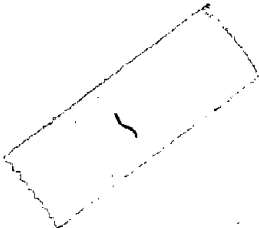


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ANALYSIS OF CUMULATIVE TRAUMA DISORDERS AND WORK METHODS



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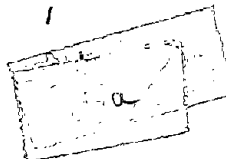
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## ABSTRACT

The purpose of this study was to demonstrate procedures for evaluating occupational factors of cumulative trauma disorders of the upper extremity in industry. Incidence rates of cumulative trauma disorders were determined for each job class in a poultry processing plant and a furniture panel manufacturing plant. Five jobs with incidence rates from 17.4 to 129.6 cases per 200,000 work hours in the poultry plant and two jobs with incidence rates of 10.9 and 15.0 cases per 200,000 work hours in the panel plant were selected for further study to identify repetitive exertions associated with cumulative trauma disorders. Films and surface electromyography were used to document hand postures and forces of experienced workers during one or more work cycles; an MTM analysis was performed to describe the work elements. Stressful exertions and work elements were identified from the films. A number of recommendations were made for redesigning the work station and the tools for eliminating stressful exertions. For example, in one poultry cutting job, an elliptically shaped handle was recommended to reduce grip force and wrist flexion. For one of the panel plant jobs, the recommendation was made to tilt the work surface to a 60-70° angle, which reduced wrist flexion and ulnar deviation.

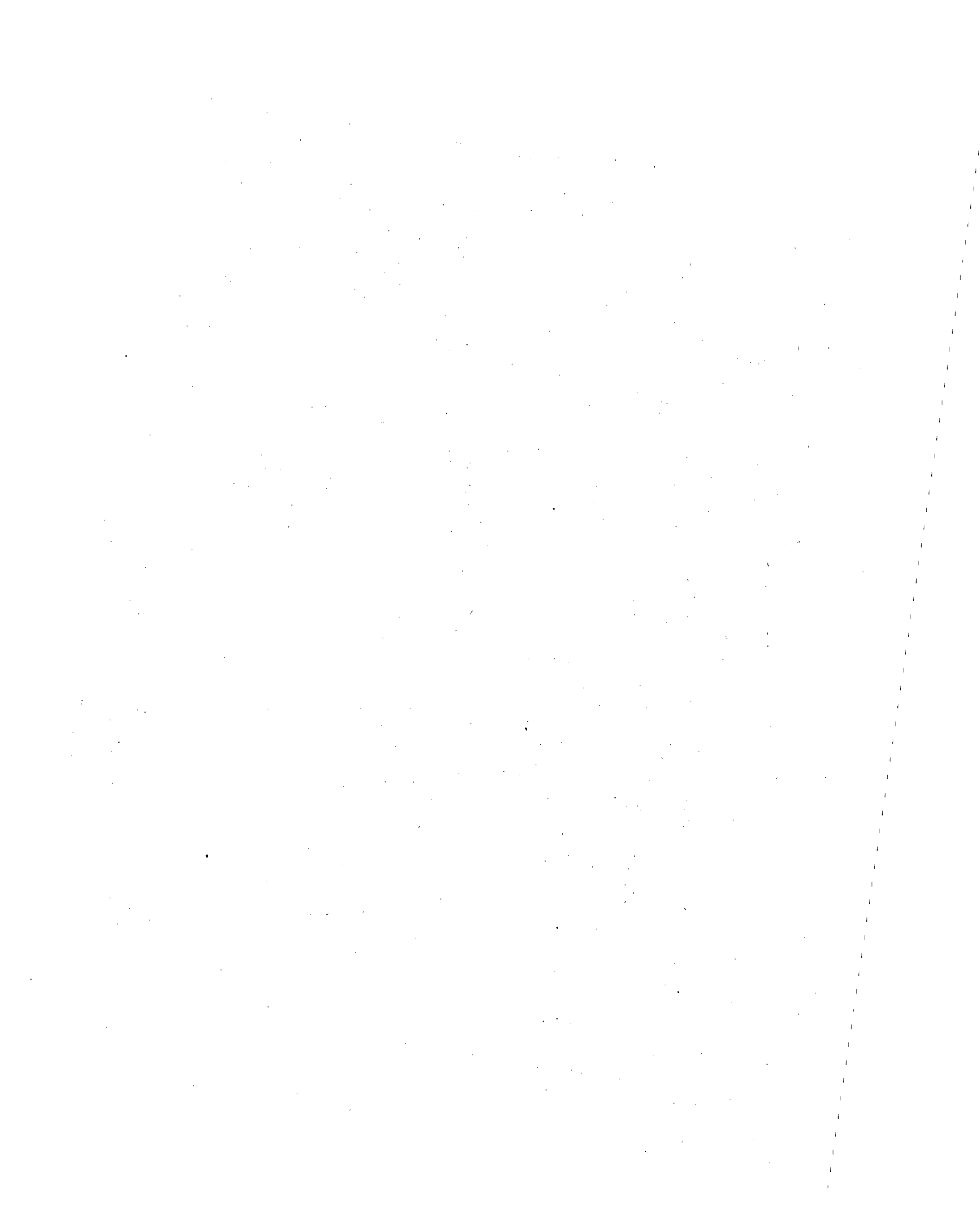


#### ACKNOWLEDGEMENT

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## I. INTRODUCTION

### 1.1 Purpose

The purpose of this study was to demonstrate procedures for evaluating cumulative trauma disorders of the upper extremity that occur in persons working in industry. This report summarizes some of the available literature and describes how health records and work methods in a meat processing and a furniture plant were analyzed in order to identify stressful work activities and to develop recommendations for control of cumulative trauma disorders.

### 1.2 Background

Past research has shown that cumulative trauma disorders of the hand, wrist, and forearm (carpal tunnel syndrome, tendonitis, synovitis, bursitis, tenosynovitis, ganglionic cysts, myositis, and strains, etc.), are common problems for workers who perform repetitive manual work (1-14). Some of the occupations for which these disorders have been reported are listed in Table 1. It also has been shown that cumulative trauma disorders can be caused, precipitated, or aggravated by repeated exertions with certain hand and wrist postures (3, 4, 8, 9, 15-27); some of the most commonly reported postures are listed in Table 2. It generally is agreed that repeated exertions with these postures should be avoided to minimize risk of cumulative trauma disorders in workers.

Measurement techniques for systematically describing manual work have been developed; activities typically are described as sequences of

Table 1: Some Occupations and Activities for Which Cumulative Trauma Problems have been Reported

Occupational Activity	Reference
Aircraft Assembly	14
Automobile Assembly	14
Buffing Machine Operator	1,14
Core Making	4
Electronics Assembly	5,8,9
Fabric Cutters, Sewers	12,13,14
Fruit Packers	14
Gardening	4
Hay Making	4
Housekeeping	22
Meat Processing	6,14
Musicians	14
Packaging	3,11,14
Postal Workers	14
Textile Workers	10
Tire and Rubber	2,3,14
Typist	22
Waitress	22

hand actions or "elements" (32, 33). Levels of detail range from gross, as in Gilbreth's Therbligs, to highly detailed, as in the MTM system. Although the MTM system, with multiple classes of "reach," "move," "turn and apply pressure," "grasp," "position," "release," and "disengage," most rigorously describes manual tasks, elements that involve stressful hand and wrist postures listed in Table 2 cannot be readily identified from this type of analysis. Other systems are required to describe specific postures corresponding to each element.

Table 2: Some Reported Occupational Factors of Cumulative Trauma Disorders of the Upper Extremity

Disorder	Reported Occupational Risk Factors	Reference
Carpal Tunnel Syndrome	1. Accustomed and unaccustomed repetitive work with the hands	15,19
	2. Work that involves repeated wrist flexion or extreme extension--	13,17,19 24,25,27
	-- particularly in combination with forceful pinching	13,25,27
	3. Repeated forces on the base of the palm and wrist	20
Tenosynovitis and peritendonitis crepitans of the abductor and extensor pollicis tendons of the radial styloid (DeQuervain's Disease)	1. More than 2000 manipulations per hour	3
	2. Performance of unaccustomed work	4,18
	3. Single or repetitive local strain	4,18
	4. Direct local blunt trauma	4,18
	5. Simple repetitive movement that is forceful and fast	2,5,18
	6. Repeated radial deviation of the wrist--particularly in combination with forceful exertions of the thumb	21
	7. Repeated ulnar deviation of the wrist--particularly in combination with forceful exertions of the thumb	1,8,9,22
Tenosynovitis of Finger Flexor Tendons	1. Exertions with a flexed wrist	25,27

Table 2 (cont.)

Tenosynovitis of the finger extensor tendons	1. Ulnar deviation of the wrist with outward rotation	8,9
Epicondylitis	1. Radial deviation of the wrist with inward wrist rotation	8,9
Ganglionic Cysts on the wrist	1. Sudden or hard unaccustomed use of tendon or joint	28
	2. Repeated manipulations with extended wrist	30
	3. Repeated twisting of the wrist	29
Neuritis in the fingers	1. Contact with hand tools over a nerve in the palm or sides of the fingers	31

Several systems have been proposed for characterizing hand and wrist posture (34-40); some of the most common are described in Table 3. They range in complexity from gross descriptions of hand action to highly detailed, digit by digit accounts of posture and load.

Table 3: Commonly Used Systems for Describing Hand Posture

Classification of Hand Positions	References
Power and Precision Handling	35-37
Pulp Pinch, Lateral Pinch, Hook Grip, etc.	38,39
Joint Positions & Site of Contact for Each Digit	40

An electromyographic procedure for estimating forces of hand exertions has been described by Armstrong, Chaffin and Foulke (4). The rectified surface EMG of the forearm flexor muscles are calibrated to indicate hand force. An EMG display monitor is placed within the field of view near the hands so that work elements, hand postures, and EMG potentials all can be recorded simultaneously on film.

In summary, the available literature provides strong evidence that cumulative trauma disorders are a common problem in occupations involving repeated exertions with certain hand and wrist postures, and indicates that procedures exist for documenting work elements so that stressful exertions can be identified.



## II. ANALYSIS OF HEALTH AND PERSONNEL DATA

Two plants volunteered to participate in this study: (1) an office furniture manufacturer in the Midwest, and (2) a poultry processing plant in the southeastern part of the country. It was agreed that the employees' participation would be voluntary with their informed consent, and that they and their employers would not be publically identified. The participating plants will be referred to as the "Panel Plant" for the furniture factory and the "Poultry Plant" for the poultry processing factory.

Accidents and personnel records were reviewed to determine the number and type of repetitive trauma complaints for each factory division. In addition, hours worked in each division were calculated by reviewing factory accounting and personnel records. Together, these data were used to compute incidence rates per 200,000 hours worked by type of disorder and by division within the factory. Jobs with high incidence rates were selected for the work methods analysis to identify stressful postures listed in Table 2.

### 2.1 Poultry Plant

Turkey carcasses are processed into various meat products. Turkeys are hung by their wings on a moving line. Workers, located along the line, are assigned one or two tasks to be performed on the turkeys. There are many departments along the line, each specializing in certain tasks; for example, the thigh skinning department removes skin only from the thighs and the boning department performs various cuts on the turkey necessary for removing meat from the carcass.



Company injury and illness logs were reviewed to identify cumulative trauma disorders during the 3 months preceding the study; medical records were not maintained before that time. The disorders were categorized as follows, and pertain to the hand, wrist, forearm, and elbows:

Neuritis -- Injury or pinching of the nerve or nerve covering.

Tendon Disorders -- Inflammation, tearing, or any other injury to the tendon or tendon sheath.

Complaints of Soreness, Aching, Swelling, Knot -- not associated with an Episode -- Disorders with nonspecific symptoms that cannot be attributed to a single event.

Numbness not Associated with Acute Episode -- Numbness in the upper extremity due to repetitive use of the body part. Numbness in the hands often is associated with carpal tunnel syndrome.

Table 4 shows the frequency, hours, and incidence rates per 200,000 hours worked of cumulative trauma disorders for the Poultry Plant. The hours are total hours and include jobs directly and indirectly related to the turkey processing. Therefore, actual incidence of persons engaged only in cutting operations probably is somewhat higher than shown.

It can be seen from Table 4 that the Thigh Skinning and Boning departments were among the largest departments and among the highest in incidence rates of cumulative trauma complaints in the plant, 129.6 and 17.4 cases per 200,000 hours worked respectively. Based on these high incidence rates and on discussions with the management about employee injuries and complaints, Breast Cut, Shoulder Cut, Oyster Cut, Thigh

Table 4: Poultry Plant--Incidence Rates per 200,000 hours worked, October 1979 - May 1980, for selected cumulative trauma disorders by plant division.  
Only those divisions displaying cumulative trauma disorders are shown.

Injuries	Trimming (58,092)*		Boning (114,794)*		Thigh Skinning (15,438)*		Turkey Parts (32,262)*		Pan Roast (30,400)*		Cured (5,024)*		Cookroll (11,538)*		Sanitation (13,310)*		Grand Total** (501,668)	
	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.
Neuritis	0	-	1	1.7	0	-	0	-	0	-	0	-	0	-	0	-	1	0.4
Tendon Disorders	0	-	1	1.7	1	13.0	0	-	0	-	0	-	1	17.3	0	-	3	1.2
Complaints of soreness, ac- hing, swelling knot -- not assoc. with acute episode	6	20.7	8	13.9	9	116.6	1	6.2	1	6.6	1	39.8	0	-	1	7.4	27	10.8
Numbness not assoc. with acute episode	0	-	0	-	0	-	0	-	1	6.6	0	-	0	-	0	-	1	0.4
Total	6	20.7	10	17.4	10	129.6	1	6.2	2	13.2	1	39.8	1	17.3	1	7.4	32	12.8

\* The hours above each column represent total hours, not direct hours.

\*\* The grand total figure is the accumulation of all divisions and all hours (both direct & indirect) in the poultry plant.

Boning and Thigh Skinning were chosen for further study. The following paragraphs describe the different cuts made in the Boning department as reported by the management and observed by the authors. Work methods were variable and some day-to-day and person-to-person variations probably occur.

Oyster Cut -- The knife is held by wrapping the fingers around the handle so that when the forearm is horizontal, the blade points down towards the worker. A cut is made around the oyster of the turkey to expose the dark meat underneath. It is a circular cut involving a large twist of the wrist and palm, and has been labeled one of the hardest jobs in the plant.

Breast Cut -- The knife is held with the index finger placed on the back of the blade and the other fingers are wrapped around the handle. A sharp twisting cut is made around the (keel) breastbone. The hand holding the meat is also twisted in order to free the meat.

Shoulder Cut -- The knife is held by wrapping the fingers around the handle, such that, when the forearm is horizontal and semi pronated, the blade points down with the sharp edge towards the body; fingers are wrapped around the handle and the blade points down. The cut involves going around the shoulder in a twisting fashion.

Thigh Boning -- The knife is held in the palm similar to the shoulder cut except that the index finger is not placed on the blade. There are four to five cuts made along the length of the thigh while the other hand pinches and twists the meat away from the bone. Both hands are exposed to high forces on this job.

Thigh Skinning -- One job is performed in this department--thigh skinning. A backlog of unskinned thighs often develops over the course of the work day and it is common for persons from other departments to assist with this backlog at the end of the shift. The thigh skinning operation recently had been changed; the original method is referred to as "Method I" and the new method as "Method II".

Method I: The worker grabs the meat in one hand and the skin in the other and pulls them apart. Both hands usually are covered by rubber gloves with light cotten inserts.

Method II: A three pronged hook is fastened to the work table. The worker grabs the skin with one or two hands, anchors the meat on the hook and pulls the skin off the thigh. Both hands usually are covered by rubber gloves with light cotton inserts.

Detailed descriptions including illustrations of the poultry jobs are given in Appendix B.

## 2.2 Panel Plant

This plant constructs sound panels designed for use in "modular" offices. Each panel consists of various component parts attached to a welded structural frame. A multi-step process machines and welds metal parts into frames that are then transported, by cart, to the upholstery division. In one process, sound insulation is placed inside the frame by hand and then covered with a cloth on both sides. A pneumatic reciprocating tool is used to force a plastic wire into a groove to stretch and anchor the cloth to the panel. Any extra fabric is cut off and thrown into a scrap box.

The upholstered panels then are transferred, by cart, to the assembly division. Various metal parts and brackets are secured to the edges of the panel by pneumatic tools. These attachments allow the panels to be free standing singularly or hooked in a series.

Company injury and illness logs were reviewed to identify cumulative trauma disorders during the 16 months preceding the study. The following definitions were used by company health personnel:

Strain -- Any overexertion or overuse of a muscle. The muscle can be pulled, torn, or twisted by assuming a number of awkward positions.

Tendonitis -- Inflammation of the tendon or tendon sheath; it is not a strain.

Ganglion -- Non-malignant fibrous cyst.

CTS -- Median nerve compression through the carpal tunnel.

Other -- All other cumulative trauma disorders of the hand, wrist, forearm or elbow not previously mentioned.

Table 5 shows the frequency, hours, and incidence rates per 200,000 hours worked for the Panel Plant. It should be noted the hours were direct hours and not total hours. Direct hours are defined as those hours involved only in construction of the panels and do not include stock handling, maintenance, inspection, etc.

Table 5: Panel Plant--Incidence rates per 200,000 hours worked, 1979 through April 1980, for selected cumulative trauma disorders by plant division.

Department	Work* Hours	Strain		Tendonitis		Ganglion		CTS		Other		Total	
		Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.	Freq.	Incid.
Machine Division	192,775	7	7.3	3	3.1	0	-	1	1.03	2	2.1	13	13.5
Weld Division	136,715	5	7.3	0	-	0	-	1	1.5	0	-	6	8.8
Paint Division	99,060	4	8.1	0	-	0	-	0	-	0	0	4	8.1
Cut and Upholstery	182,886	6	6.6	1	1.1	1	1.1	1	1.1	1	1.1	10	10.9
Assembly Division	250,055	14	11.2	3	2.4	0	-	0	-	2	1.6	20	14.2
Grand Total**	1,805,059	41	7.5	7	.77	1	1.1	3	.33	6	.66	58	6.4

\* The hours above each column represent hours directly involved in construction of the panels.

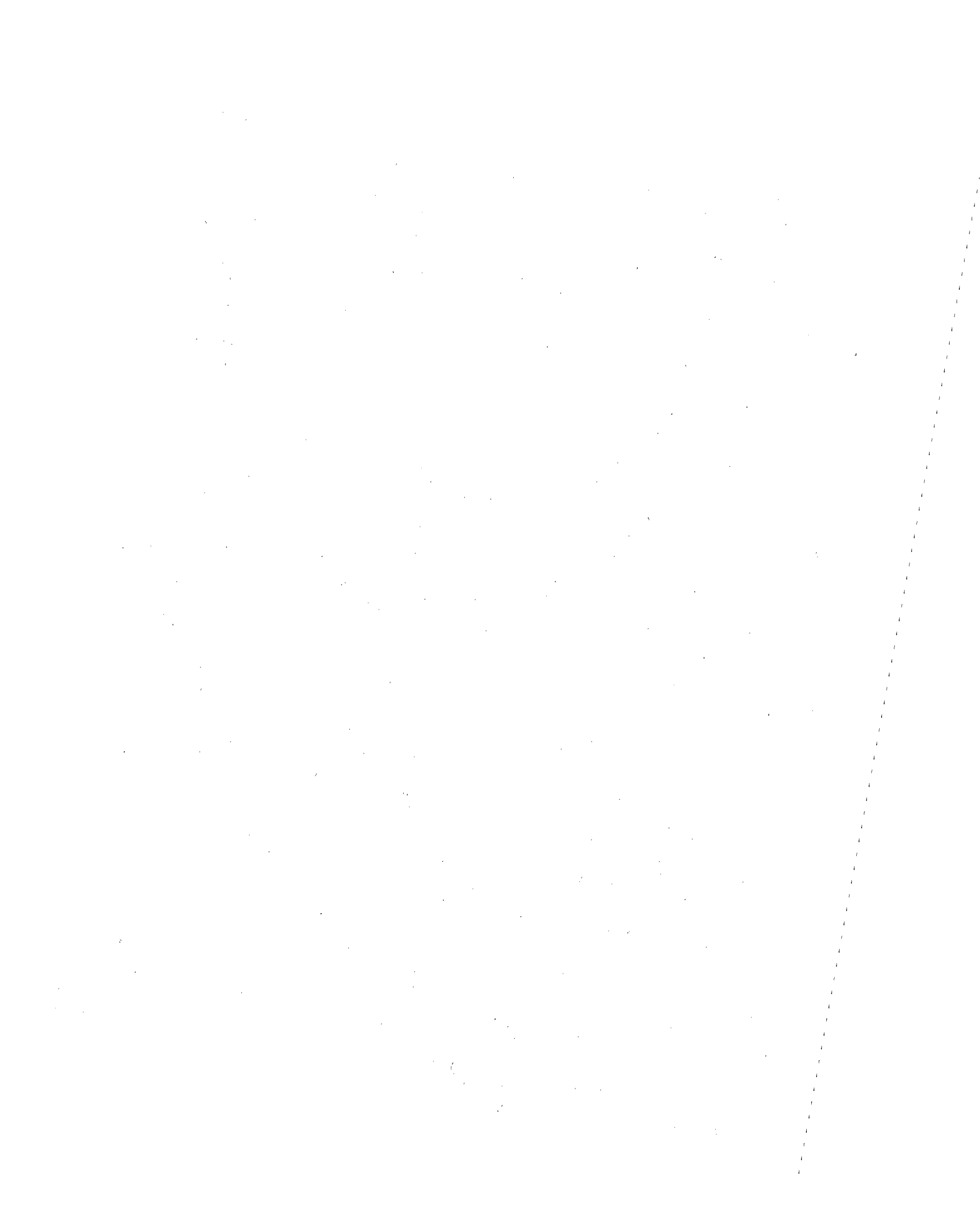
\*\* The grand total figure is the accumulation of all divisions and all hours (both direct and indirect) in the Panel Plant.

Divisions with a high incidence of cumulative trauma disorders were of interest. Three divisions fulfilled this requirement: the cut and upholstery, the weld, and the assembly divisions with incidence rates of 10.9, 8.8, and 14.2 cases per 200,000 hours respectively. (See Table 5.) Jobs in the Cut and Upholstery and Assembly divisions were the most structured and hence were most suited for this study. These jobs are:

Cut and Upholstery -- Acoustical panels are assembled from metal frames, sheets of cardbord, and plastic wire using pneumatic hammers and scissors.

Assembly -- Brackets and finishing strips are attached to upholstered panels using screws and pneumatic screwdrivers.

Detailed job descriptions are given in Appendix C.



### III. WORK METHODS ANALYSIS

Films were used for documentation of work elements, upper extremity postures, and surface EMGs as shown in Figure 1 (32, 33, 41, 42).

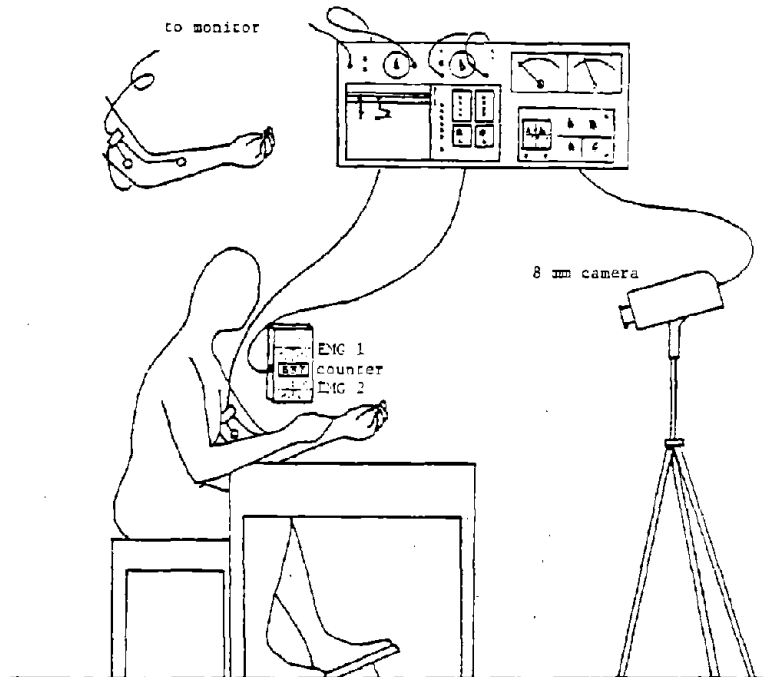


Figure 1: Cinematography and electromyography were used to record hand and wrist positions (from Armstrong, Chaffin and Foulke, 30).

