDERPRESSER	2	14	16
CUTTER	11	3	14
SHIPPER	2	1	3
OTHER	14	7	21

DISTRIBUTION OF JOB TITLES BY SEX OF WORKER

JOB TITLE	MALES	FEMALES
STITCHER	1	265
PRESSER	12	15
FLOOR HELP	1	25
FINISHER	1	23
UNDERPRESSER	6	10
CUTTER	11	3
SHIPPER	1	2
OTHER	4	17
TOTAL	37	360

CUTTER

POSTURE - Standing (100%)

UPPER LIMBS - Lift bolts of material
Spread material on cutting table
Use machine to cut patterns

- Wrist deviation
- Shoulder abduction

LOWER LIMBS - N.S.

LIFTING - Up to 80 lbs.

ENVIRONMENT - N.S.

5

FLOOR HELP

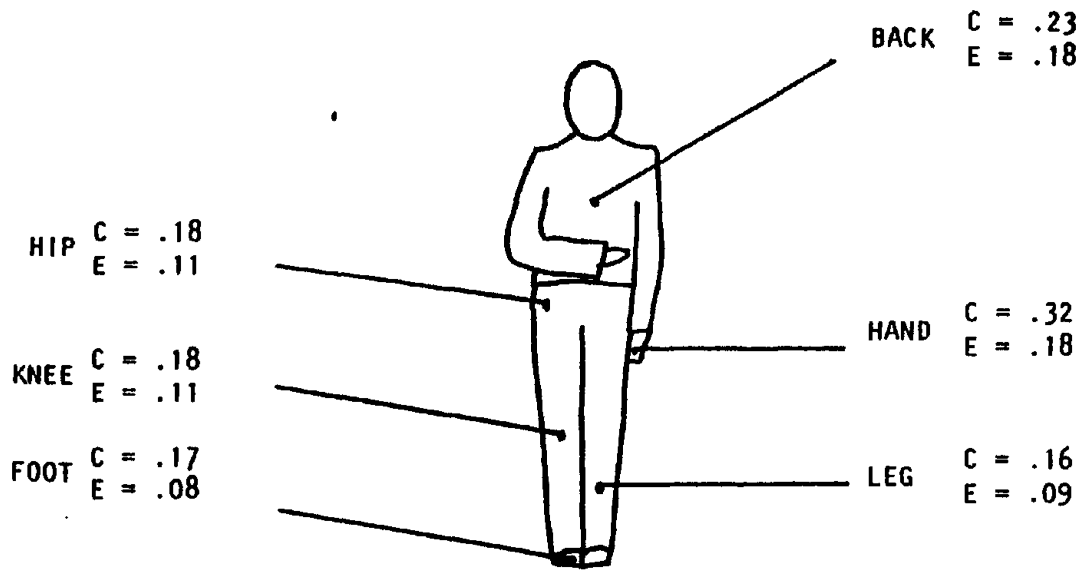
POSTURE	-	Standing (100%)
		-Walking, carrying
UPPER LIMBS	-	Lift, carry bundles of material
LOWER LIMBS	-	Walk
LIFTING	-	Up to 20 lbs.
ENVIRONMENT	-	N.S.