Amplified and rectified surface EMG signals were calibrated before and after each test for each subject to estimate hand forces. The electrodes were left attached for 15 to 60 minutes during which they were filmed for 5 to 10 minutes. Films were made from multiple views at three frames per second and at 18 frames per second to document all activities and postures. A sample sequence of hand postures is shown in Figure 2.



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Figure 2: Sample film of worker cutting right breast on turkey processing line. EMG and film frame counter are shown in lower right hand corner of each frame. (See Appendix B2 for complete job description and analysis).

A system for describing postures is described in Appendix A. Joint positions were classified as one of up to six equally spaced segments within the range of motion. Hand positions were classified according to which fingers were used, finger position, and the location of external loads on the hand. Work elements were classified according to the scheme of the MTM Association (32). Plots of work elements, upper extremity posture, and hand force for the job shown in Figure 2 are included in Appendix B2.

### 3.1 Poultry Plant

Films were taken of six different subjects for five operations at the plant. A lead worker, capable of performing all the Boning operations, was used both as a fill-in on the line (while another subject was tested) and as a subject for all filmed operations in the boning department. Table 6 summarizes the age, sex, height, length of employment, dominant hand, and hands and muscle groups studied for all subjects on each operation. By coincidence, all subjects were right handed. Films of one subject from each operation were completely analyzed; films of other subjects were used to determine positioning from other views and to assess the consistency among workers.

### 3.2 Panel Plant

Four volunteers, two from Assembly and two from Cut and Upholstery, were filmed in the Panel Plant. The age, sex, height, dominant hand, and hands and muscle groups studied (by EMG) for each subject are summarized in Table 7. It is noted that time allowed only

Table 6: Age, Sex, Height, Hand and Muscle Groups for Ten Subjects on Five Different Jobs at Poultry Plant.

Type of Cut	Oyster Cut		Breast Cut		Shoulder Cut		Thigh Boner		Thigh Skinning	
	#1	#2	#3**	#4	#5**	#6	#7**	#8		#9**
Subject	55	30	31	31	30	30	17	34	30	21
Age	F	F	F	F	F	F	F	F	F	M
Sex	5'0"	5'3"	5'2"	6'1"	5'3"	5'3"	5'4"	5'7"	5'3"	6'0"
Height	>1 year	>1 year	>1 year	>1 year	>1 year	>1 year	.8 of 1 year	>1 year	>1 year	.4 of 1 year
Length of Time Working at Plant	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right
Dominant Hand	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right
Hand(s) Studied	*FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP	FDS & FDP
Muscle Group Studied by EMG										

\* FDS - Flexor Digitorum Superficialis  
 FDP - Flexor Digitorum Profundus  
 \*\* Subjects studied in film analysis.

Table 7: Age, Sex, Height, Hand and Muscle Group for Each Member of Each Team on the Two Jobs at Panel Plant. All subjects worked at least 1 year on their respective jobs.

Job #1 - Assembly		
	Subject #1	Subject #2
Team #1	(A) 28 (B) Male (C) 5'5" (D) Right (E) Right/Left (F) RH: FDS & FDP* LH: FDS & FDP	(A) 21 (B) Male (C) 5'8" (D) Right (E) Left only (F) FDS & FDP
Team #2	(A) 22 (B) Male (C) 5'10" (D) Right (E) Right only (F) FDS & FDP	(A) 22 ** (B) Male (C) 5'10" (D) Right (E) Right/Left (F) RH: FDS & FDP LH: FDS & FDP
Job #2 - Upholstery		
	Subject #1	Subject #2
Team #1	(A) 21 (B) Male (C) 5'11" (D) Right (E) Left only (F) FDS & FDP	(A) 28 ** (B) Male (C) 5'11" (D) Right (E) Right only (F) FDS & FDP Right Triceps
Team #2	(A) 29 (B) Male (C) 5'9" (D) Right (E) None (F) No EMG taken - just filmed	(A) 21 (B) Male (C) 5'11" (D) Right (E) None (F) No EMG taken - just filmed

\* FDS - Flexor Digitorum Superficialis  
FDP - Flexor Digitorum Protundis

\*\* Subjects studied in film analysis.

KEY

(A) Age	(B) Gender
(C) Height	(D) Dominant Hand
(E) Hand studied by EMG	
(F) Muscle groups studied	

three teams to be filmed complete with EMG. Films of one subject from each division were completely analyzed; both subjects were right-handed. Films of other subjects were used to help determine positioning from different views and to assess the consistency between team members.



#### IV. RESULTS AND RECOMMENDATIONS

Work methods and motion analyses were performed on five jobs from the Poultry Plant and two jobs from the Panel plant as described in Section III; the results of these analyses are summarized in Appendices B and C. Films and plots of work elements and corresponding postures were reviewed to identify stressful exertions listed in Table 2. Comments and recommendations for each of these jobs follow.

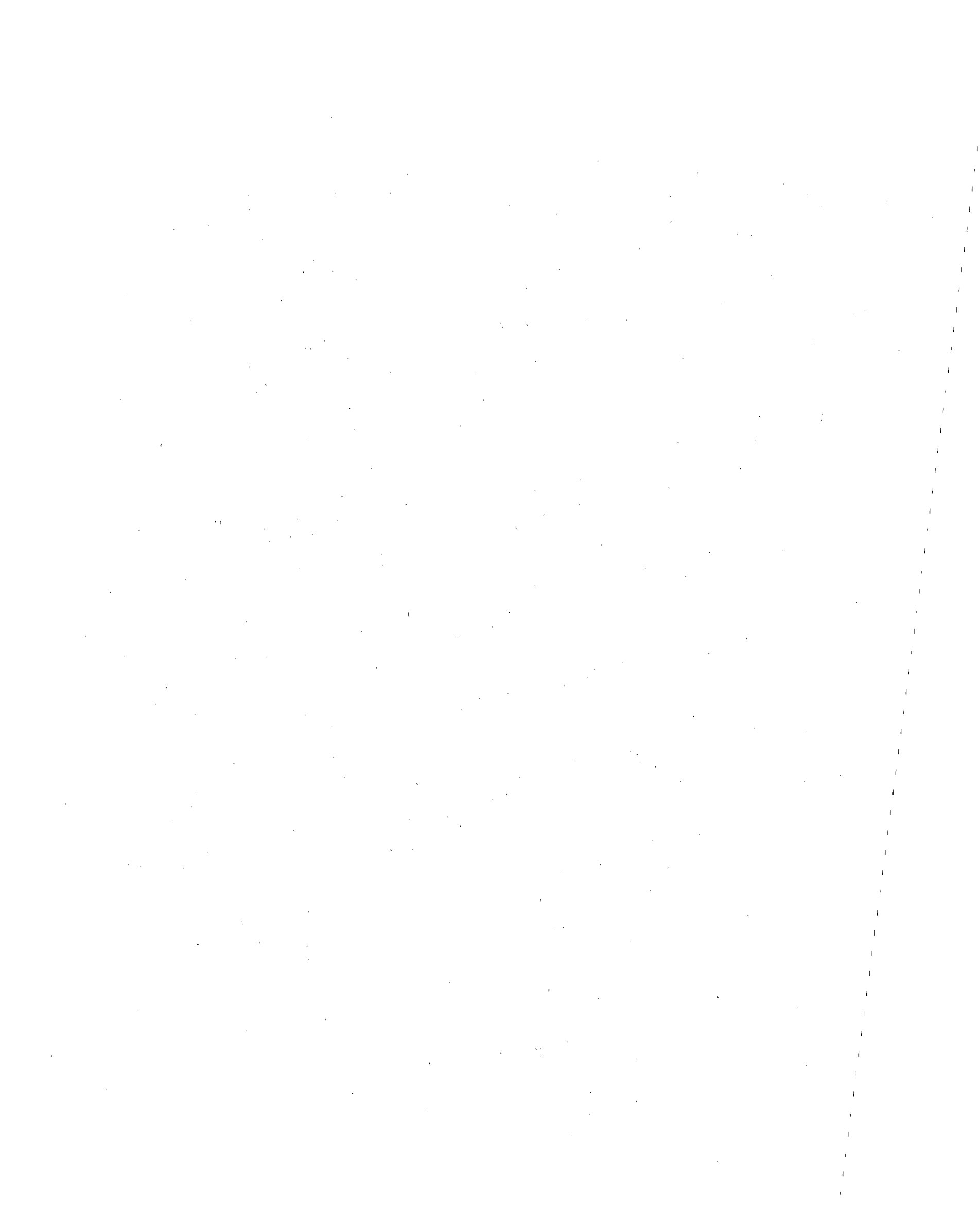
Only right-handed subjects were analyzed because of the small size of the study. Although many of the recommendations apply to both right and left-handed subjects, others will require some modification for left-handed persons.

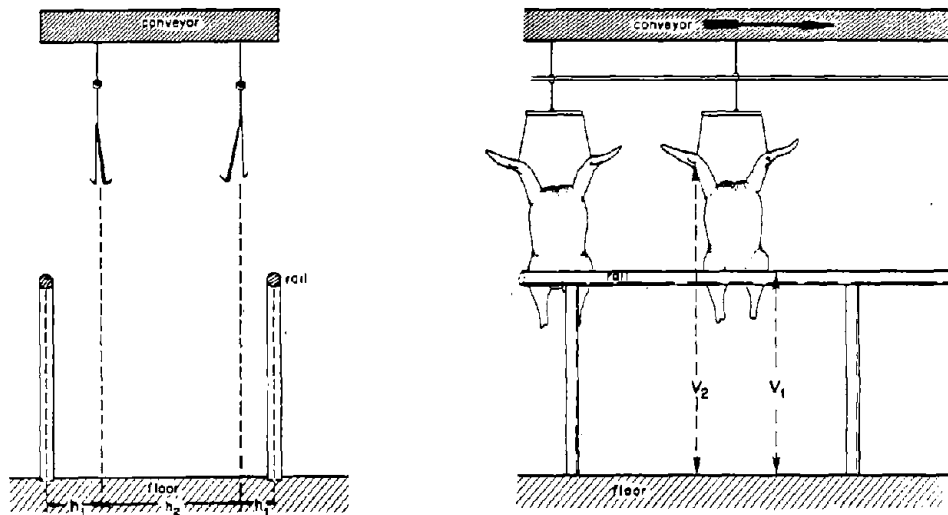
##### 4.1 Poultry Plant

Five jobs in the poultry plant that had documented histories of cumulative trauma disorders described in Section 2.1 were analyzed to identify the stressful postures listed in Table 3. They included: Oyster Cut, Shoulder Cut, a Breast Cut, Thigh Boning and Thigh Skinning.

###### 4.1.1 Oyster Cut (see Appendix B1)

Workers reach over a guardrail (see Figure 3) with their left hand and grasp the left thigh to orient the turkey for cutting. Forceful exertions (see Figure B1.7b) often are made to pull the turkey into position as it approaches the worker and to hold the turkey in position as it moves away (see Figure B1.7, t = 10 to 14 seconds). The importance of timing should be emphasized to workers so that they do





	Oyster Cut	Breast Cut	Shoulder Cut	Thigh Boning
$h_1$	11"	11"	11"	7"
$h_2$	18"	18"	18"	16"
$V_1$	26"	26"	26"	26"
$V_2$	51"	51"	51"	51"

Figure 3: Front and side views of work station along with nominal dimensions are shown for Oyster cut, Breast cut, Shoulder cut, and Thigh Boning stations.

not begin cutting too soon or too late. Workers should be well trained in the use of proper work methods and knife maintenance to minimize the time and, hence, the distance that must be reached to perform the oyster cut. Workers should try to shift their weight from the left

foot to the right foot to follow the turkey rather than hold it in one spot. A potential modification to the work station includes reducing the distance between the guardrail and the turkey to reduce the reach distances. A second guardrail or shield might be located at the level of the shackles to prevent persons from getting caught on the conveyor. The use of conveyors that slow to stop the turkey in front of each worker should be considered in future installations.

The knife for the oyster cut is held by wrapping the fingers around the handle with the blade pointed down (see Figure B1.1 and B1.6a). Because the diameter of the handle is considerably smaller than the inside grip diameter of a relaxed hand, a constant grip force is required to prevent dropping the knife (see Figure B1.6b;  $t = 6$  to 12 seconds). Additional force is required to overcome the passive forces of the rubber gloves and cloth liners that often are worn. These exertions are fatiguing and result in continuous insult to the tissues of the hand. The knife handle design should be modified so that a sustained grip exertion is not required between cuts. This might be done in two ways. First, the circumference of the handle could be increased to fit the inside of the hand. A circular or elliptical shape with a circumference of 4.5 to 5.0 inches is recommended (31,43).

Bumps on the sharp side at each end of the handle act as knife guards and are supposed to help keep the fingers from sliding from the handle and cutting the worker and from dropping the knife (see Figure B1.1). When the knife is held with the sharp edge towards the worker

(see Figure B1.1), the fingers do not come into contact with the guards and the risk of the hand sliding off from the knife handle appears to be increased. A strap or a shroud could be shaped to fit comfortably over the back side of the hand. Such a shroud would also act as a guard to prevent the hand from sliding off the handle (see Figure 4). A stiff handle and shroud that slips on and off for selection and cleaning could be molded from a lightweight plastic.

The oyster cut is begun with the knife pointed straight down; the knife then goes through approximately  $135^{\circ}$  of rotation (see Figure B1.1). The workers must move their wrist from a completely flexed to a completely extended position while making forceful exertions (see Figures B1.5b and B1.6b at times = 3 to 6 seconds and 12 to 15 seconds). The cross-sectional shape of the knife handle is rectangular. Consequently, the sharp edge of the knife blade tends to be held towards the worker and the angle of cutting is controlled by flexing and extending the wrist. The wrist is held in a flexed position during 50% to 75% of the oyster cut cycle. Wrist flexion in combination with forceful exertions is a factor of carpal tunnel syndrome (see Table 2) and should be avoided. This might be achieved by using a banana shaped knife handle shown in Figure 4. Workers could regrasp the handle in another position rather than flex their wrist. Also, the above recommendation should reduce the strength required to hold the knife for cutting.

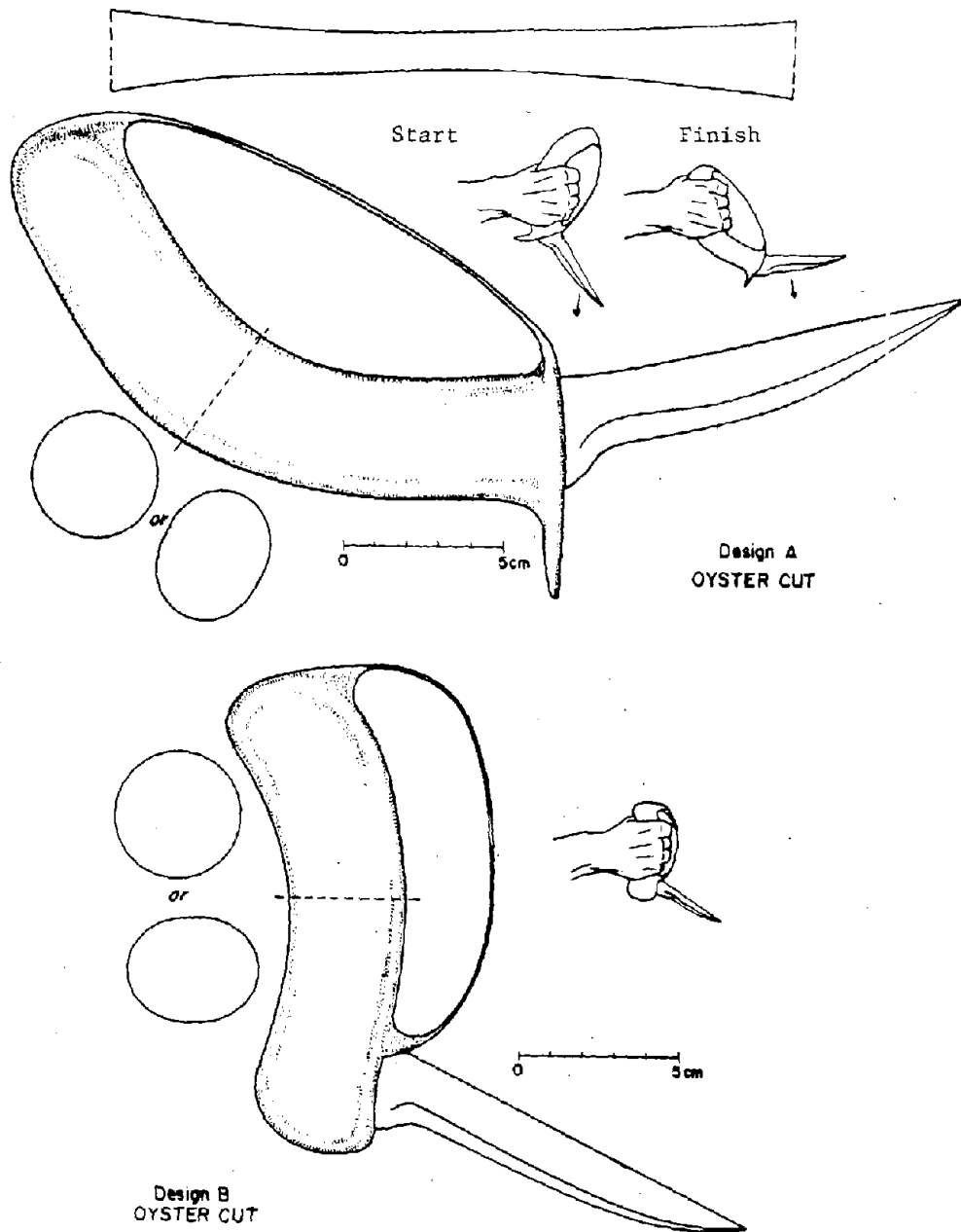


Figure 4: Two possible banana shaped handle designs to reduce wrist deviations in oyster cutting are shown.

#### 4.1.2 Breast Cut (see Appendix B2)

High forces (4 to 8 kg) are exerted with the left hand to grasp and hold turkeys in position for cutting during most of the breast cut cycle (see Figure B2.7b). Recommendations for knife sharpness, worker training and work station design described in Section 4.1.1 are applicable to minimize stresses on the left hand. A cut out for the toes under this part of the line would provide extra room for workers to position themselves with the turkeys and help reduce extreme reaches at the beginning and end of cutting cycles.

The workers studied held the knife with their index finger on the backside of the blade so that with the forearm horizontal, the tip of the blade pointed away from their body and the sharp edge was directed down (see Figure B2.1). Consequently, much of the cutting force is exerted with the index finger. The wrist must be repeatedly flexed and ulnarly deviated (see Figure B2.5a and b) to hold the tip of the knife down and to direct the sharp edge inward along the rib cage (see Figure B2.1). Forceful flexion of the wrist is a factor of carpal tunnel syndrome and ulnar deviation of the wrist is a factor of DeQuervain's disease (see Table 2). The knife handle should be redesigned so that the blade can be held in the cutting position without ulnar or radial deviation and without flexion or extreme extension. Two possible designs are shown in Figure 5. Recommendations for handle size and use of slings and guards in Section 4.1.1 apply to the designs shown in Figure 5.

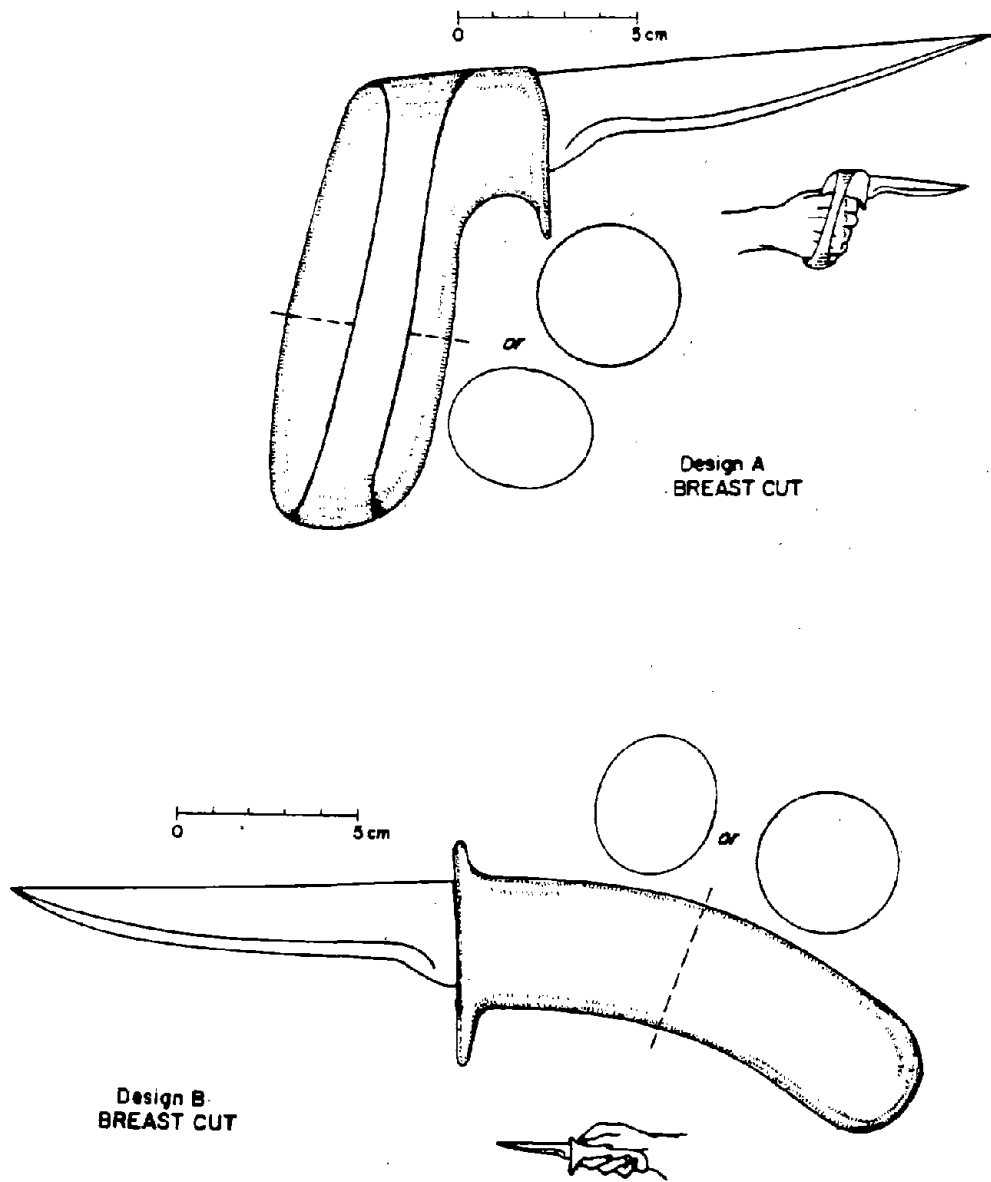


Figure 5: Two possible knife designs to reduce wrist deviation in breast cutting are shown.

#### 4.1.3 Shoulder Cut (see Appendix B3)

The left hand is rested on the shackle or wing to stabilize the turkey for shoulder cutting. Stresses on the left hand appear to be insignificant. The left shoulder is cut with the knife held in the right hand so that, with the forearm horizontal, the tip points away from the worker and the sharp edge points down (see Figure B3.1). The worker then reaches over the turkey and makes a semicircular cut with the blade pointed down (see Figure B3.1). This cut requires elevation of the elbow (see Figure B3.3), inward rotation of the forearm (see Figure B3.4b), and ulnar deviation and flexion of the wrist (see Figure B3.5). Repeated elevation of the arm causes shoulder fatigue and could lead to a cumulative trauma injury of muscles, tendons, and bursa in the shoulder. Repeated wrist flexion in combination with forceful exertions (see Figure B3.6b) is a risk factor of carpal tunnel syndrome and should be avoided; repeated ulnar deviation of the wrist is a factor of DeQuervain's Disease and should be avoided (see Table 2).

The right shoulder is cut with the knife held in the right hand so that, with the forearm held horizontal, the tip of the knife points down with the sharp edge toward the worker (see Figure B3.1). A semicircular cut is made by reaching over the turkey with blade pointed down. This cut requires radial deviation (see Figure B3.5a) and inward rotation (see Figure B3.4b) in combination with a forceful exertion (see Figure B3.6b). Radial deviation in combination with inward forearm rotation is regarded as a risk factor of epicondylitis (see Table 2) and should be avoided.

The basic problems with shoulder cuts are related to reaching over the turkey and to the range of knife motion required. The direction of the cut goes through approximately 180°. Some of the ulnar deviation and flexion of the wrist might be reduced by using a knife blade that is bent towards the sharp edge as shown in Figure 6. A second possibility might be to divide each shoulder cut into two cuts as shown in Figure 7; each cutter could face the back of the turkey and makes one cut on both shoulders. Since the shackles rotate, the approaching turkey can be repositioned for the most comfortable cut position. A knife handle design with an angle of 45° to 90° to the cutting edge shown in Figure 8 is suggested to minimize wrist deviation. The knife is held with the blade pointing up and away from the worker.

#### 4.1.4 Thigh Boning (see Appendix B4)

The fingers of the right hand (only right-handed persons were studied) are wrapped around the handle so that, with the forearm held horizontal, the knife is held horizontal and the sharp edge is pointed down (see Figures B4.1 and B4.6b). Ulnar deviation and flexion of the right wrist in combination with forceful exertions is repeated throughout most of the thigh boning cycles (see Figures B4.5 and B4.7b). Ulnar deviation of the wrist is a factor of DeQuervain's disease and wrist flexion is a factor of carpal tunnel syndrome (see Table 2); both of these postures should be avoided.

Ulnar deviation and flexion of the hand holding the boning knife might be eliminated by reorienting the blade with respect to the handle. A suggested modification in which the blade is bent towards

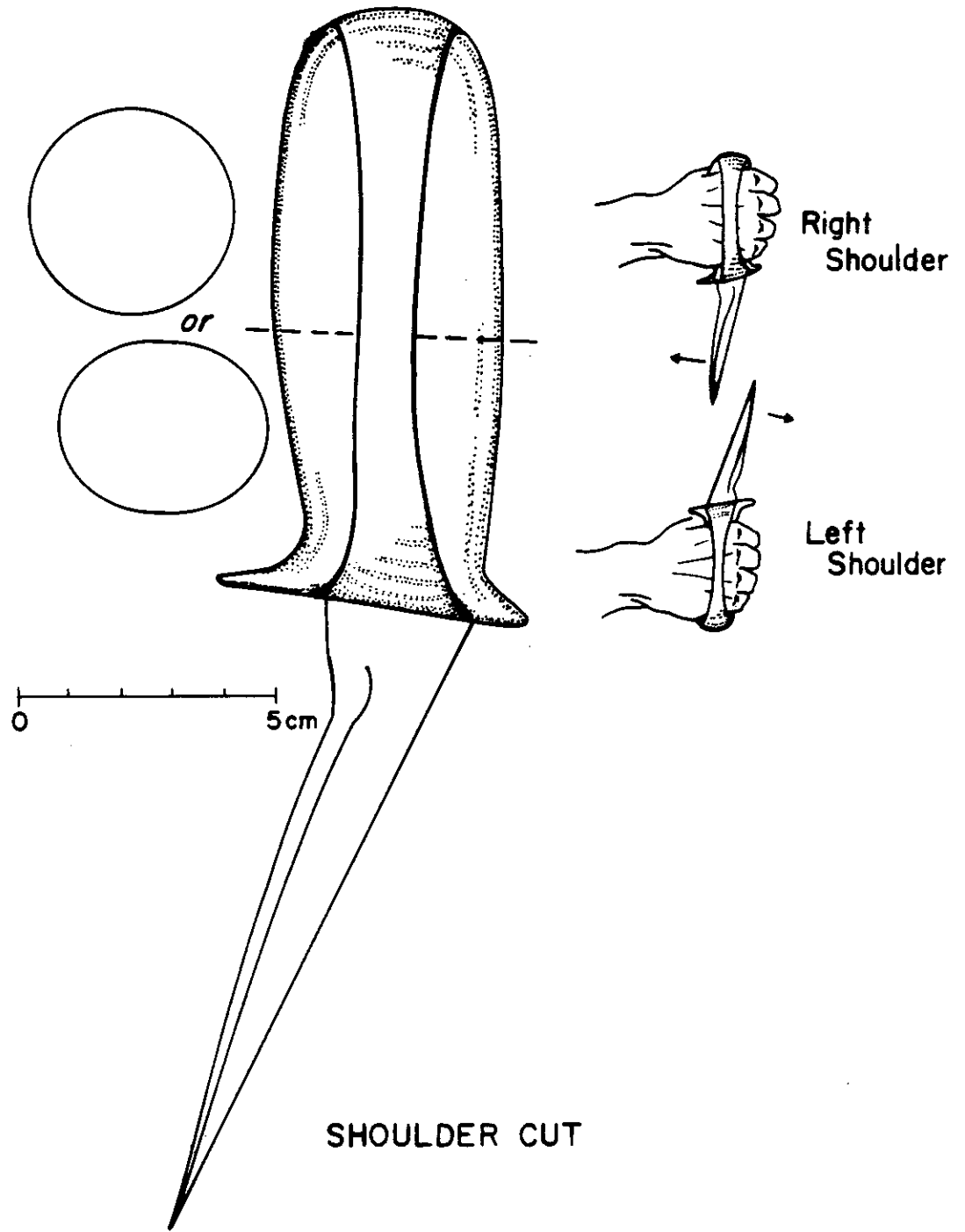


Figure 6: A possible knife design to reduce wrist deviation in shoulder cutting is shown.

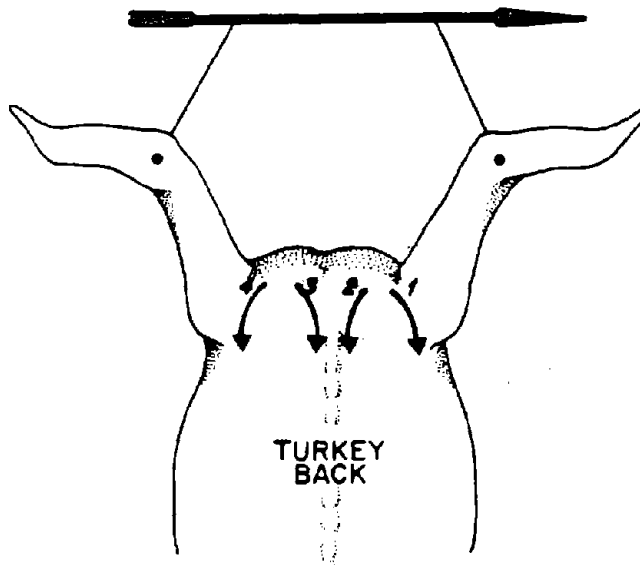


Figure 7: An alternate shoulder cut procedure in which each of two workers face the back side of the turkey and cut half of both shoulders should reduce the range of required wrist motion.

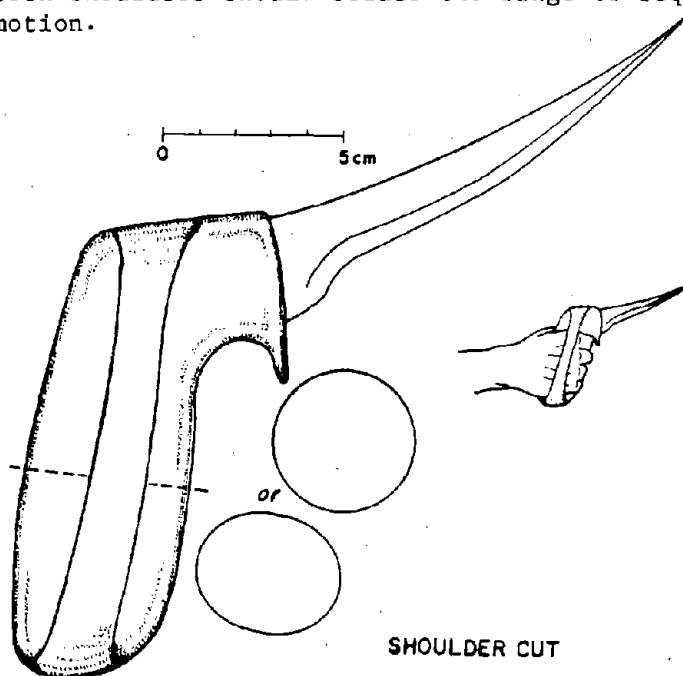


Figure 8: A possible knife design to reduce wrist deviation in the alternate shoulder cutting procedure (Figure 7) is shown.

the sharp edge is shown in Figure 9. The blade can be held horizontally with the forearm horizontal but without ulnar deviation and wrist flexion. It is also suggested that the knife handle diameter be increased to facilitate holding the knife between cuts (see Section 4.1.1). A shroud or strap also might be used to help hold the knife in a relaxed hand and to reduce risk that the hand will slip off the handle.

High forces are exerted with the hand (see Figure B4.6b at  $t = 4$  and 14 seconds) to complete the final cut in the thigh boning operation. Knives should be kept sharp to minimize these forces. Also, the effect of blade shape on cutting force should be studied (see Figure 9).

The left hand is used to grasp and hold the turkey thigh during the boning cycle. A wire mesh glove is worn to protect this hand from the knife; a lateral pinch is used to peel the meat away from the thigh bone during each cut (see Figure B4.7a). The lateral pinch results in irritation to the skin on the side and palm of the first two digits. Such exertions also could result in neuritis in these fingers (see Table 2). Modifications to the gloves should be investigated to facilitate gripping the turkey thigh while minimizing irritation to the fingers. While it is desirable to wear rubber gloves beneath the wire mesh, such gloves should be carefully selected for best fit and maximum flexibility. Hand sizes and shapes vary so considerably that a broad range of glove styles and sizes should be stocked and employees should be assisted in selecting the best fit. Lastly, the use of barbs on the palmar surface of the wire mesh gloves might facilitate pinching and

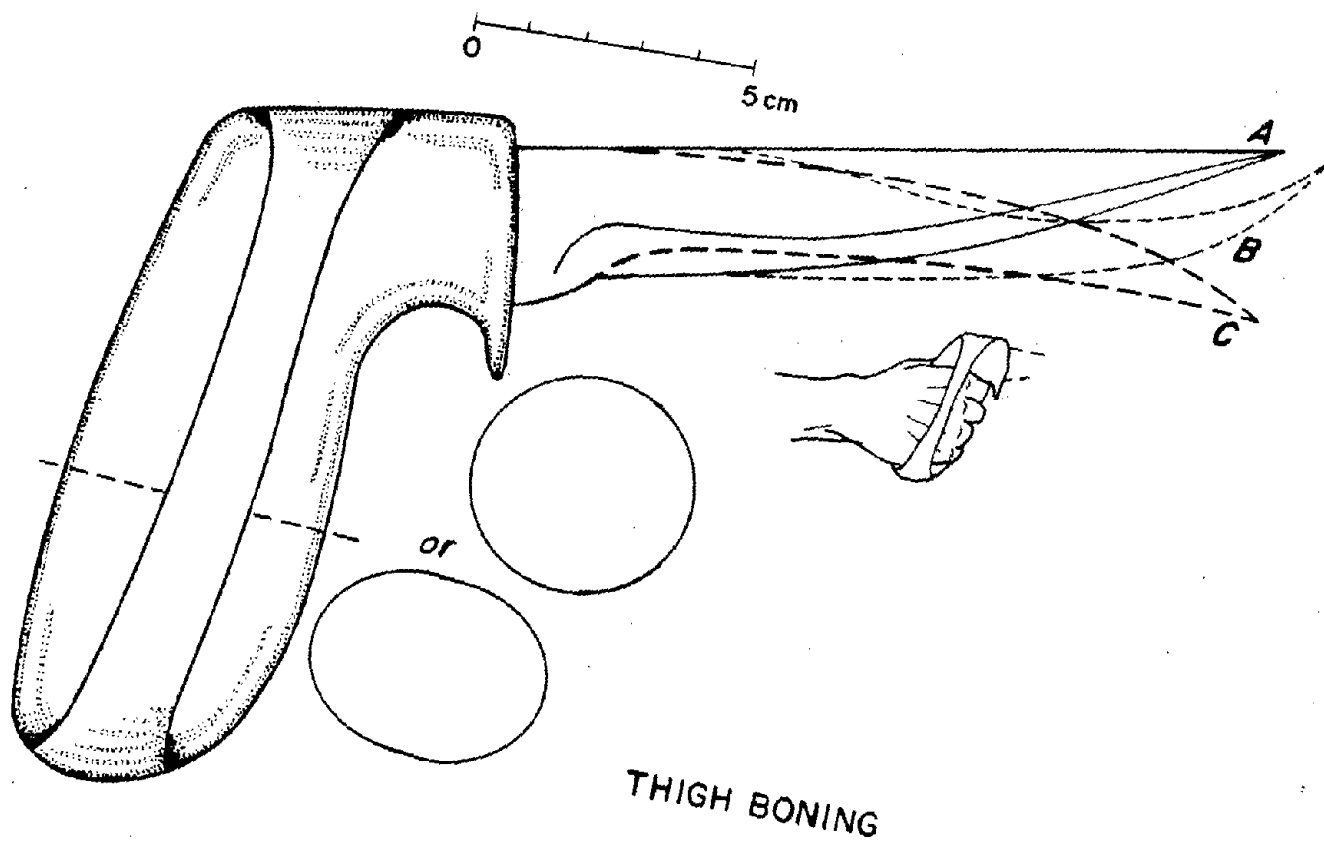


Figure 9: One possible knife handle design with three blade designs to reduce wrist deviations in thigh boning are shown.

pulling the meat away from the bone. Length and sharpness of such barbs should be optimized to minimize risk of a self inflicted wound and to maximize traction.

#### 4.1.5 Thigh Skinning (see Appendix B5)

Two methods of thigh skinning were compared: Method I, using only the hands, and Method II, using a hook anchored on the surface of a work bench (see Figure B5.1). Thighs can be skinned nearly twice as fast with Method II (holding a thigh in each hand and using the hook), than in Method I (using both hand for one thigh) (see Figure B5.2). It is recommended that a production standard or goal be established so that some of the time savings of the hook method are used to provide rest allowances. Workers should then be encouraged to distribute their work uniformly over the shift.

As studied here, Method II required more force than did Method I (see Figures B5.6b and B5.7b). This extra force could be due to differences in hand postures--more pulp pinching is used in the hook method while more palm pinching is used in the grasp method. An additional rest allowance and proper instruction might help the worker to grasp the skin better when the hook is used.

Repeated forceful exertions in combination with ulnar deviation and flexion of the wrist are required to skin thighs in both methods (see Figure B5.5). Wrist posture might be controlled by the size, shape, and orientation of the hooks that are used to anchor the meat. Adding tines to the hook would make it easier to catch the meat.

When skinning with the right hand, there is a tendency to pull the skin toward the right side of the worker's body, and when skinning with the left hand, there is a tendency to pull the skin toward the body and to the left. Sometimes there is a tendency for the meat to slide off the side of the hook. The tines could be arranged like spokes on a large wheel with the points directed inward, forcing the meat inward and holding it. Extra space might be provided between every third tine for finger clearance when removing meat. The horizontal parts of the tines might be directed downward slightly to eliminate flexing of the wrist. When anchoring the thighs, workers should try shifting their body weight slightly to minimize how far they must move their arms. Also, workers should be instructed to keep their wrists in a relaxed posture and avoid rapid wrist movements.

A last possibility is to investigate skinning the thighs before they are removed from the turkey. Such a procedure would reduce handling of the thighs; the exact procedure would depend on when in the process thighs are skinned.

## 4.2 Panel Plant

Two jobs in the panel plant with high rates of cumulative trauma disorders (Table 4) were analyzed. As described in Section III, they included Upholstery and Assembly.

### 4.2.1 Upholstery (see Appendix C1)

The application of tape to seal the fiberglass panels to the frame requires repeated flexion and ulnar deviation of the wrist. Also,

forceful exertions are required at each corner to break the tape. Ulnar wrist deviation is a factor of DeQuervain's disease, wrist flexion is a factor of tenosynovitis and carpal tunnel syndrome (see Table 2). Both postures should be avoided. Use of an appropriately designed tape dispenser might make it possible to hold and apply the tape without repeatedly flexing and ulnarly deviating the wrist. Also, a dispenser could be equipped with a blade to facilitate cutting the tape at each corner. A commercially available tape dispenser design is shown in Figure 10.

The palm hammer is held in the hand and activated by pressing it against the work surface. Thus, it might be expected that most of the work associated with this task is pushing on the palm hammer; however, force measurements show that for most of the time more force is exerted with the hand than with the arm (see Figure C1.6). Tool oscillation, tool weight, and sensory fatigue all could contribute to high hand forces. High peak forces caused by the reciprocating action of the palm hammer probably are sufficient to overcome frictional forces between the skin and the hammer so that there is a tendency for the tool to slide out of the hand. The attachment of a leather cushion to the handle no doubt would help to overcome this problem both by increasing friction between the tool and the hand and by reducing the peak forces transmitted to the hand.

A sample tool weighs 2.75 pounds exclusive of the weight of the hose. It is held by the finger tips with the hammer end horizontal so that it tends to roll out of the hand. Efforts to balance the palm

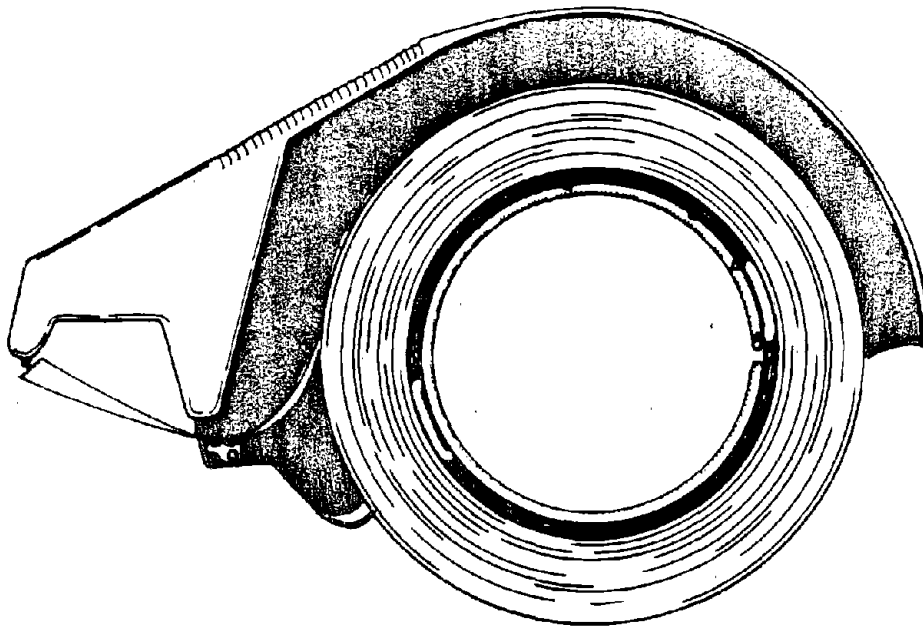


Figure 10: A tape dispenser (Scotch model 3MH12) to reduce wrist deviation in taping panels is shown.

hammer might include reducing some of the material in the tool housing (particularly on the hammer end) and relocating the air-line inlets.

Touch sensitive nerve endings in the palmar side of the fingers fatigue quickly. It has been reported that loss of touch feedback results in application of increased force by persons gripping things with their hands. Efforts to reduce sensory fatigue should focus on reduction of contact forces between the hand and the tool. This might be done by reducing tool weight and improving balance as described above, by reducing handle size to better fit the hand and by using a compliant handle material. The handle size and shape should make it possible for workers to completely wrap their fingers around it. A normal circumference of 4.5 to 5 inches is suggested for an initial design. A dense, closed cell foam plastic or a thick leather might be used to cover the handle so that fingers do not directly touch the metal handle. A possible handle design is shown in Figure 11.

Excess fabric is cut away from the edge of the panel with a pair of scissors. The scissors are held open in one position and used like a knife. Workers must flex and ulnarly deviate their wrist to hold the scissors in the cut position (see Figure C1.5a and b, right hand t = 37 to 42 seconds). These postures are factors of carpal tunnel syndrome and DeQuervain's disease and should be avoided. The scissors have hard metal handles that touch the sides of the fingers; contact forces on the sides of the fingers have been implicated in digital neuritis (see Table 2) and should be avoided. It is suggested that a knife or razor blade be used for this cut. The blade could be mounted in a fixture to

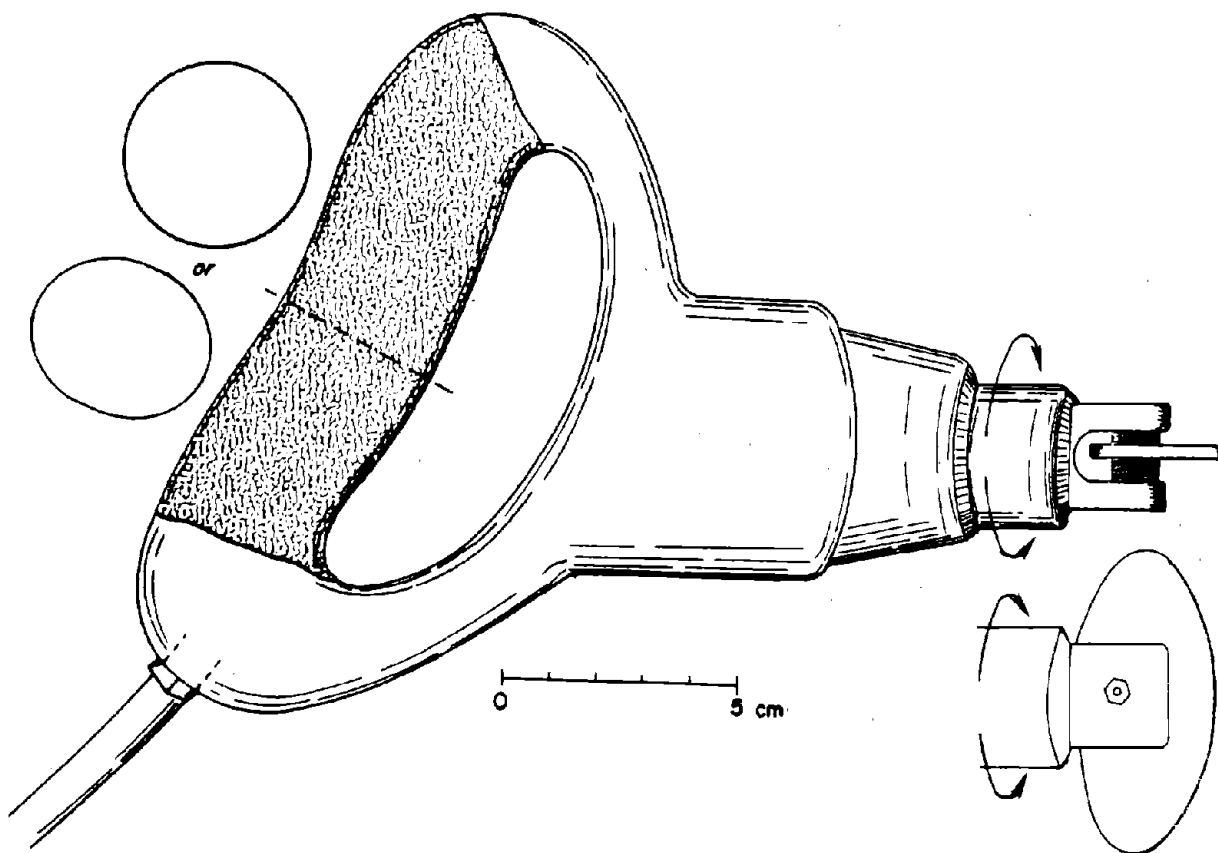


Figure 11: A possible hammer design for inserting plastic lace in upholstery is shown.

guard it and guide it during the cut. The blade should be mounted on a handle so that it can be held in the cutting position with a relaxed wrist posture. Both right and left handed versions of the tool should be provided. A possible design is shown in Figure 12.