STITCHER

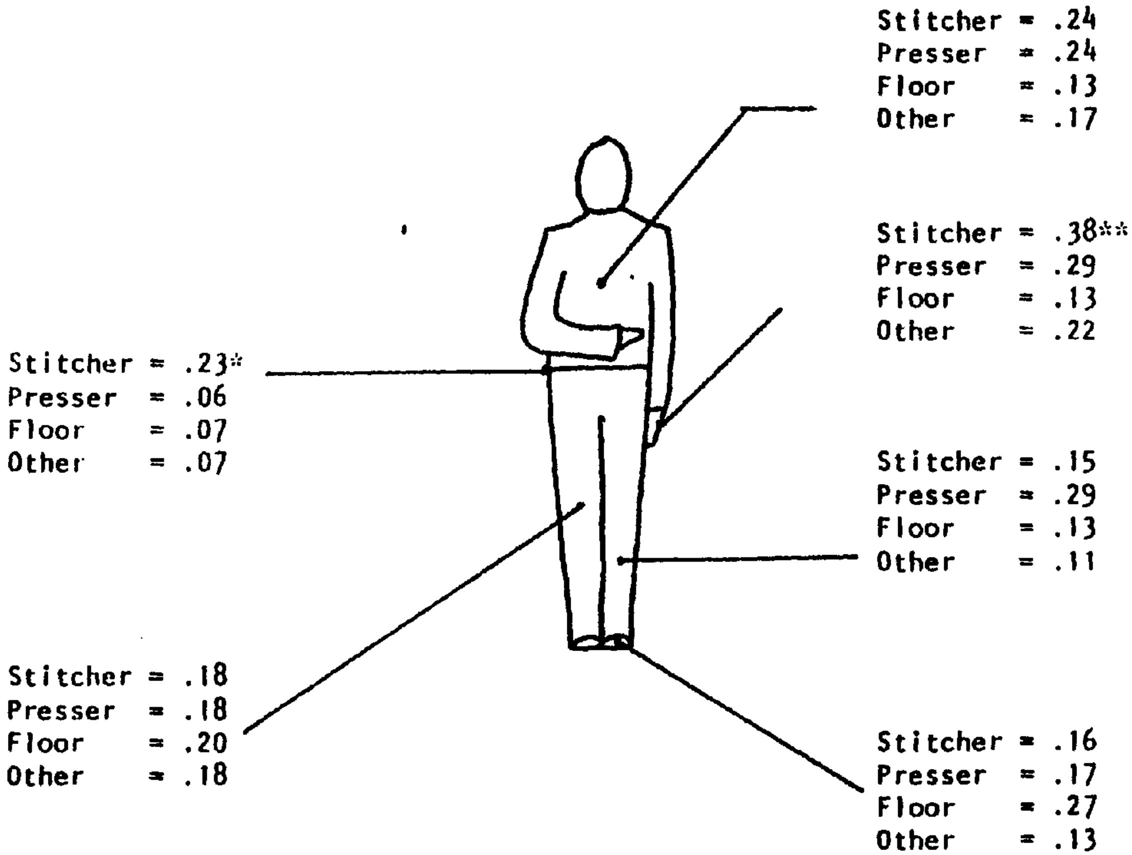
POSTURE	-	Seated (100%)
UPPER LIMBS	-	Operate sewing machine -Frequent finger presses -Frequent wrist deviations -Neck flexion
LOWER LIMBS	-	Operate knee pedal Operate foot pedal
LIFTING	-	N.S.
ENVIRONMENT	-	N.S.

PRESSER

POSTURE	-	Standing (100%)
UPPER LIMBS	-	Reach for garment (Shol. Abd.) Reach for buck (Shol. Abd.) Operate hand controls Hang garment (Shol. Abd.)
LOWER LIMBS	-	Operate foot pedals
LIFTING	-	N.S.
ENVIRONMENT	-	Hot and humid at times



PREVALENCE OF PAIN
BY LOCATION ON BODY
(C = CENTRAL MASS.
E = EASTERN MASS.)