#### 4.2.2 Assembly (see Appendix C2)

Working in pairs, each assembler performs the same basic tasks to attach face plates to the sides of acoustical office panels. The right wrist is repeatedly flexed and ulnarly deviated to align the pistol shaped pneumatic screwdriver for inserting screws into the vertical edges of panels. These exertions are in combination with ten to twenty kilogram force exertions (see Figure C2.6). Wrist flexion in combination with forceful exertions is a reported risk factor of CTS; ulnar deviation is a reported factor of DeQuervain's (Table 2). Repetitions of both types of postures and exertions should be avoided. The existing work station design in which workers must reach down to hold the screwdriver horizontally to insert screws causes flexion and ulnar deviation of the wrist. Raising the surface of the table so that the screwdrivers can be engaged without bending down and while holding the forearm should help reduce wrist flexion and ulnar deviation. Another possibility would be to select another type of screwdriver. One possible design in which a banana shaped handle is connected to the back of the tool is shown in Figure 13. The hand can slide back and forth to adjust the orientation between the screwdriver bit and the hand rather than bend the wrist. Handle diameters should be small enough so that the fingers can be wrapped completely around them. A

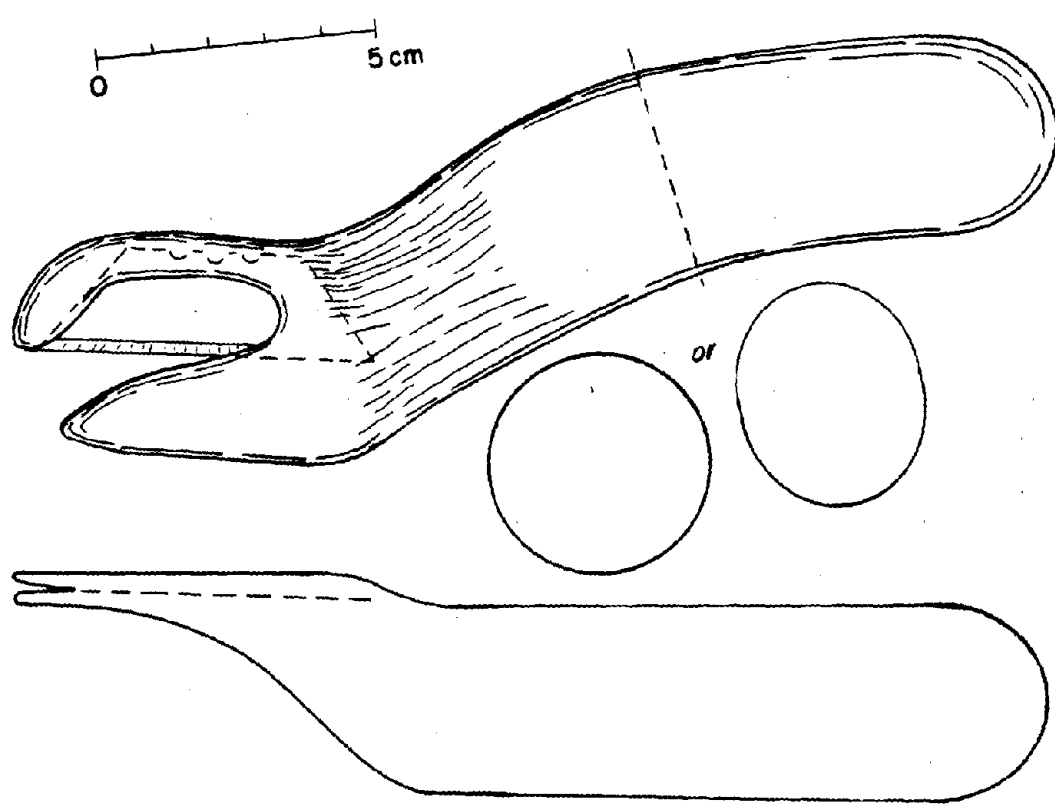


Figure 12: Suggested handle and blade designs for reducing contact stresses and wrist deviation in trimming are shown.

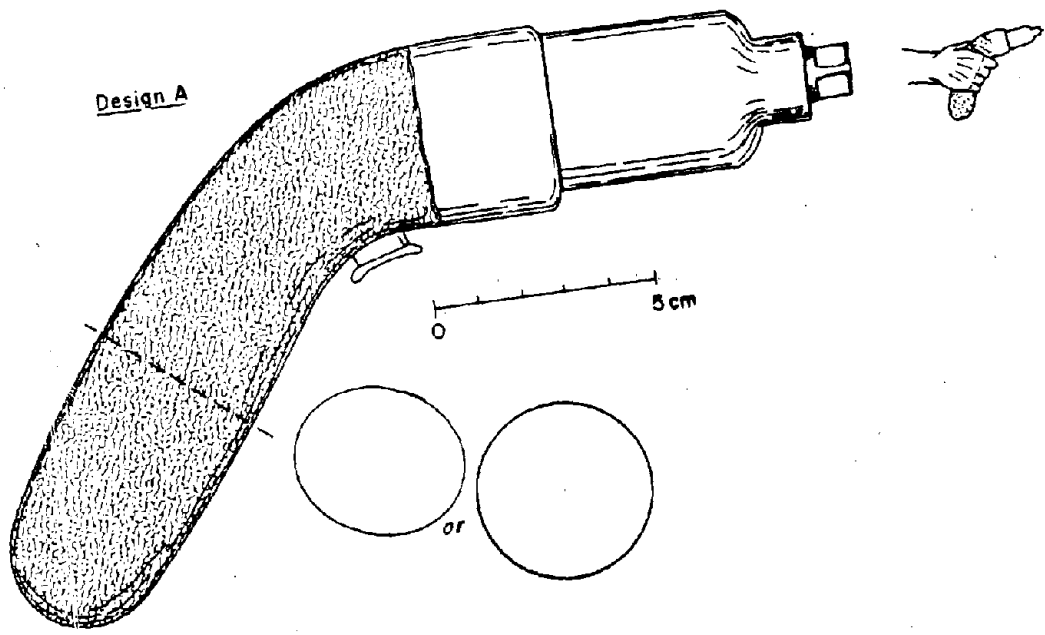


Figure 13: A possible handle designs for pneumatic screwdrivers used to screw for inserting screws in a vertical surface 30" to 40" above the floor.

circumference of 4.5 inches is recommended (43). A second design might be based on the palm hammer shown in Figure 11.

Wrist flexion and ulnar deviation also occur when workers point their pistol shaped screwdrivers up to engage screws that are to be inserted into the edge of panels. These deviations might be reduced if the screws were placed in a cartridge. Cartridges then could be mounted under the edge of the panel so that workers could reach down to engage a screw in a magnetic bit without moving their wrist (see Figure 14). Making a stock attendant responsible for loading and delivering cartridges would allow the assemblers to spend more time assembling.

Another possible work station modification would be to tilt the work surfaces so that the panels are held on a 60 to 70° angle (see Figure 15). An axial shaped screwdriver could be used on the tilted edge without flexion or ulnar deviation. Also, the screwdriver could be suspended over the work surface to eliminate bending over to pick it up. Such a design would give workers improved visibility of the edge of the panel when they are trying to align face plates and screws. Also, the hands and face plate could be rested and steadied on the edge of the panel during the alignment process. The use of tilted jigs would require separate work stations for each assembler and additional handling of panels to transfer them from one work station to the next; however, handling panels on their side would be less stressful than laying them on a flat surface because they can be held close to the body. Also, the tilted jigs would require less space, would provide greater space for storage of parts under the edge of the panel, and reduce time spent walking to get parts. A rack could be placed next to

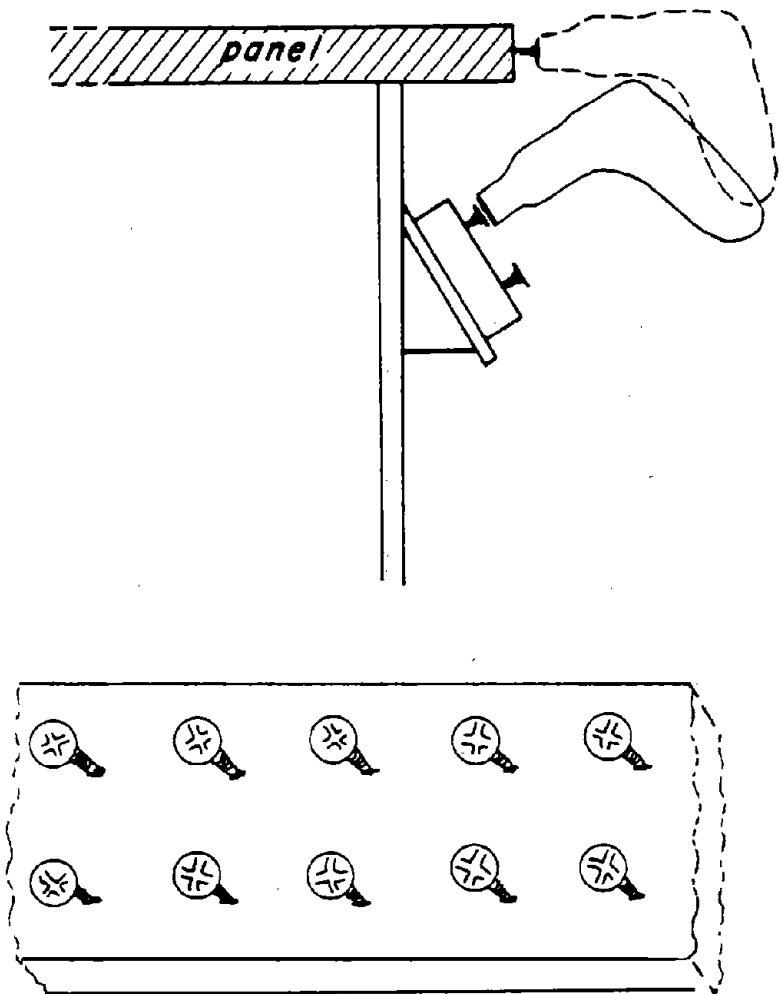


Figure 14: Possible cartridge arrangement to hold screws below edge of work surface.

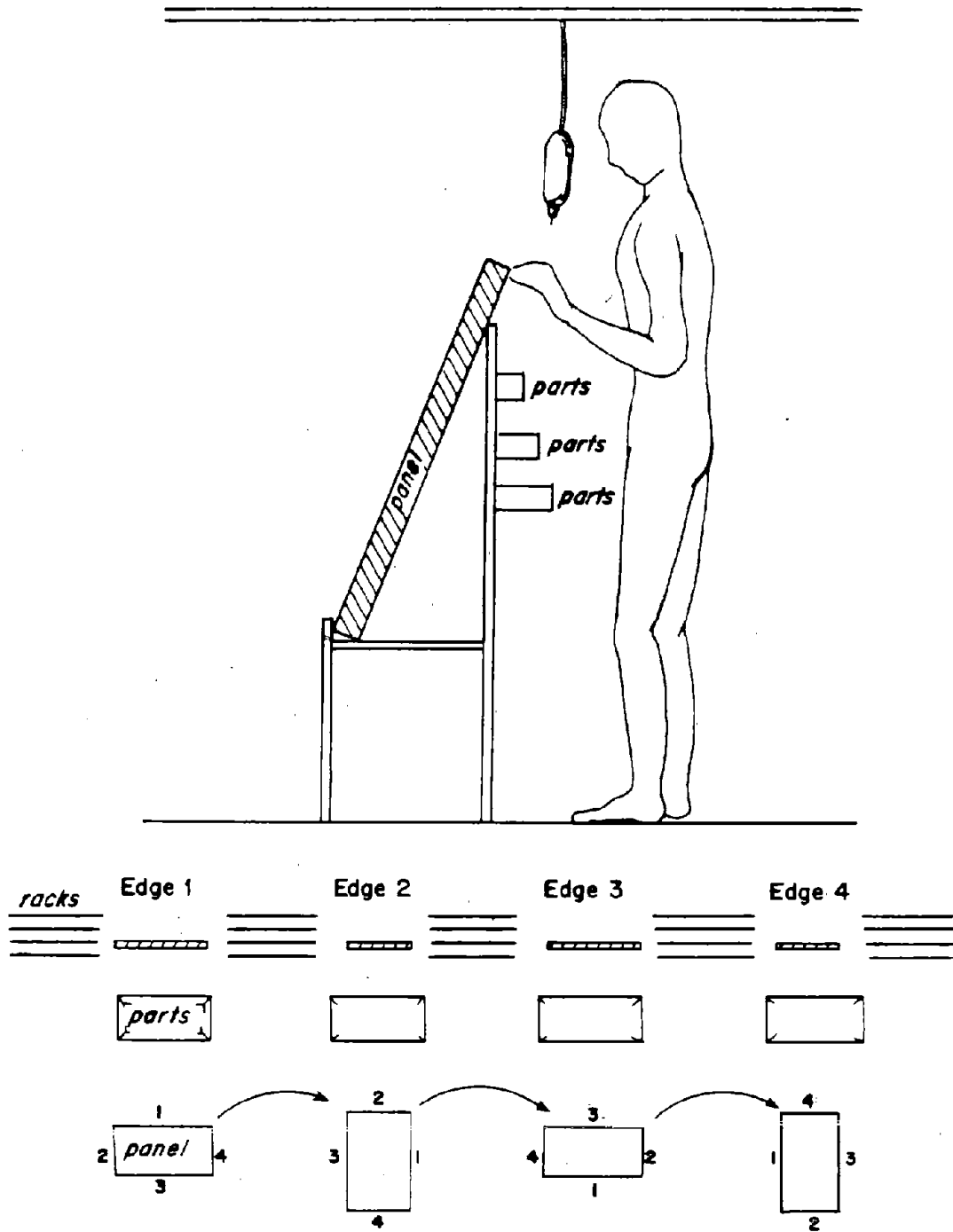


Figure 15: Possible jig arrangement to hold panels for attachment of edge hardware. A screwdriver is suspended over head and parts are stored underneath the panel.

each work station to store unfinished panels; such an arrangement would allow persons to work faster or slower than the next. Presently, the pace is set by the slower person in each pair.

A knife is used to tuck in fabric between panel and face plates. The small size of the handle could cause neuritis due to high contact force on the surface of the hand. The handle circumference should be increased to 4.5 inches to afford good grip (43). It also appears that the blade is longer and sharper than necessary, thus creating needless risk of injury. One possible design in which a disc is used instead of a blade to provide maximum freedom of wrist movement with no impact to the work surface is shown in Figure 16.

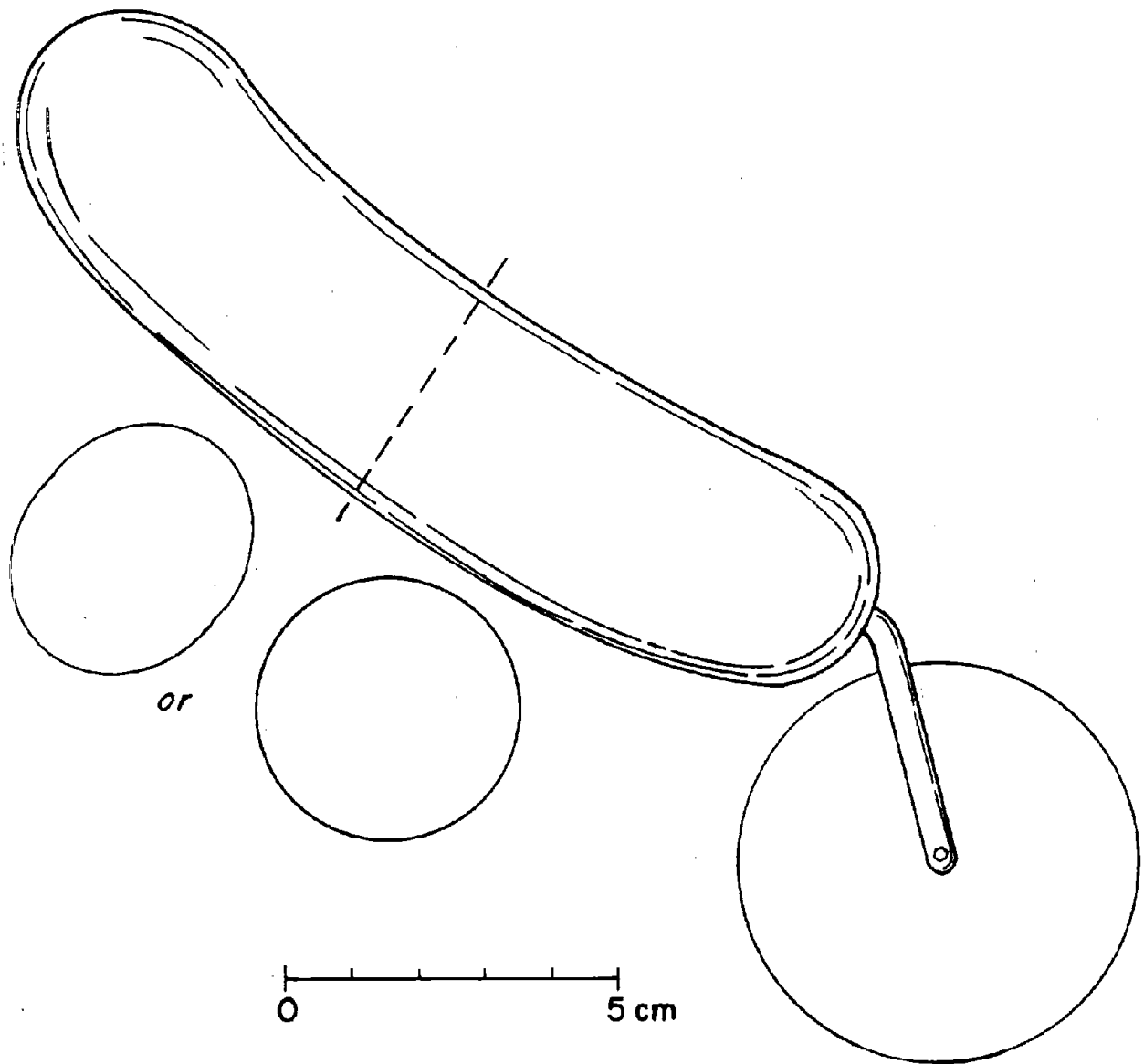


Figure 16: Possible tool for tucking fabric under face plate on edge of panel. Disc effectiveness is not affected by handle position about axis of rotation.

## V. SUMMARY

The purpose of this study was to demonstrate procedures for evaluating cumulative trauma disorders of the upper extremity that occur in persons working in industry. Five jobs in a poultry plant with incidence rates from 17.4 to 129.6 cases of cumulative trauma disorders per 200,000 work hours and two jobs in a furniture plant with 10.9 and 15.0 cases per 200,000 hours were studied to identify stressful postures, forces and work elements. Possible job modifications were suggested to reduce stressful forces and postures associated with cumulative trauma disorders. These suggestions were based on past studies of cumulative trauma disorders and work postures. In some cases, suggestions involve modification of tool handles so that the tool can be held without deviating the wrist. In other cases the recommendations involve relocating the work surface so that it can be reached without deviating the wrist. These analyses did not examine the rate of work because the relationship between work rates and cumulative trauma disorders has not been established. As in all cases, testing of these suggestions with simulations in laboratories or with in-plant pilot studies is essential before they are implemented on a large scale. This is especially true where recommendations are to be utilized by left-handed persons.



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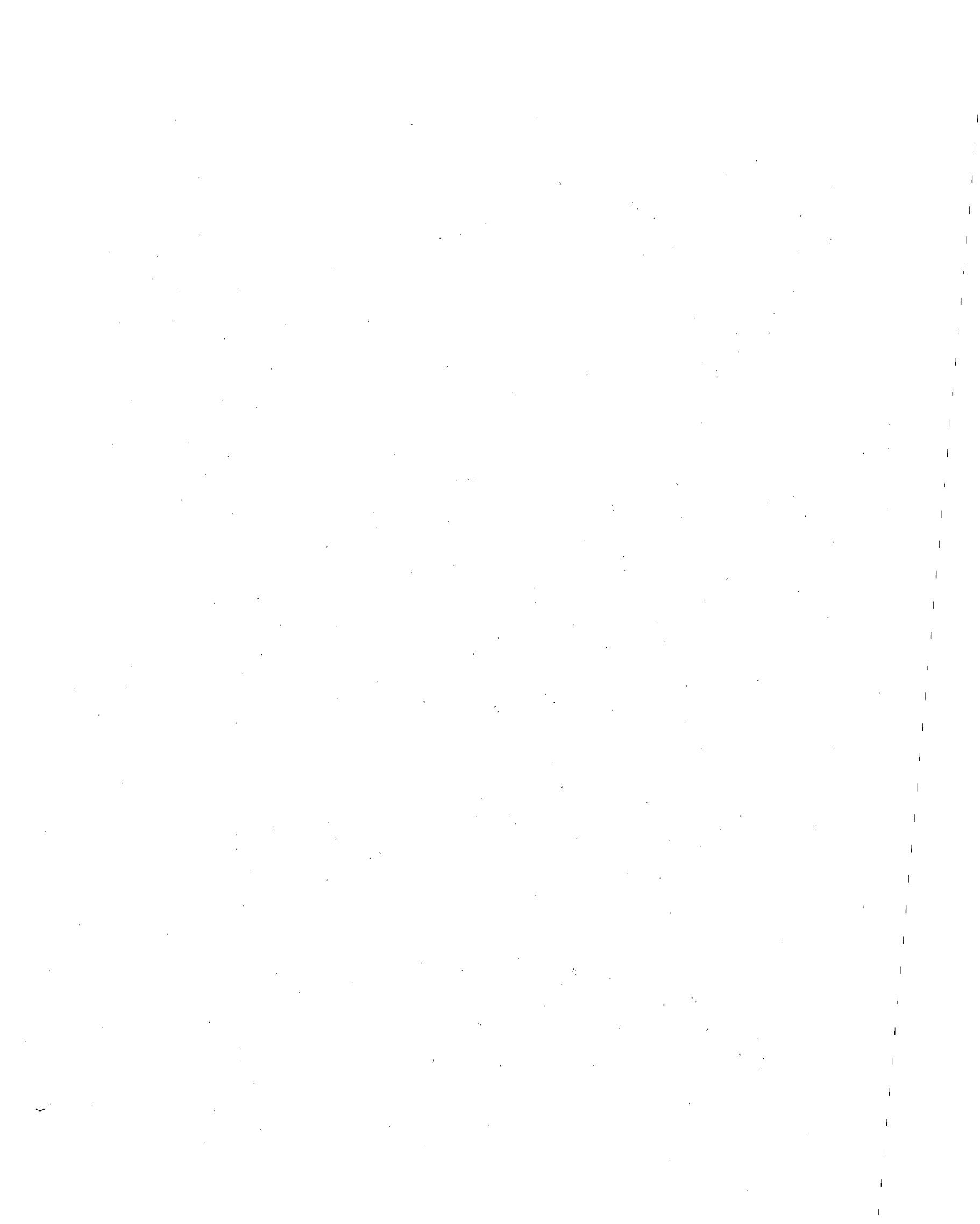
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APPENDIX A

Classification of  
Upper Extremity Positions



## Introduction

This appendix describes a scheme for classifying postures of the upper extremity. One variable is included for each degree of freedom for the wrist, elbow, and shoulder joints. Each variable can take on one of three to six values depending on the position of the joints. Hand positions are described by up to six variables, the first indicates how the hand is positioned and loaded; the following correspond to the numbers of the loaded digits. The sequence and criteria for assigning values are described in the following sections of this appendix.

A worksheet is shown in Table A1 for recording postural information from films. Each line contains all possible values for each variable. The film analyst starts on the left hand side of the page and circles the appropriate classification for each degree of freedom for each joint. The worksheet also contains values for recording EMG reading and comments. Separate forms filled out for right and left hands can be cross-referenced by frame numbers.



## SHOULDER POSITION

Shoulder position has three degrees of freedom: shoulder extension-flexion, adduction-abduction, lateral-medial angles. Shoulder flexion-extension angle, the angle of the upper arm in the sagittal plane with respect to the frontal plane, is the first degree of freedom. It ranges from fully flexed at  $1^{\circ}$ , arm pointed above torso, to fully extended at  $235^{\circ}$ , arm pointed below and behind torso (44). The full range is divided into five equal sectors as shown in Figure A1.

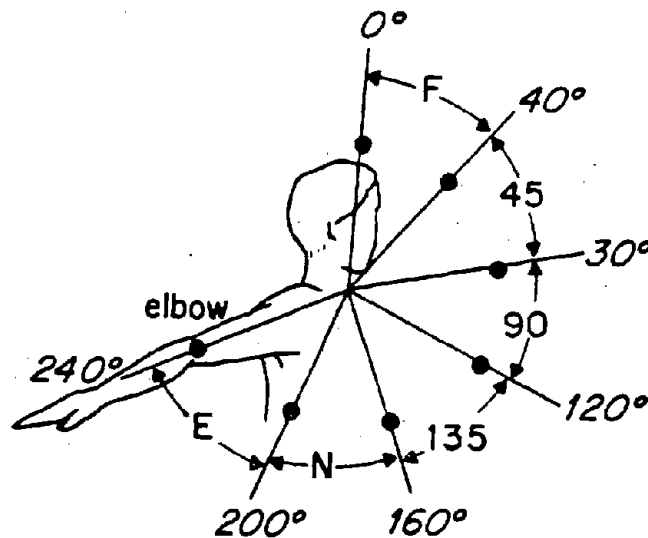


Figure A1: Shoulder flexion-extension of the upper arm is classified as one of six positions in the sagittal plane.