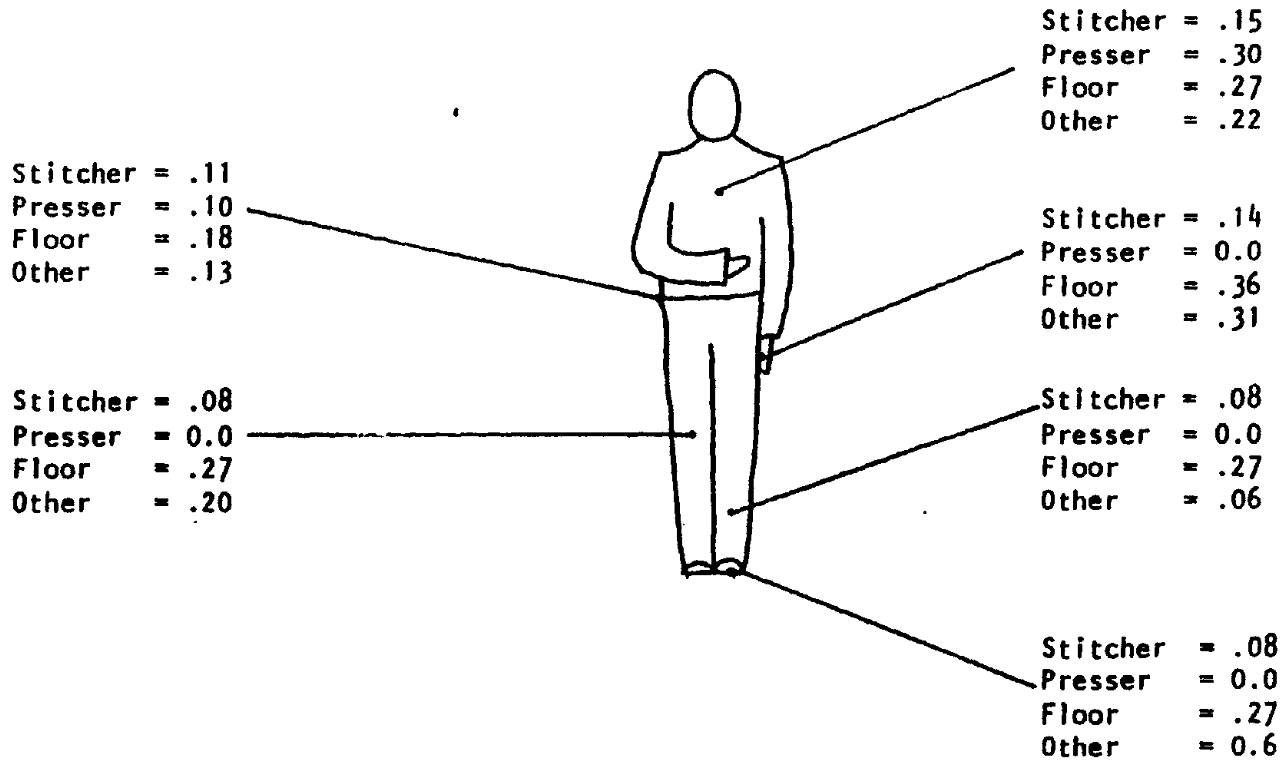
PREVALENCE OF PAIN BY JOB TITLE

CENTRAL MASS. SHOPS

(n = 190)

* $p < .05$

** $p < .10$



PREVALENCE OF PAIN BY JOB TITLE

EASTERN MASS. SHOP

(n = 207)

PRESSER FOLLOWUP

BACK PAIN (4 of 4)

Neck/Upper Back	- 50%	Current Pain - 50%
Shoulders	- 75%	
Middle Back	- 0%	
Lower Back	- 25%	

HIP PAIN (2 of 2)

Left Hip	- 50%	Current Pain - 100%
Right Hip	- 50%	

KNEE PAIN (2 of 3)

Left Knee	- 50%	Current Pain - 100%
Right Knee	- 50%	

HAND PAIN (5 of 5)

Left Hand	- 40%	Current Pain - 60%
Right Hand	- 80%	

STITCHER FOLLOWUP

BACK PAIN (21 of 50)

Neck/Upper Back	- 40%	Current Pain - 63%
Shoulders	- 58%	
Middle Back	- 6%	
Lower Back	- 25%	

HIP PAIN (15 of 29)

Left Hip	- 47%	Current Pain - 53%
Right Hip	- 67%	

KNEE PAIN (18 of 22)

Left Knee	- 28%	Current Pain - 60%
Right Knee	- 56%	

HAND PAIN (41 of 47)

Left Hand	- 82%	Current Pain - 61%
Right Hand	- 88%	

POSSIBLE DESIGN CHANGES -- STITCHER

1. Eliminate or redesign knee pedal.
2. Slant surface of sewing table to reduce neck flexion.
3. Rotate workers between straight-stitch tasks and complex-stitch tasks.

POSSIBLE DESIGN CHANGES -- PRESSER

1. Lower the height of clothing racks to reduce shoulder abduction angles when reaching for and replacing garments.

2. Install and/or use foot controls to raise and lower press.

3. Provide stool to eliminate continuous standing.

OBJECTIVE DIAGNOSTIC TESTS FOR HAND/WRIST DISORDERS

1. TINEL'S SIGN (CTS)
2. MODIFIED PHALEN'S TEST (CTS)
3. THUMB ROTATION TEST (DJD)
4. FINKELSTEIN'S TEST (DEQUERVAIN'S DISEASE)

VALIDITY OF PHALEN'S TEST AGAINST
REPORTS OF PERSISTENT PAIN

TEST RESULTS

		POS.	NEG.	TOTAL
	PAIN	12	25	37
SYMPTOMS	NO PAIN	22	148	170
	TOTAL	34	173	207

Sensitivity = 12/37 = .32
Specificity = 148/170 = .87
Prevalence = 34/207 = .18

MEASURES OF TEST VALIDITY AGAINST REPORTS OF PERSISTENT PAIN

OBJECTIVE TEST	SENSITIVITY	SPECIFICITY
PHALEN'S TEST (HAND)	.32	.87
TINEL'S SIGN (HAND)	.08	.98
THUMB ROTATION (HAND)	.12	.95
FINKELSTEIN'S TEST (WRIST)	.56	.91