Shoulder adduction-abduction, the angle created by the upper arm and the transverse plane of the body, is the second degree of shoulder freedom. It ranges from full adduction at  $55^{\circ}$ , arm pointed toward and in front of torso, to full abduction at  $135^{\circ}$ , arm pointed behind and away from torso (44). The full range is divided into four equal sectors as shown in Figure A2.

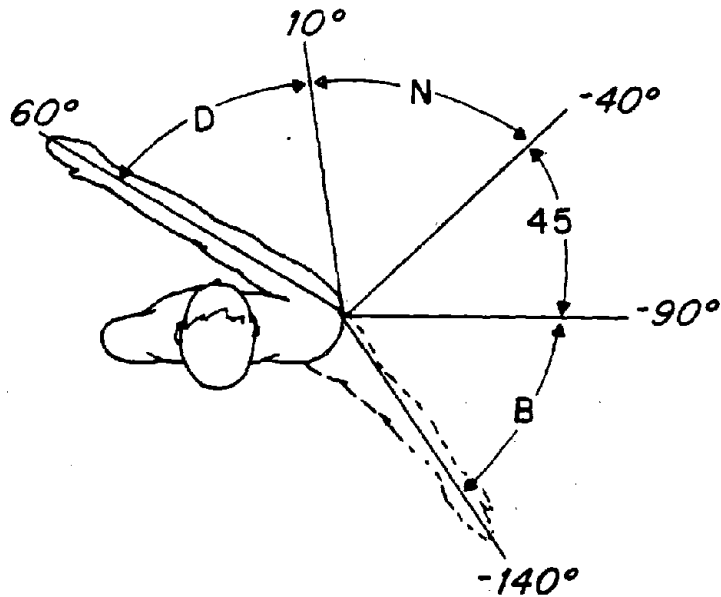


Figure A2: Shoulder Adducting-Abduction angle of the upper arm is classified as one of four sectors in the transverse plane.

Shoulder lateral-medial, the angle of rotation of the upper arm about its long axis, is the third degree of freedom. A maximum range of motion is obtained when the upper arm projects forward  $90^\circ$  to the frontal plane of the body as shown in Figure A3. The shoulder lateral-medial angle ranges from a full medial position, forearm pointed towards the midplane, of  $97^\circ$  to a full lateral position, forearm pointed away from midplane, of  $-34^\circ$  (44). The full range of motion is divided into four equal sectors as shown in Figure A3.

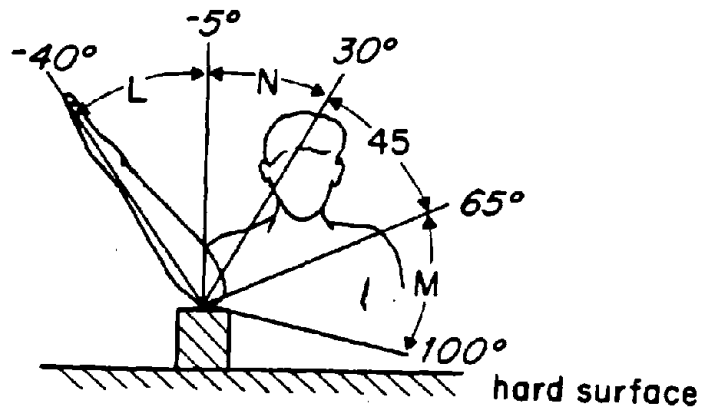


Figure A3: Shoulder: Lateral-Medial angle of the upper arm is classified as one of four sectors in the frontal plane.

ELBOW POSITION

The elbow position has two degrees of freedom: elbow angle and elbow rotation. Elbow angle is the angle made by flexing and extending the elbow moving the hands toward and away from the shoulder;  $0^\circ$  corresponds to a fully extended elbow and  $145^\circ$  a fully flexed elbow (44). The full range of motion is divided into four equal sectors as shown in Figure A4.

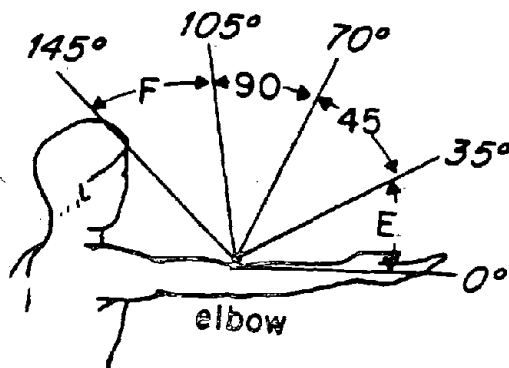


Figure A4: Elbow angle is divided into four equal sectors.

Elbow rotation is the angle of rotation of the forearm about its long axis with respect to the upper arm and has a  $190^{\circ}$  range of motion (44). Forearm rotation is divided into three equal sectors, supinated, neutral, and pronated, such that when the forearm is horizontal, the palm points up, horizontal, or down (see Figure A5).

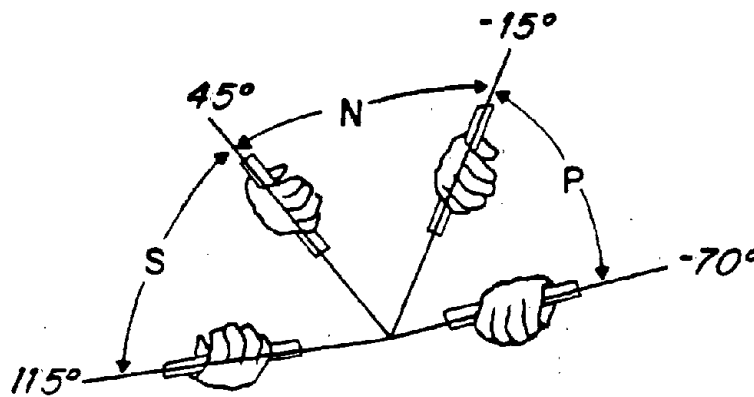


Figure A5: Elbow rotation is divided into three equal sectors.

#### WRIST POSITION

The wrist position is the angle between the long axis of the hand and the forearm and has two degrees of freedom, wrist deviation and wrist angle. Wrist deviation refers to movement from side to side (movement from the thumb towards the little finger or visa versa). Wrist deviation has a range of motion of  $57^{\circ}$  (45) and is divided into three equally spaced sectors as shown in Figure A6.

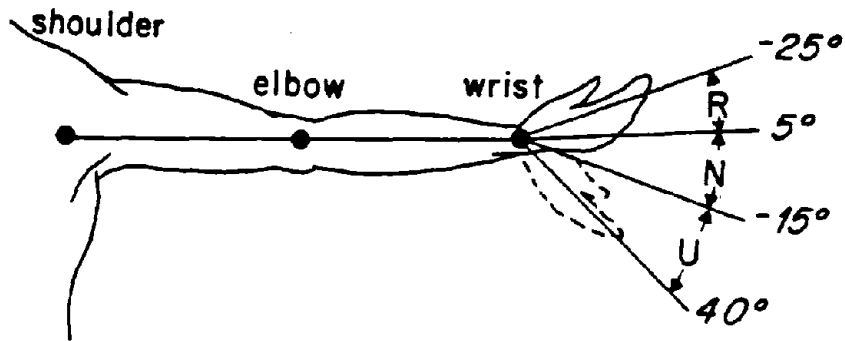


Figure A6: Wrist deviation is classified as one of three equal sectors.

Wrist angle refers to movement towards the front or the back of the hand and has a  $131^\circ$  range of motion (46). Wrist angle is divided into five equally spaced sectors as shown in Figure A7.

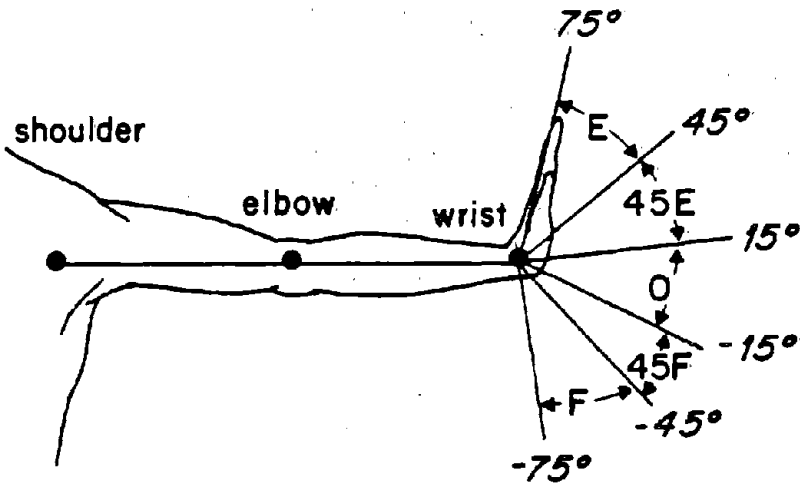


Figure A7: Wrist angle is classified as one of five equally spaced sectors.

FINGER POSITIONS (adapted from Jacobson and Sperling, 40)

Five general classes of finger positions are used: the grasp, pulp pinch, lateral pinch, palm pinch, and finger press (see Figure A8). Each of these classes is further categorized by the exact digits

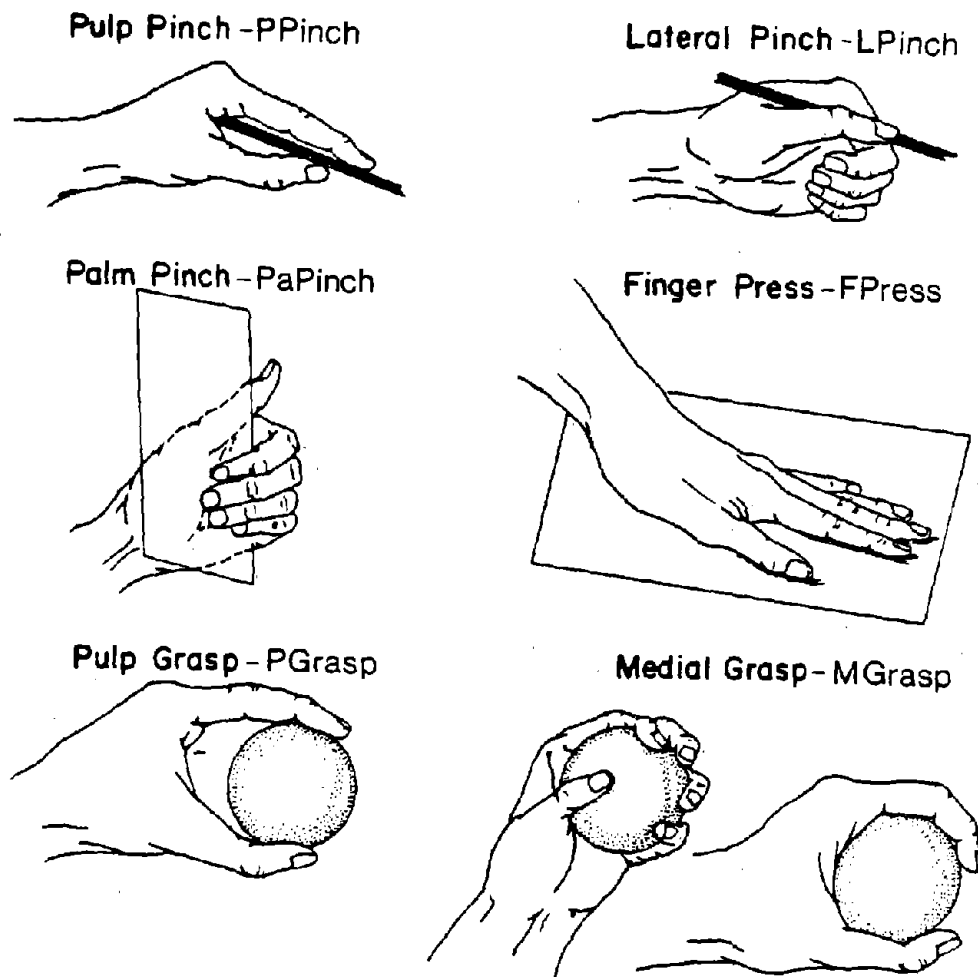


Figure A8: Six basic classes of finger position are used: grasp, pulp pinch, lateral pinch, palm pinch, and finger pinch. Grasp is further divided into pulp grasp or medial grasp depending on how much contact there is between the hand and the object being grasped.

used. The numbering system used:

0 = palm (only where applicable)

1 = thumb

2 = forefinger

3 = middle finger

4 = ring finger

5 = little finger

The grasp is defined as an exertion where the object is supported between the fingers, thumb, and palm. There are two different types of grasps each defined by the region of the fingers where most of the pressure is applied (See Figure A8). A grasp in which the object does not contact the hand between the first and second knuckle is designated as a pulp grasp (P on work sheet), a grasp in which the object is in continuous contact from the palm to the finger tips is designated as a medial grasp (M on work sheet).

The pulp pinch (PPinch on work sheet) occurs when any number of fingers grip an object, with direct opposition between pulps and the thumb (See Figure A8).

The lateral pinch (LPinch on work sheet) is also the result of direct opposition between the fingers and the thumb, but the pressure contact is either on the medial surface or sides of the fingers (See Figure A8).

A palm pinch (PaPinch on work sheet) is the same as a pulp and lateral pinch except the fingers exert pressure on the palm of the hand and not the thumb. Therefore, a 1 PaPinch is possible where as a 1 PPinch is not (See Figure A8).

Finger press (FPress on work sheet) is a push by any of the five digits and the palm against a fixed working surface. This type of finger position occurs if one wishes to keep an object stationary (on a surface) or to guide it into a machine of some kind (See Figure A8).

APPENDIX B

Job Descriptions and Analyses  
for Poultry Plant  
(All right-handed subjects)

Work Methods Analysis for Plant

## APPENDIX B1

### Oyster Cut

The oyster cutter makes a crescent shaped incision above each thigh to separate the meat from the backside of the pelvis bones (see Figure B1.1). The knife is held in the right hand (only right-handed workers were observed) with the tip of the blade pointed down and the sharp edge towards the worker (see Figure B1.1). The blade is inserted at the eleven o'clock position on the left side and worked in and out in a clockwise manner to the five o'clock position. Next, the blade is inserted into the one o'clock position of the right side and worked in and out to the seven o'clock position. The blade is then bent outward to open the incision. The left hand is used to hold and orient the turkey for cutting.

The oyster cutter cuts every third turkey or 6 turkeys per minute. If the turkeys are large, each worker cuts only one oyster per turkey; if the turkeys are small, each worker cuts two oysters per turkey. Based on seven hours of cutting per shift, an oyster cutter could cut from 2,530 to 5,040 oysters per shift depending upon the turkey size.

Annotated MTM elements and upper extremity postures for two cycles of a representative worker are shown in Figures B1.2 through B1.7. Joint positions are expressed according to the scheme described in Appendix A.

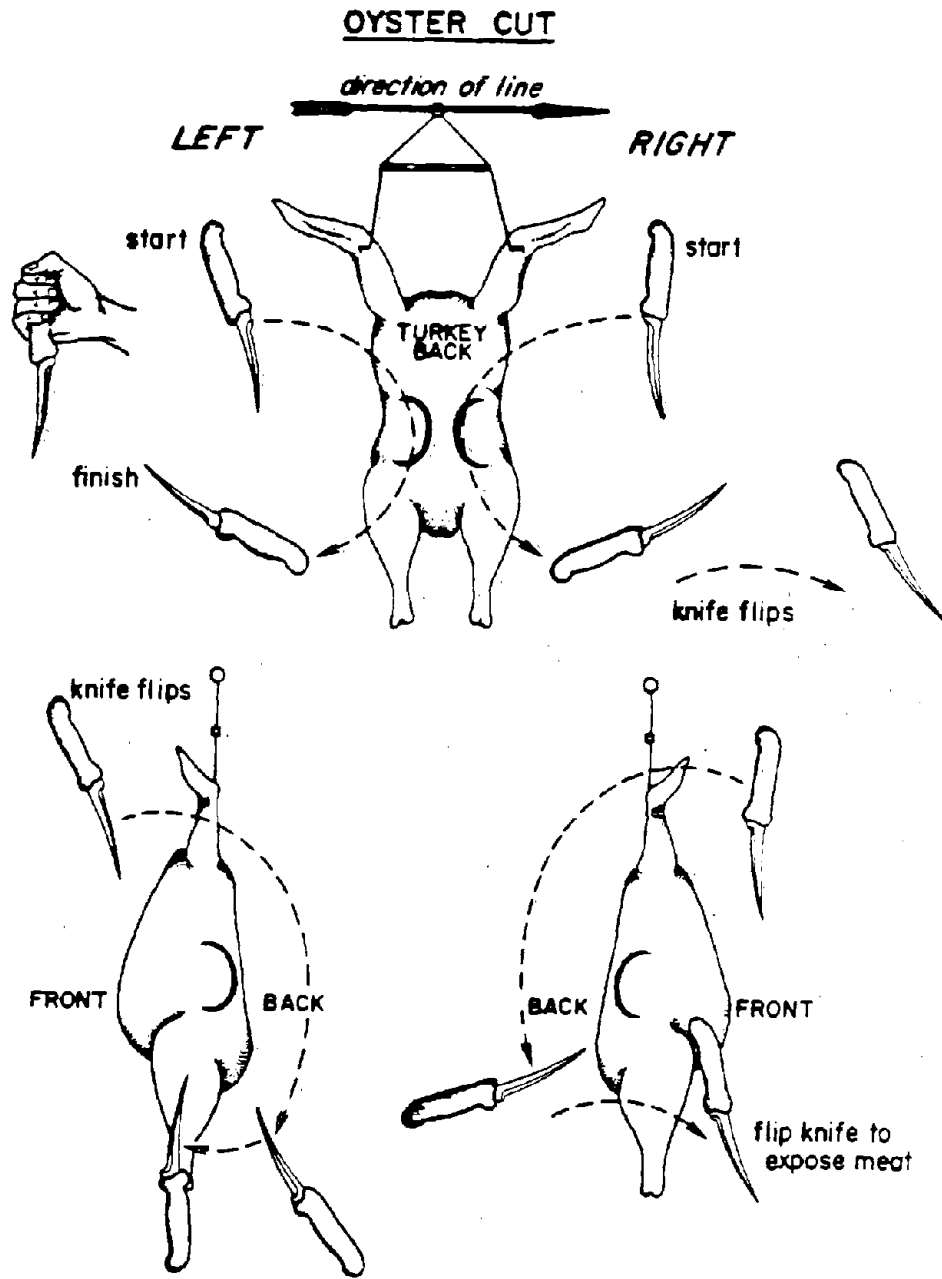
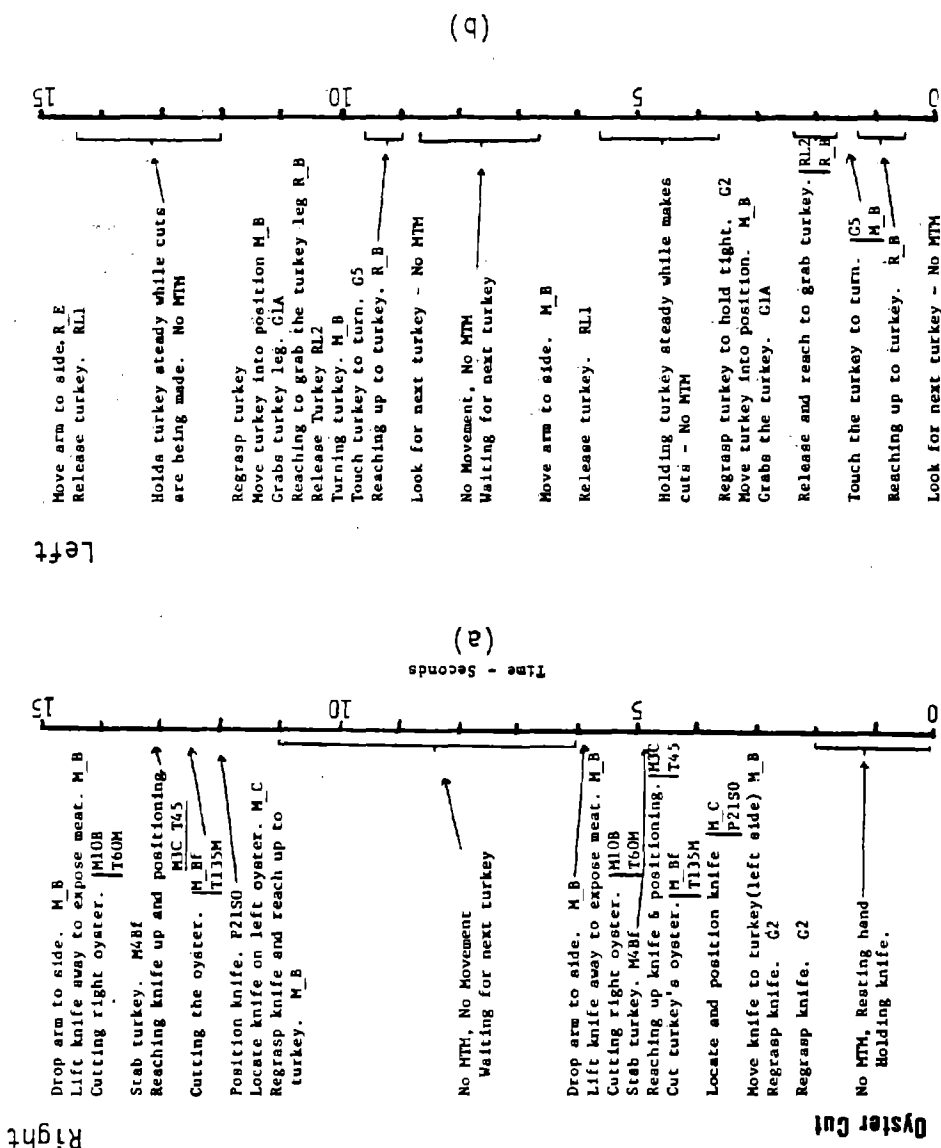


Figure Bl.1: The knife design and cutting sequence are shown for both the right and left Oyster Cuts.

Figure B1.2: MTM elements and element descriptions for two cycles of oyster cut. Both the right and left oysters are cut in each cycle.



(b)

(a)

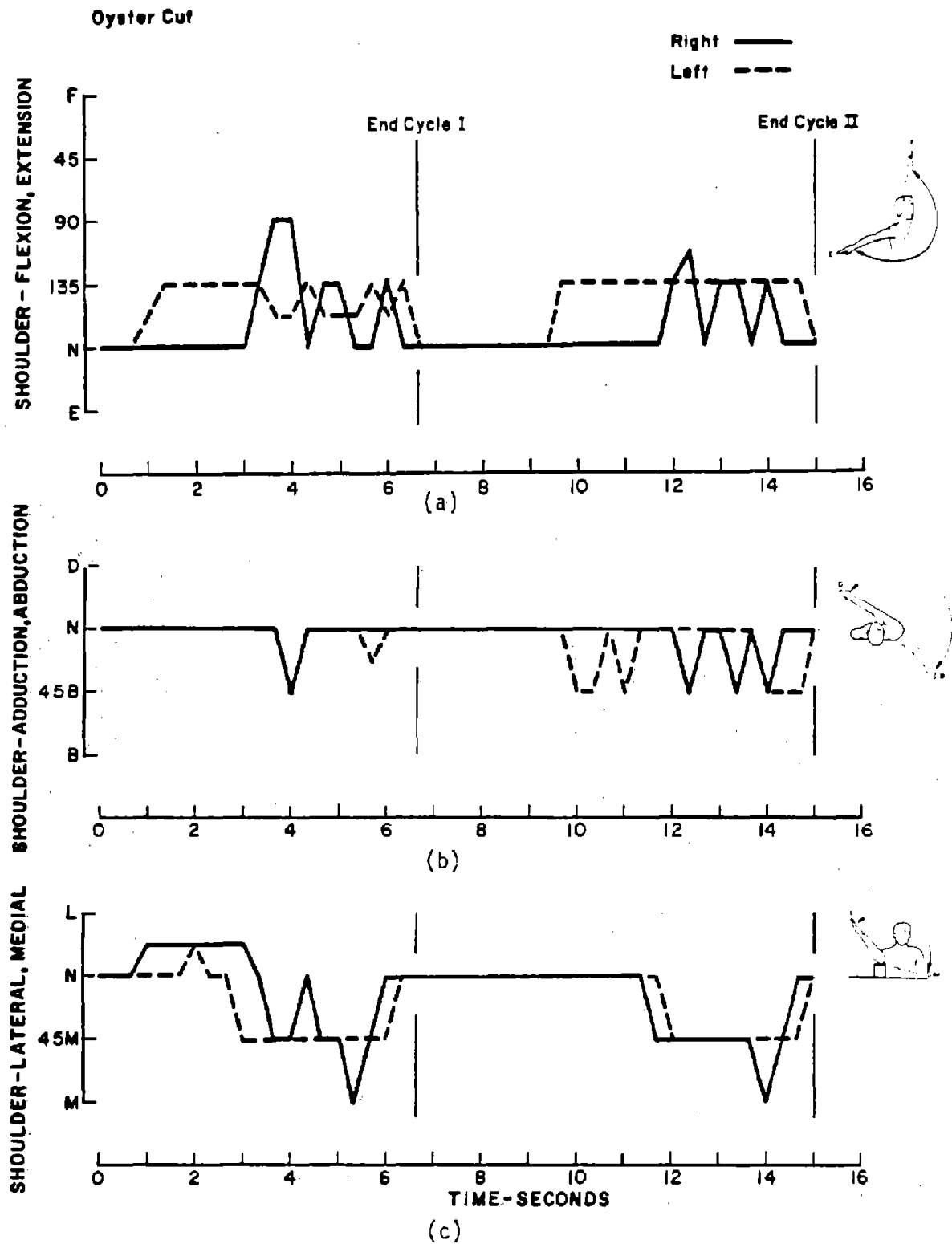
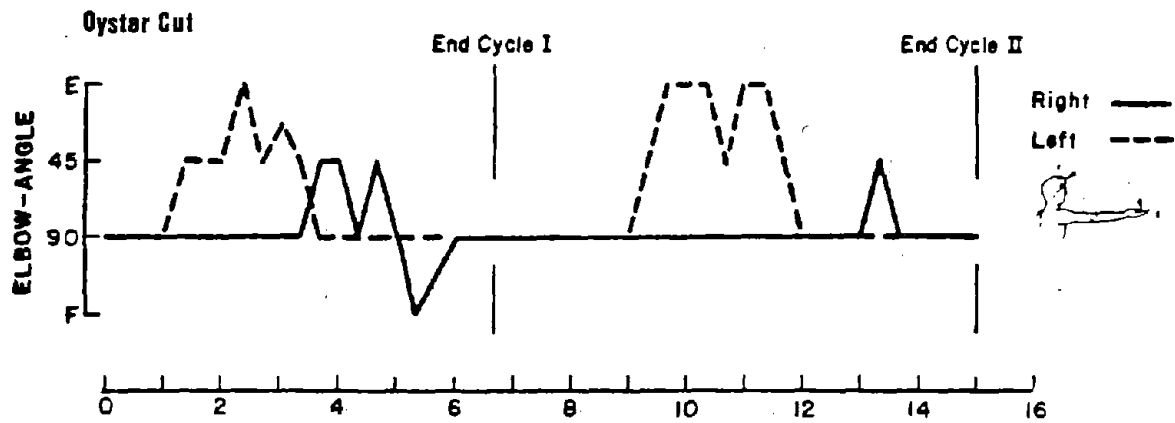
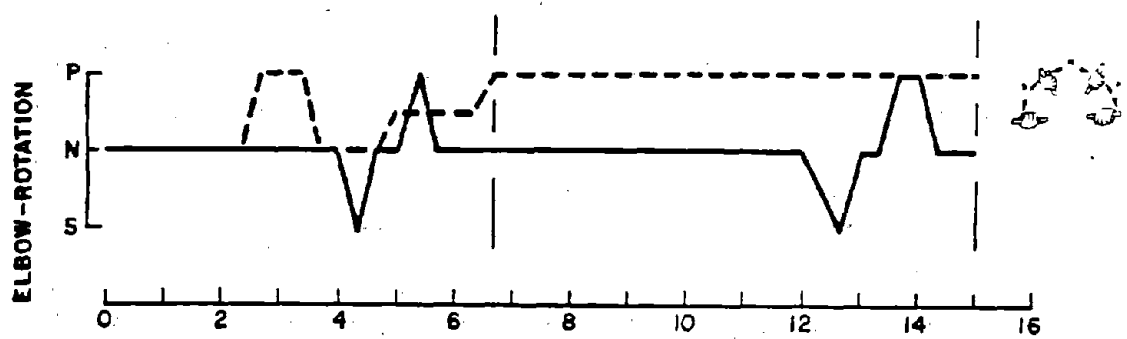


Figure B1.3



(a)



(b)

Figure B1.4

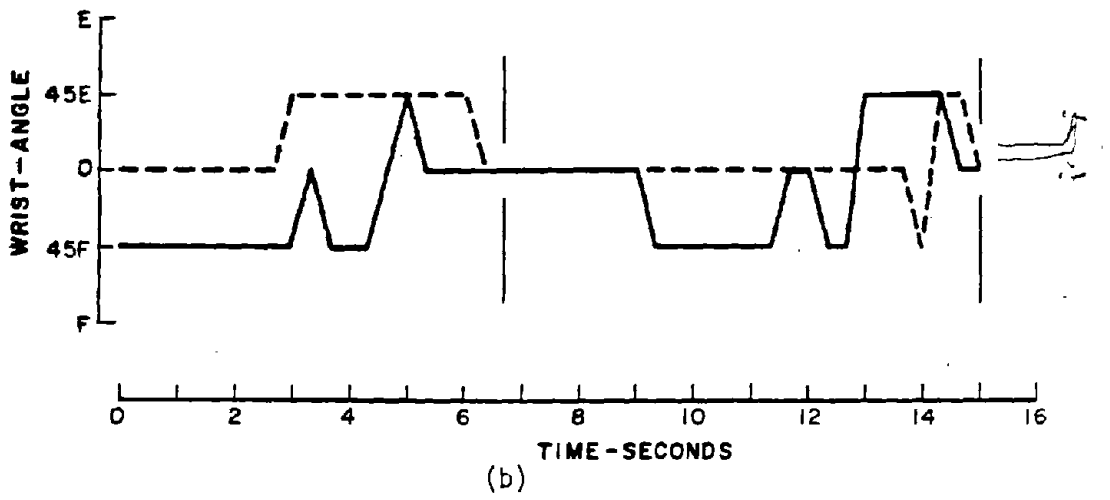
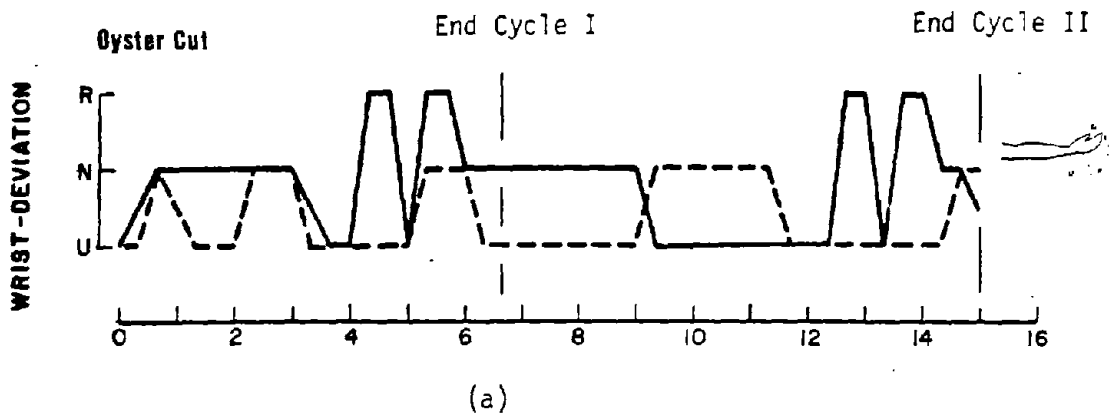


Figure B1.5

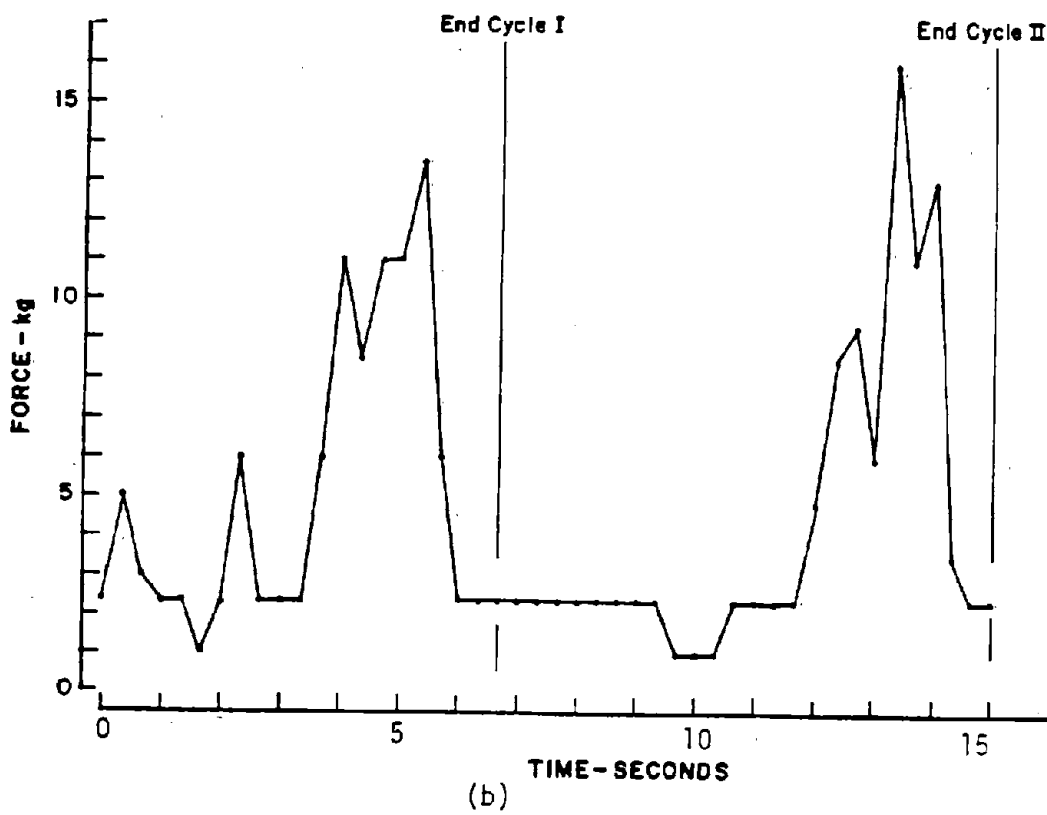
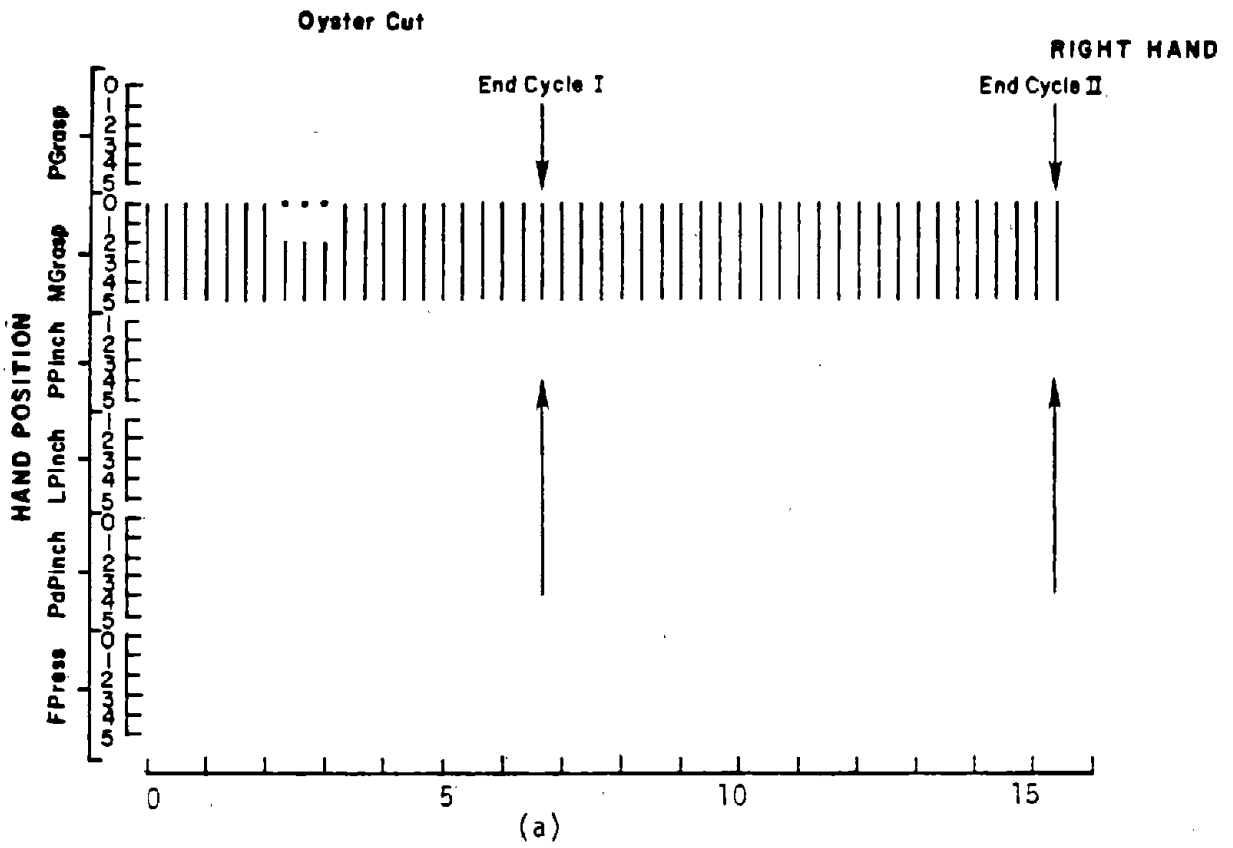


Figure B1.6

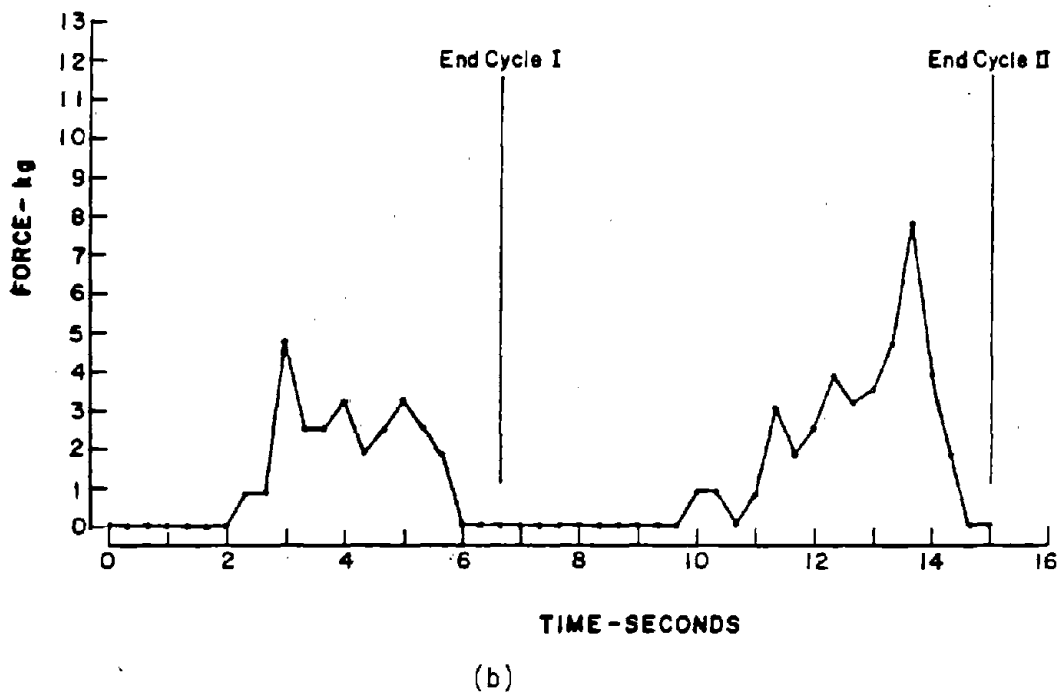
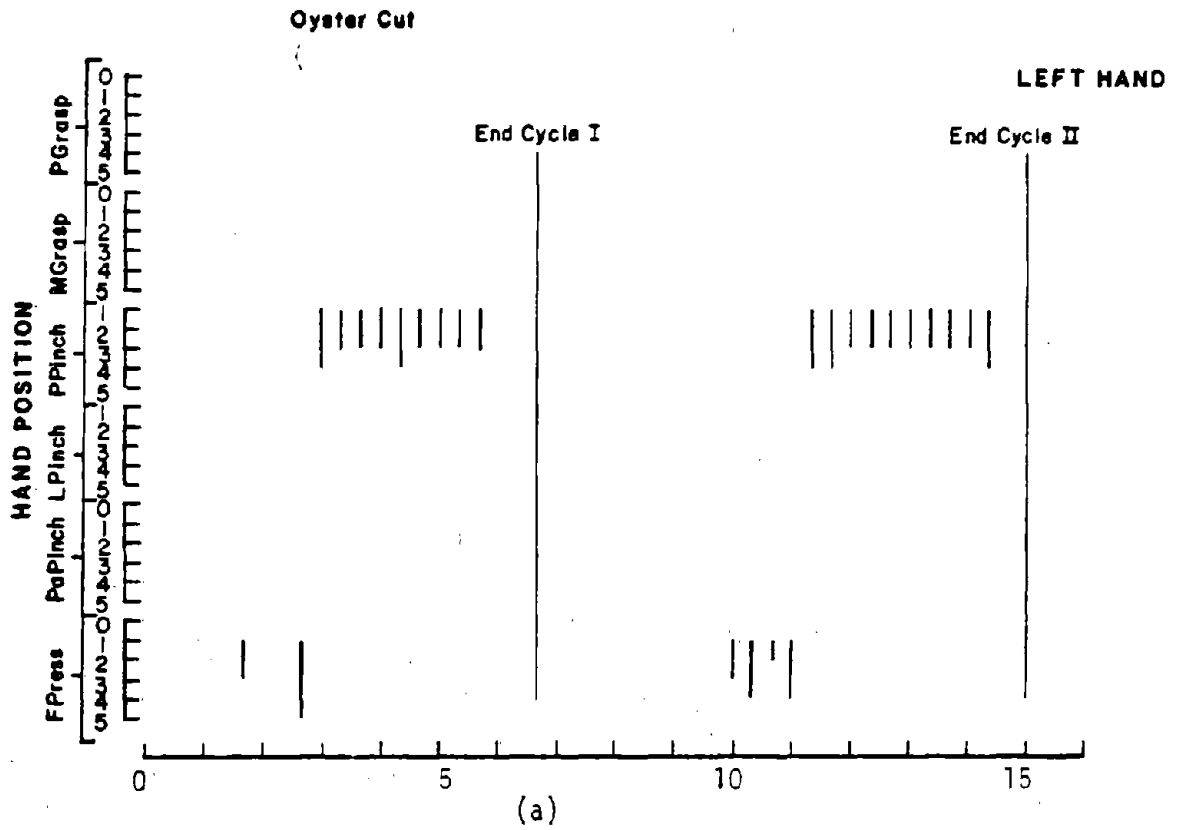


Figure B1.7

## APPENDIX B2

### Breast Cut

The turkeys, hanging from overhead conveyors by their wings, are rotated so that their breast faces the worker. One worker cuts only one of two breasts on a given turkey. The knife is held in the right hand (only right-handed cutters were studied) with the index finger on the back side of the blade with the top pointed away from the cutter and the sharp edge down (see Figure B2.1). Three separate cuts are required to separate the breast. First an incision approximately three inches across and two inches is made down towards the sternum (see Figure B2.1). The turkey then is rotated to the workers' left to expose the right breast under the wing. A second incision then is made 3 inches horizontally and two inches downward towards the sternum, stopping at the starting point of the first cut. The loose breast is grasped with the left hand. A third cut then is made to deepen the first two cuts 2 to 3 inches. The knife is inserted downward under the wing and worked in and out along the rib cage to the sternum.

Each breast cutter cuts every fourth turkey or about 4.5 turkeys per minute. Based on seven hours of cutting per shift, a breast cutter could make as many as 5,670 cuts per shift.

Annotated MTM elements and upper extremity postures for two cycles of right breast cut are shown in Figures B2.2 through B2.7. Joint positions are expressed according to the scheme described in Appendix A.

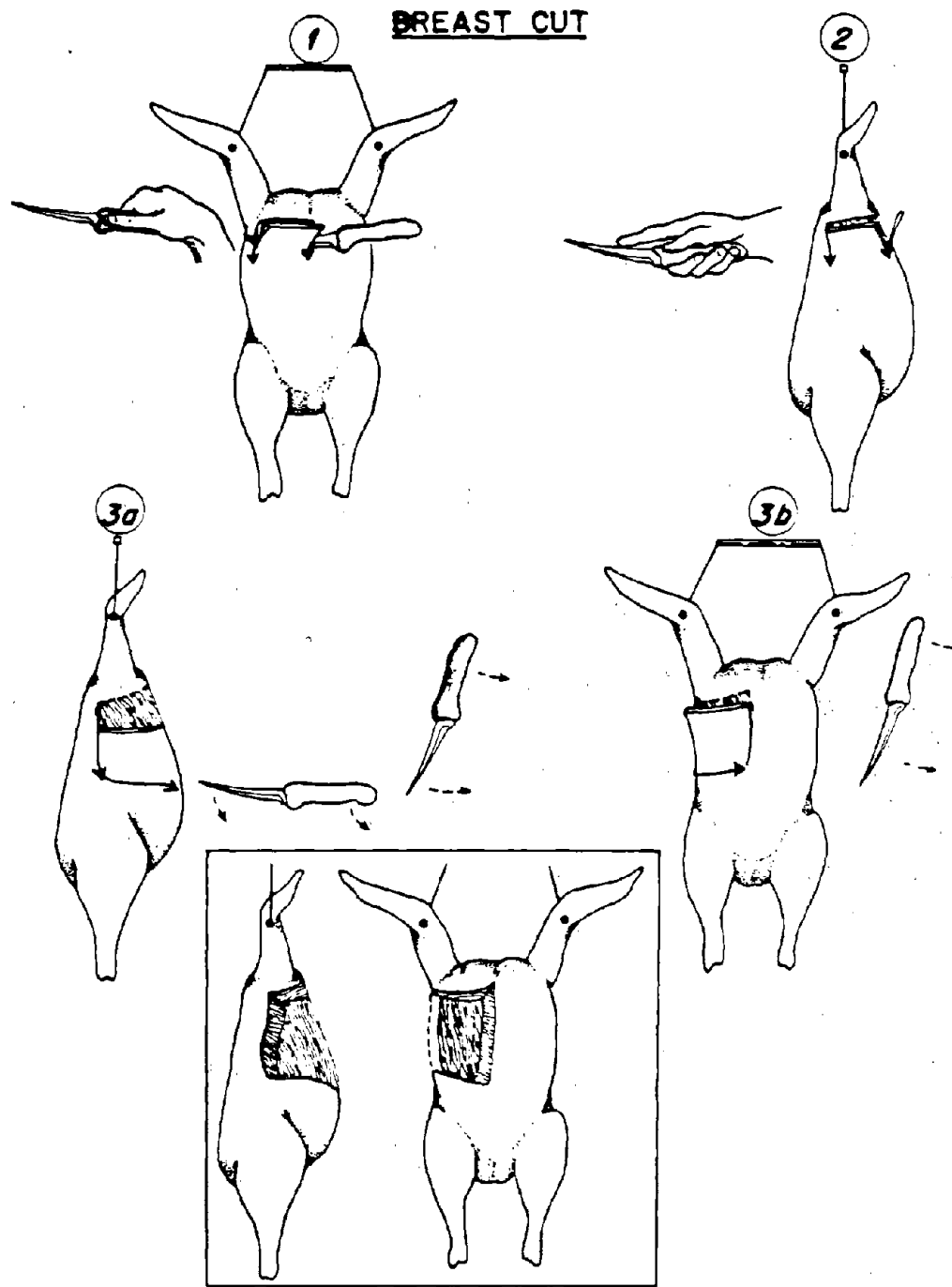
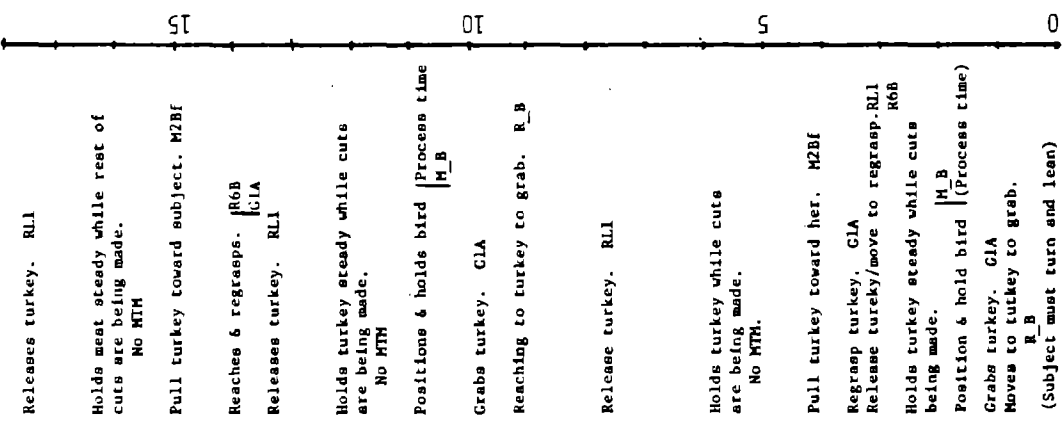


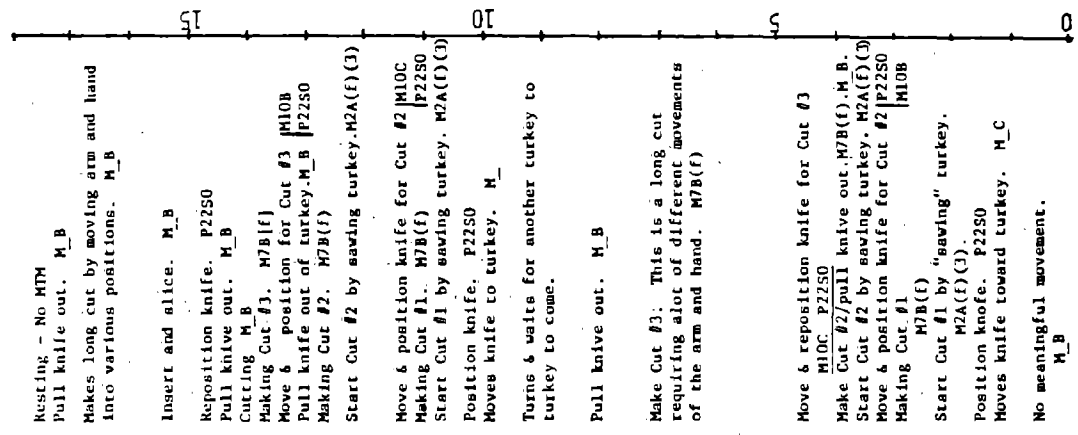
Figure B2.1: The knife design and cutting sequence are shown for the right Breast Cut.

LEFT



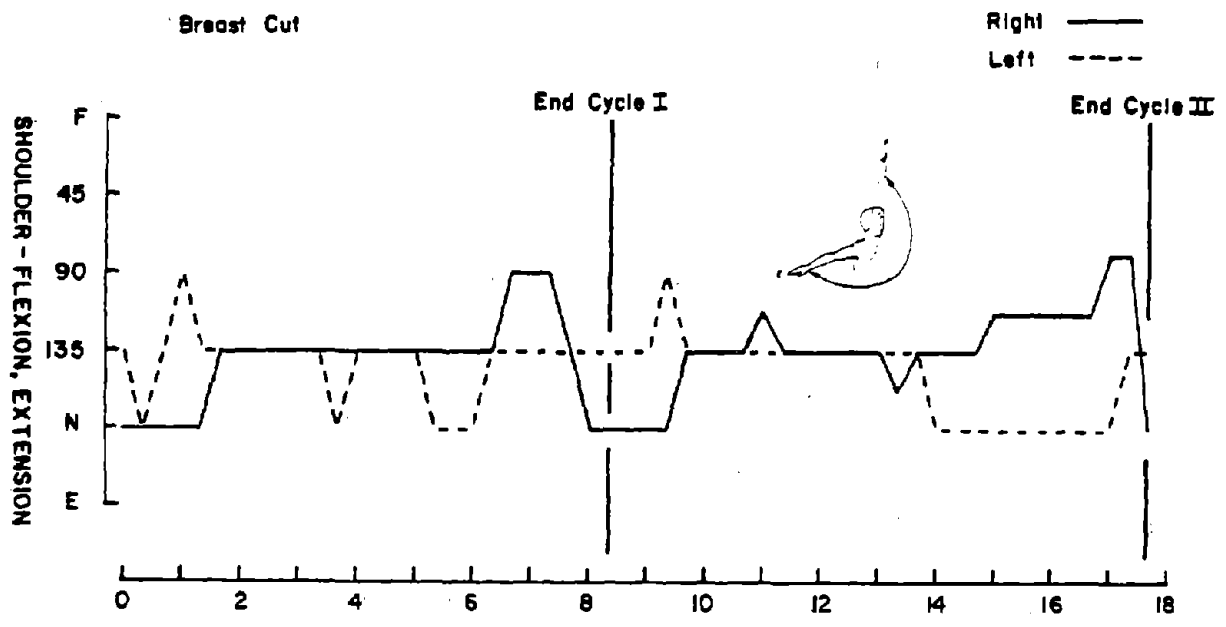
(a)

RIGHT

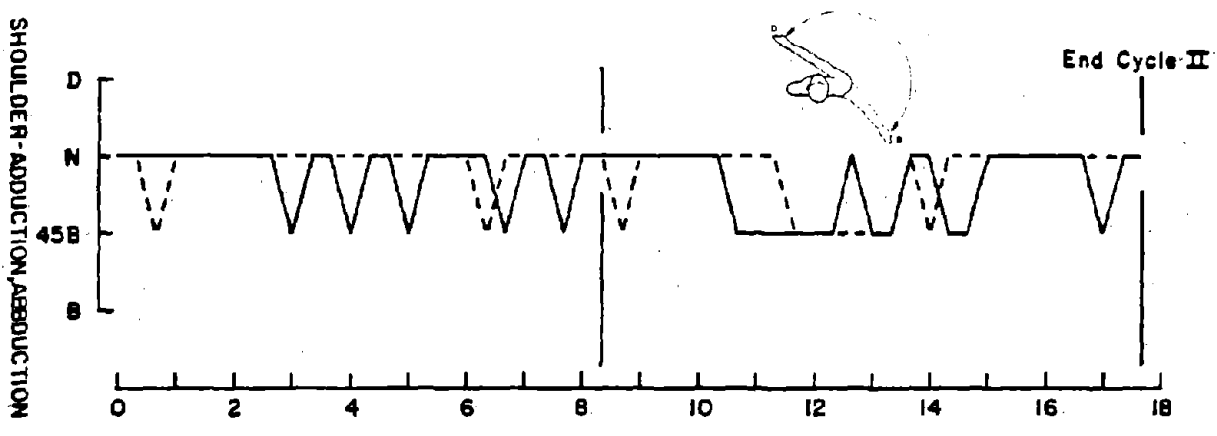


(b)  
Time/seconds

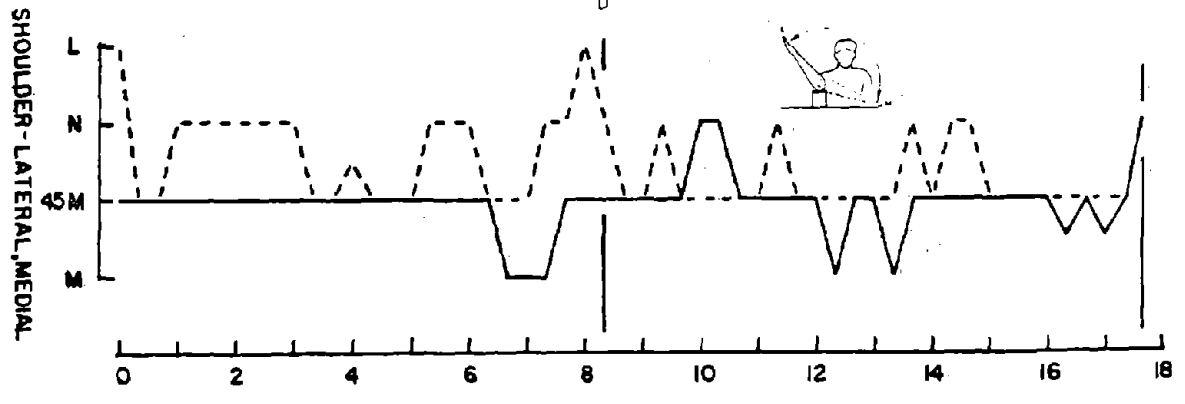
Figure B2.2 MTM elements and element descriptions are shown for two cycles of right breast cut.



a



b



c

Figure B2.3

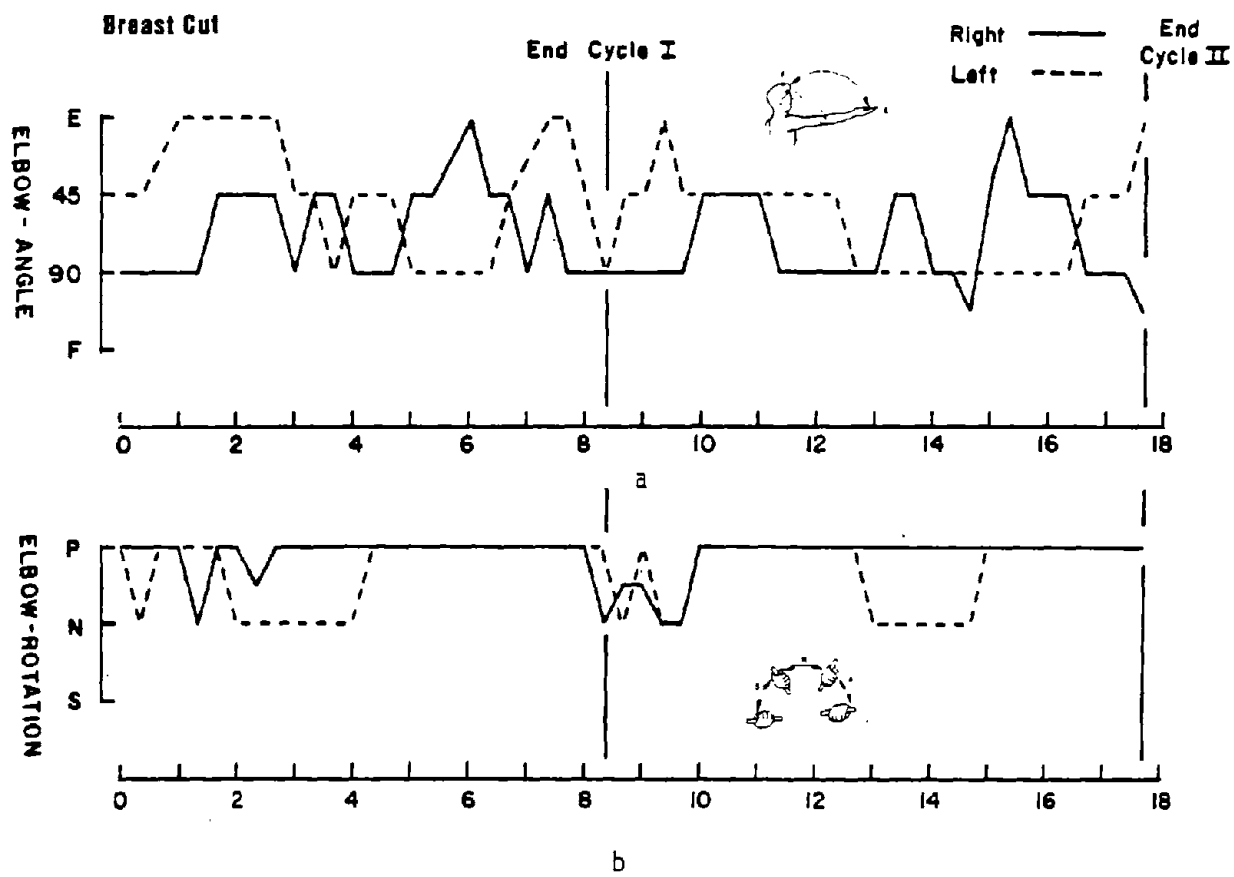


Figure B2.4

Breast Cut

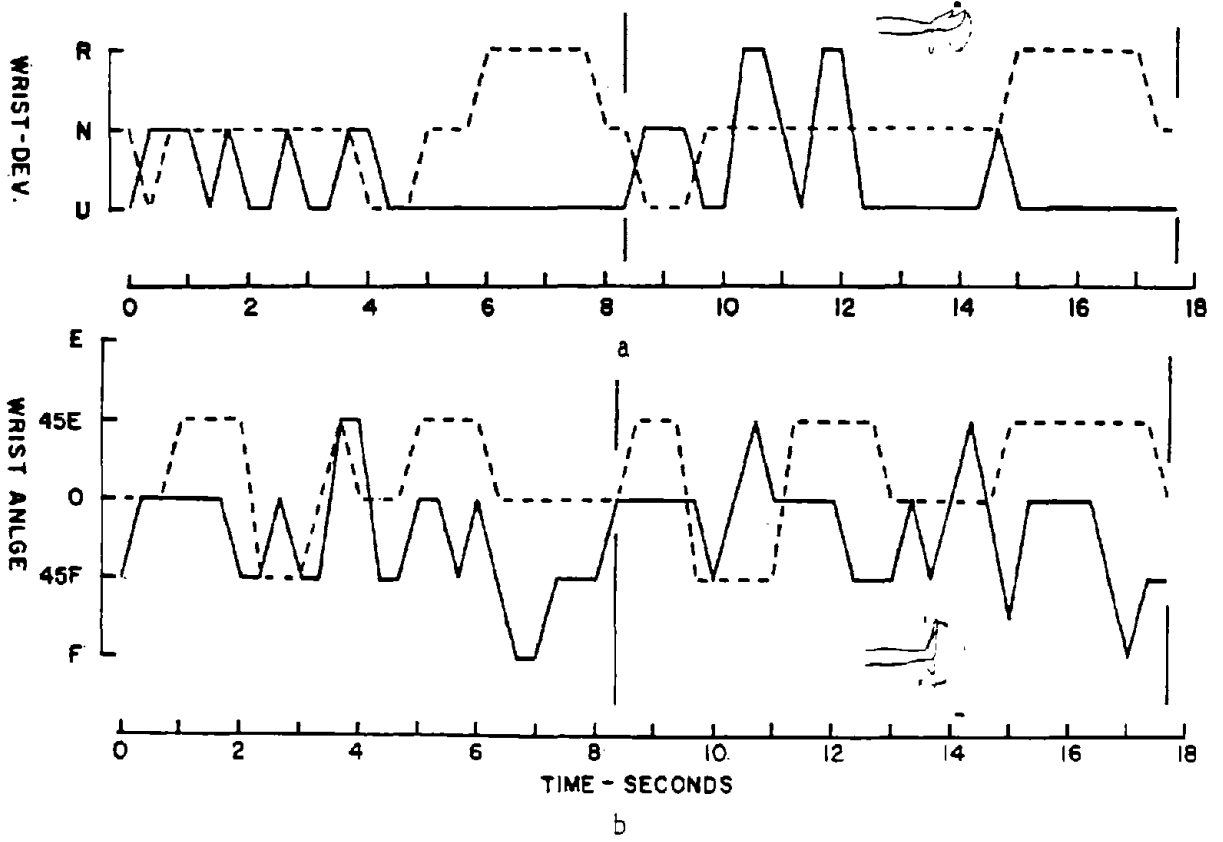


Figure B2.5

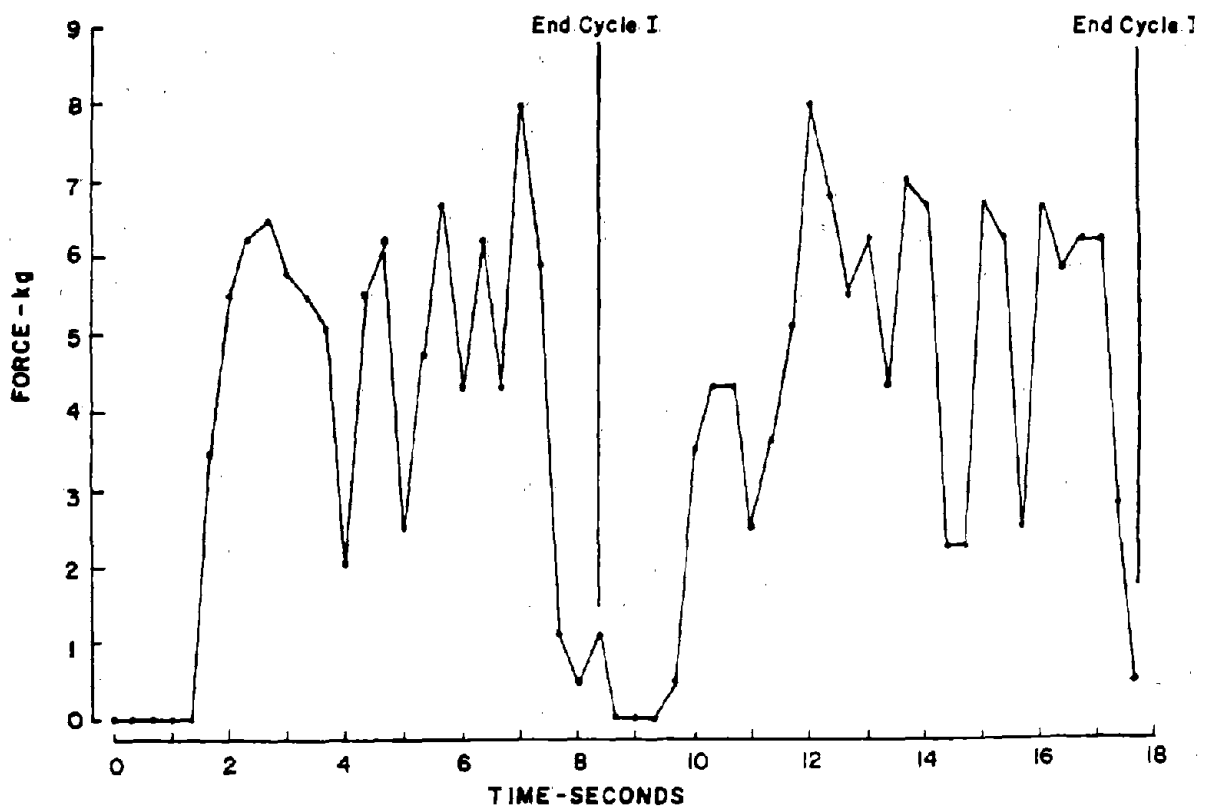
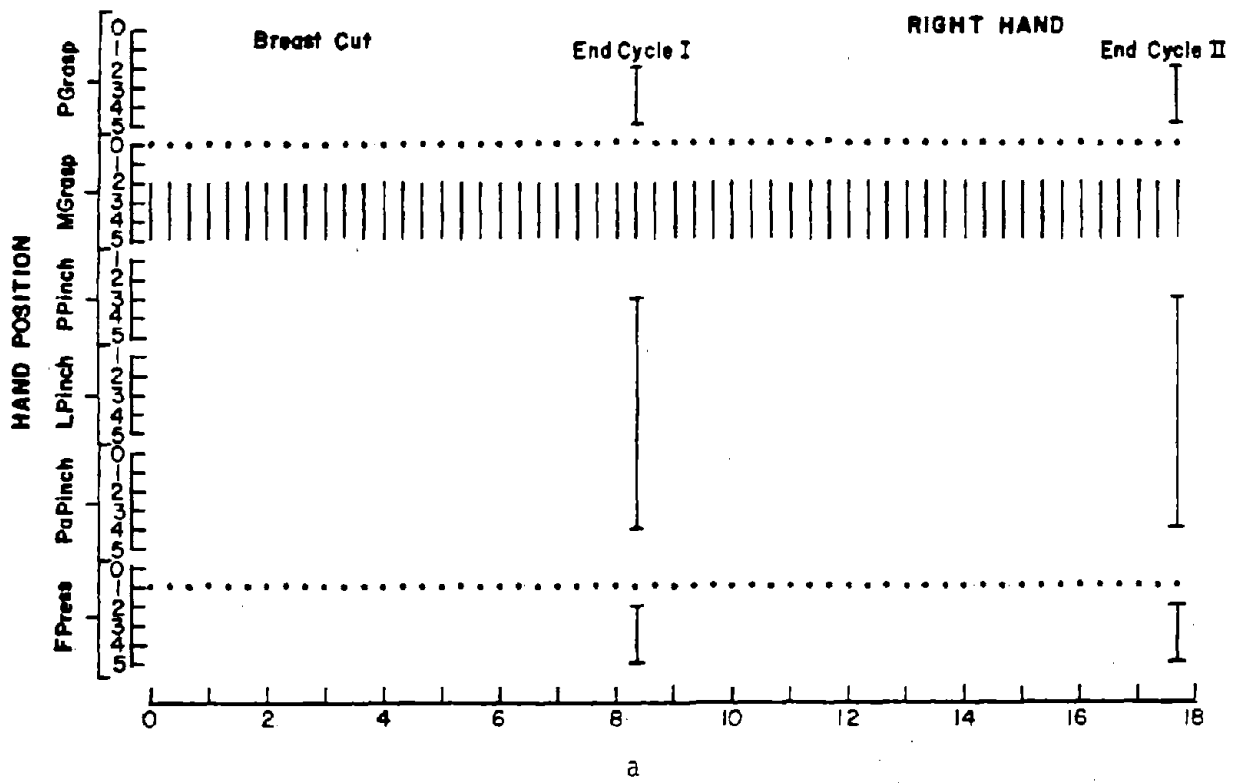


Figure B2.6

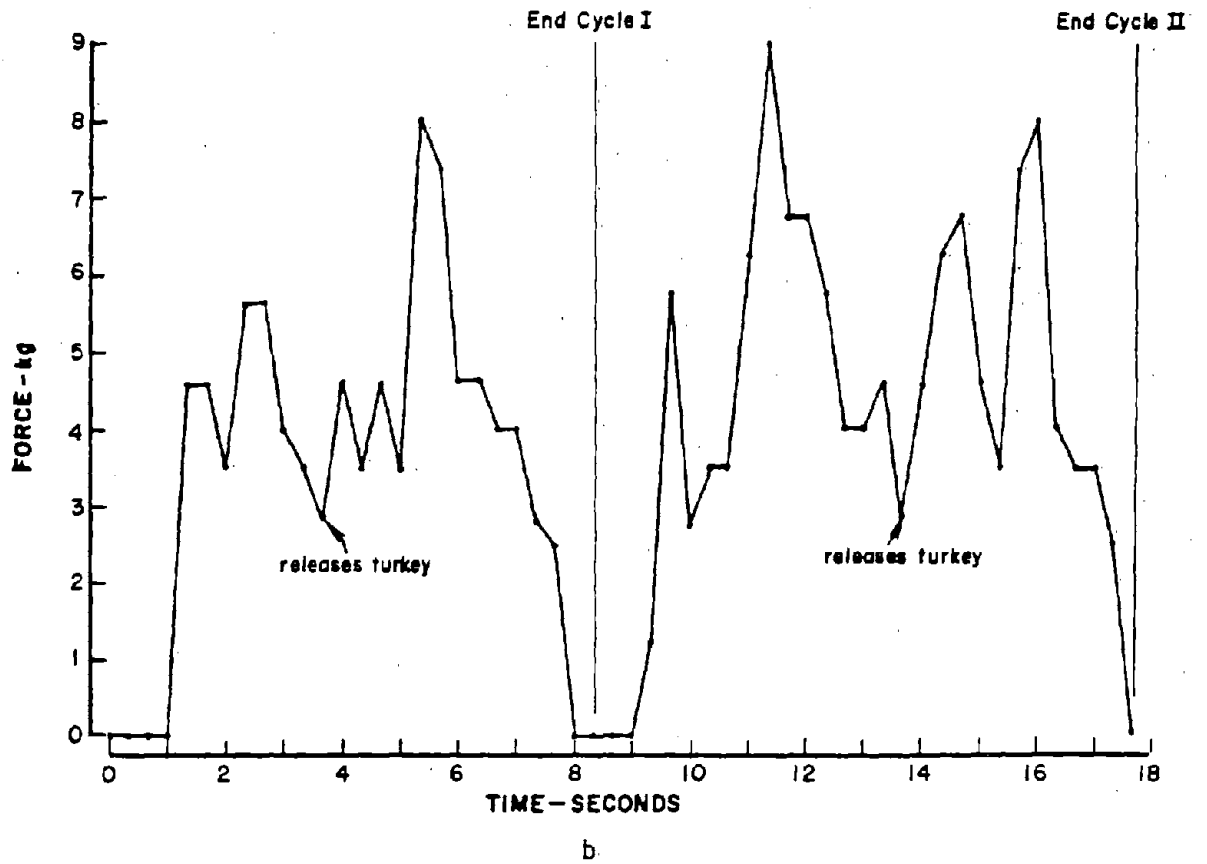
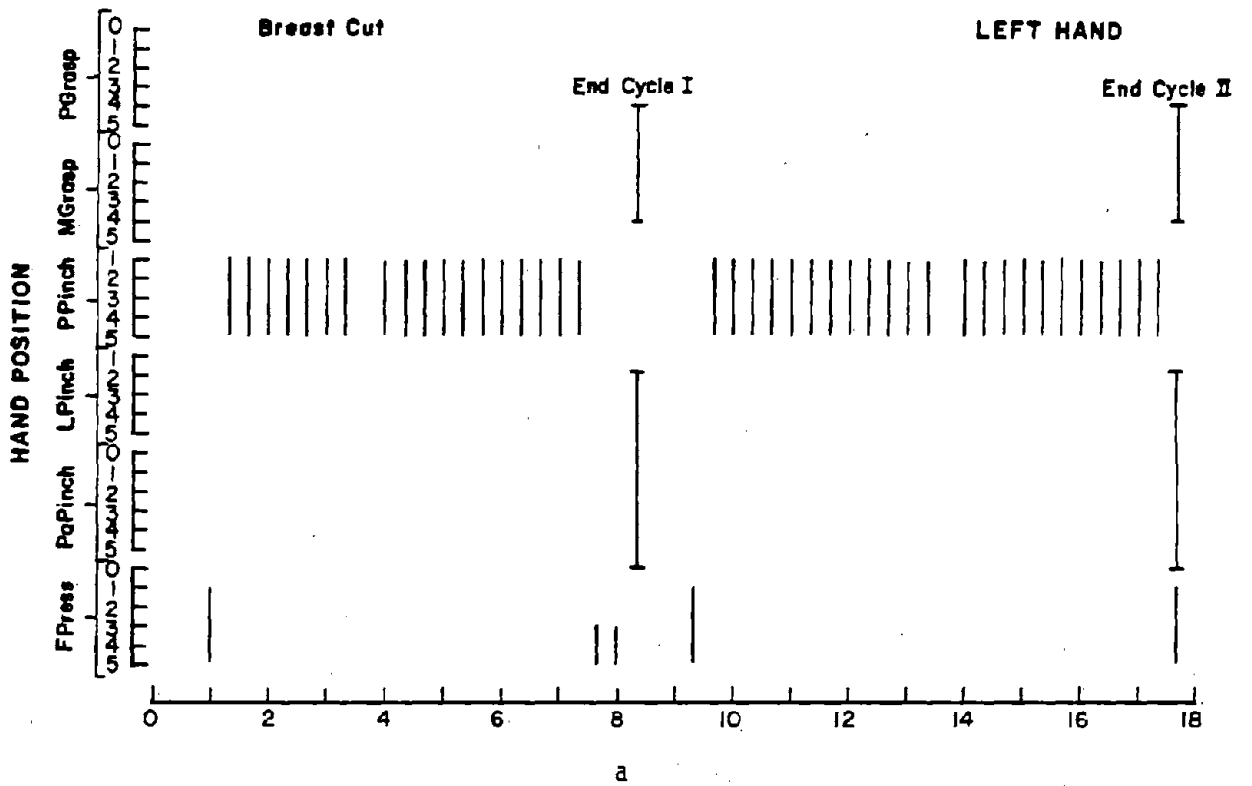


Figure B2.7

## APPENDIX B3

### Shoulder Cut

The turkeys hang from an overhead conveyor by their wings and pass by the work station from the shoulder cutter's right to left side. The left hand (only right-handed subjects were studied) is used to stabilize the turkey with its breast toward the worker. The right hand is used to hold the knife. The fingers are wrapped around the knife handle so that when the forearm is horizontal, the blade points away from the worker with the sharp edge down for cutting the turkeys' left shoulder (see Figure B3.1). The fingers are wrapped around the handle so that when the forearm is held horizontally, the tip of the blade points down with the sharp edge toward the worker for cutting the right shoulder (see Figure B3.1). The shoulder cutter makes an incision to separate the meat from the back between the wing and spine.

For both left and right shoulder cuts, the knife is inserted near the wing joint and worked in and out until reaching the center of the back (see Figure B3.1). Shoulder cutters cut one or the other shoulder of every turkey or 18 turkeys per minute. If seven hours of cutting per shift are assumed, it is estimated that as many as 7,570 cuts are made per shift.

Annotated MTM elements and upper extremity postures for one cycle of left and one cycle of right shoulder cut are shown in Figures B3.2 through B3.7. Joint positions are expressed according to the scheme described in Appendix A.

## SHOULDER CUT

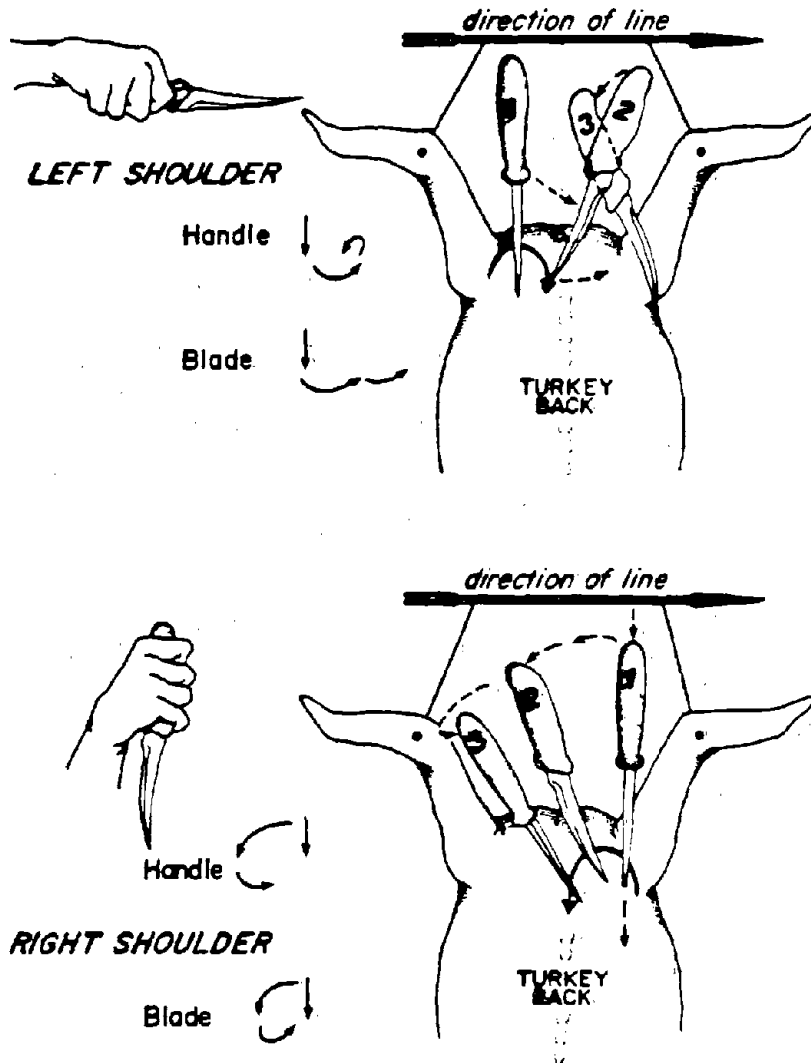


Figure B3.1: The knife design and cutting sequence are shown for both the right and left Shoulder Cuts.

Figure B3.2: MTM elements and element descriptions are shown for two cycles of shoulder cuts. The left shoulder is cut in the first cycle and the right shoulder is cut in the second cycle.

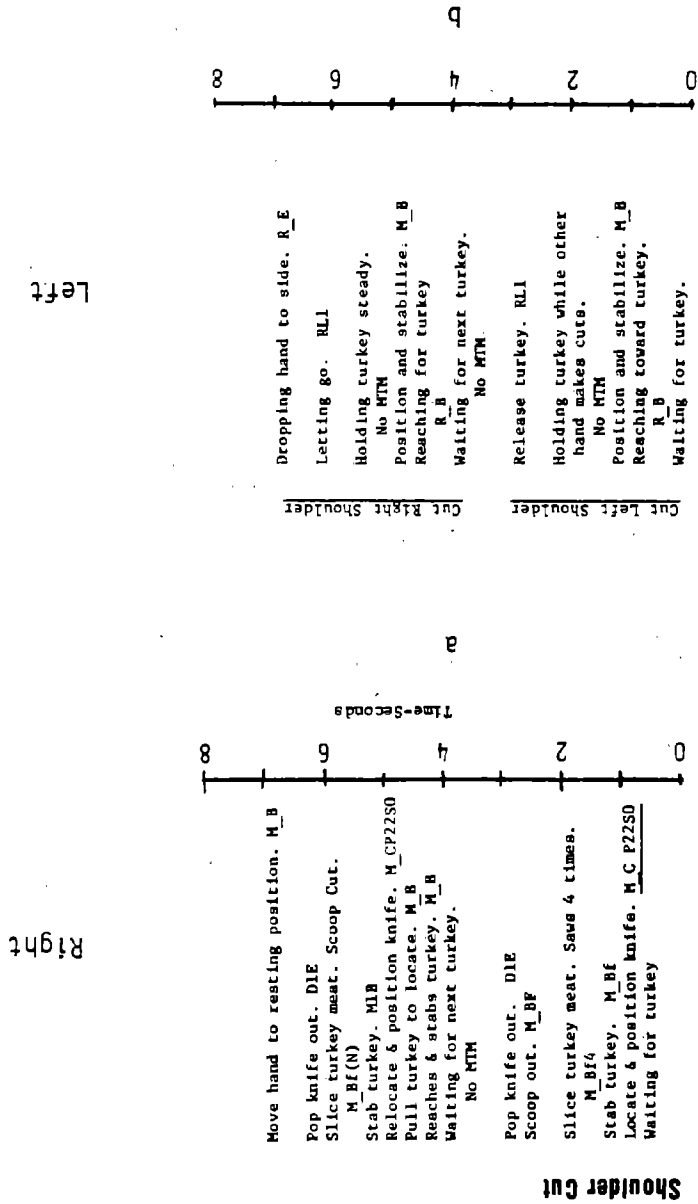


Figure B3.2: MTM elements and element descriptions are shown for two cycles of shoulder cuts. The left shoulder is cut in the first cycle and the right shoulder is cut in the second cycle.

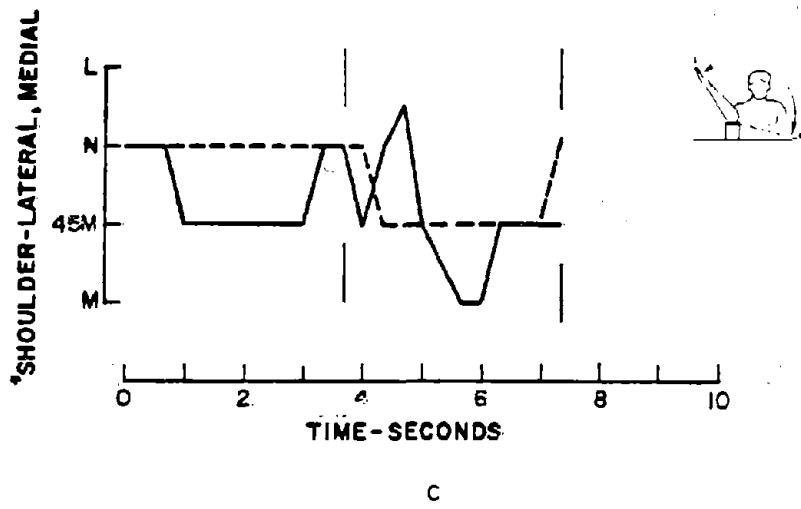
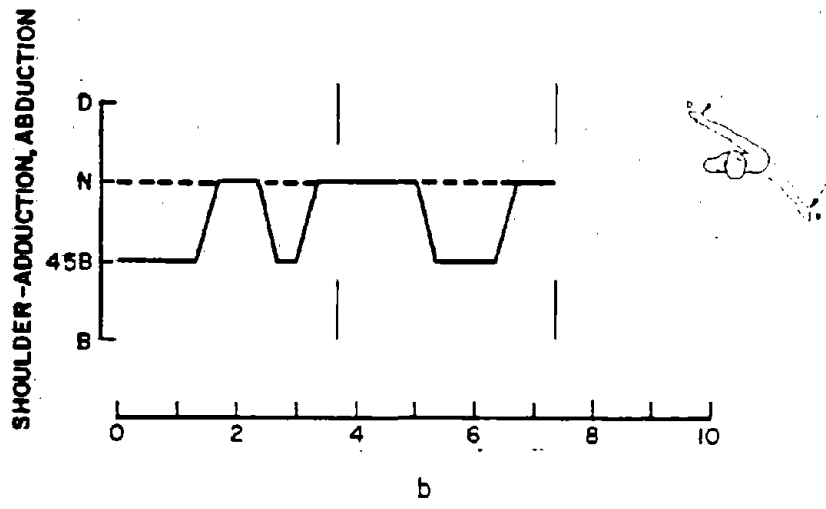
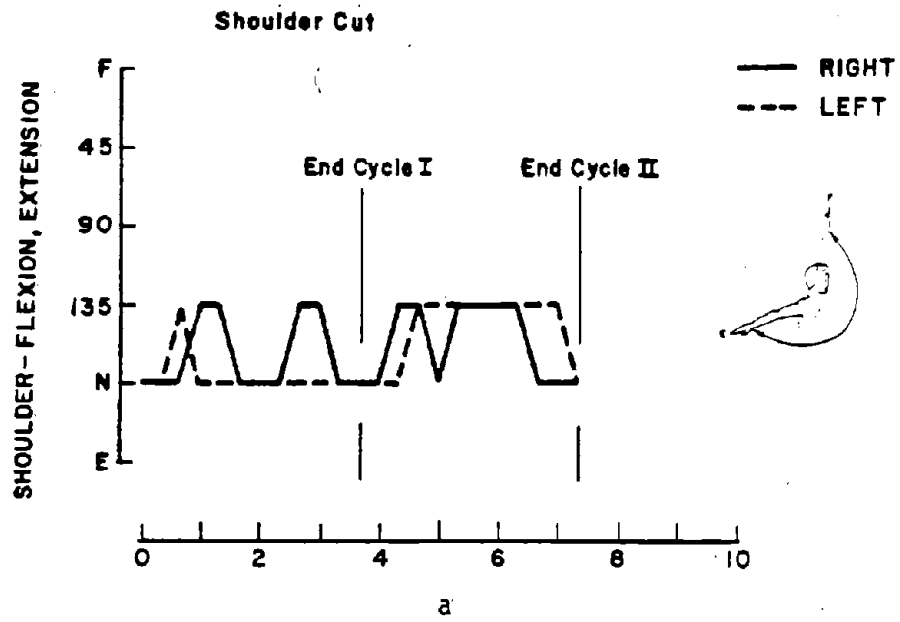


Figure B3.3

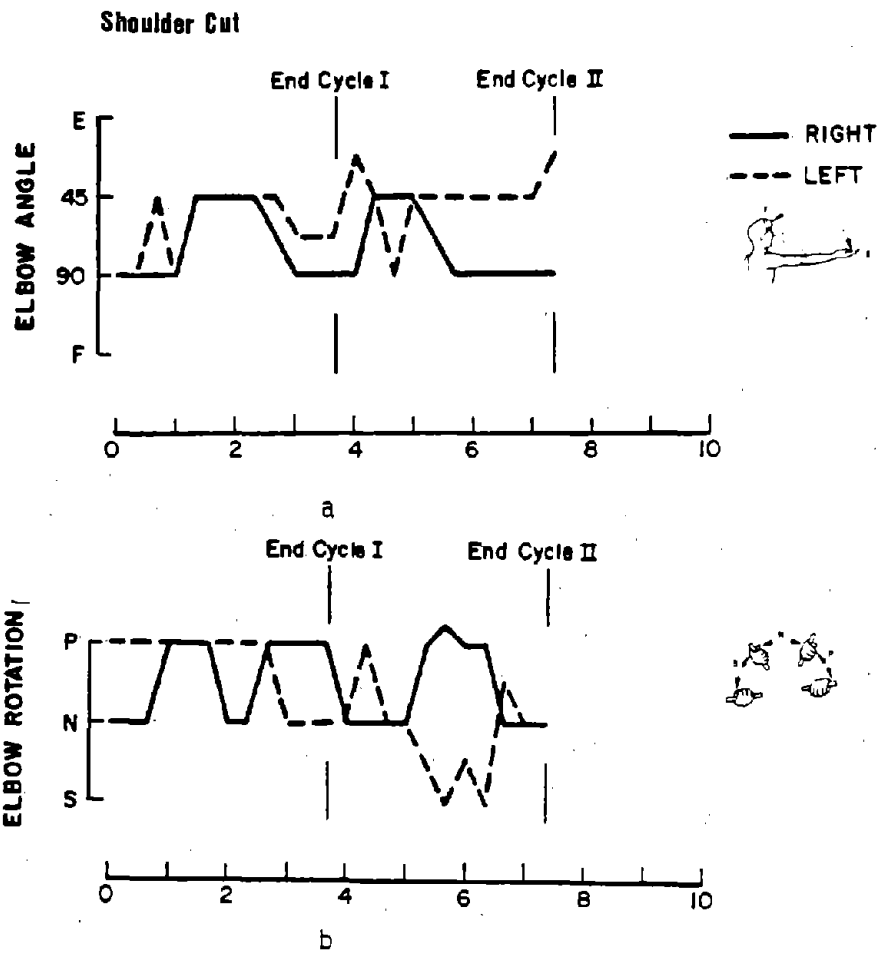
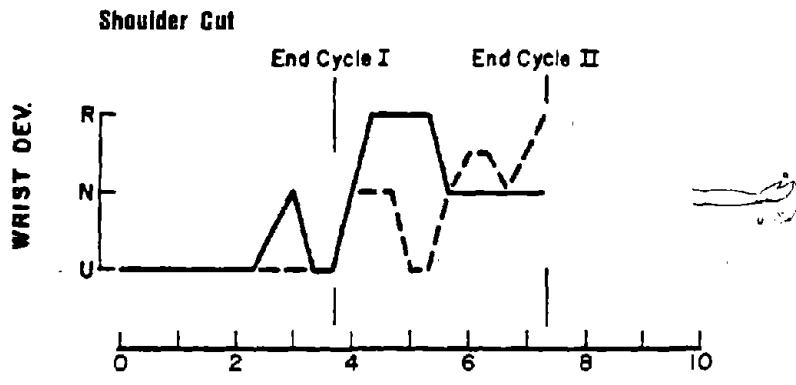
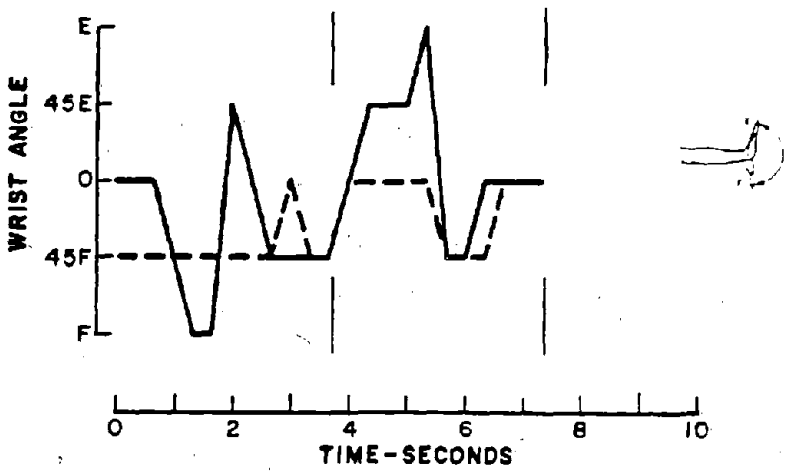


Figure B3.4



a



b

Figure B3.5

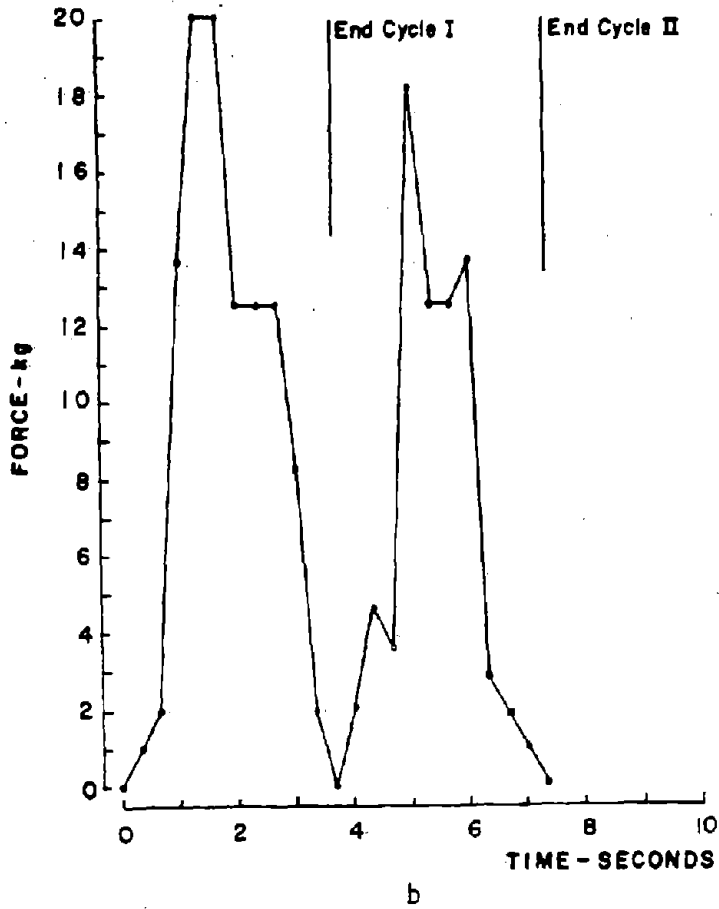
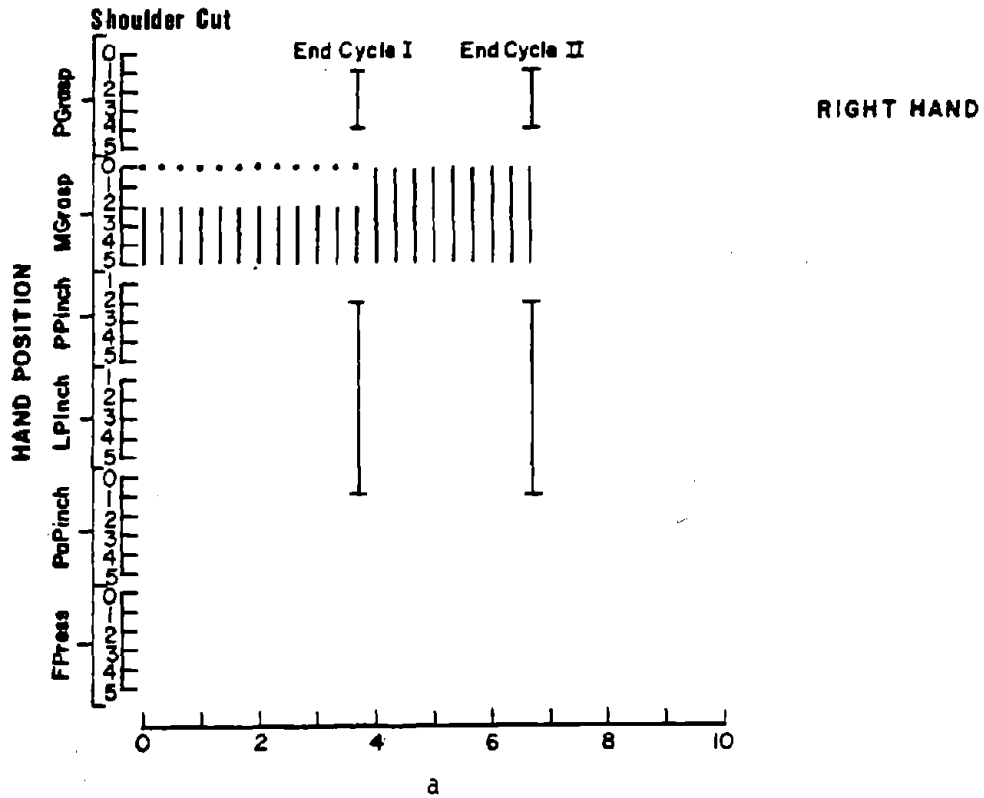


Figure B3.6

Shoulder Cut

LEFT HAND

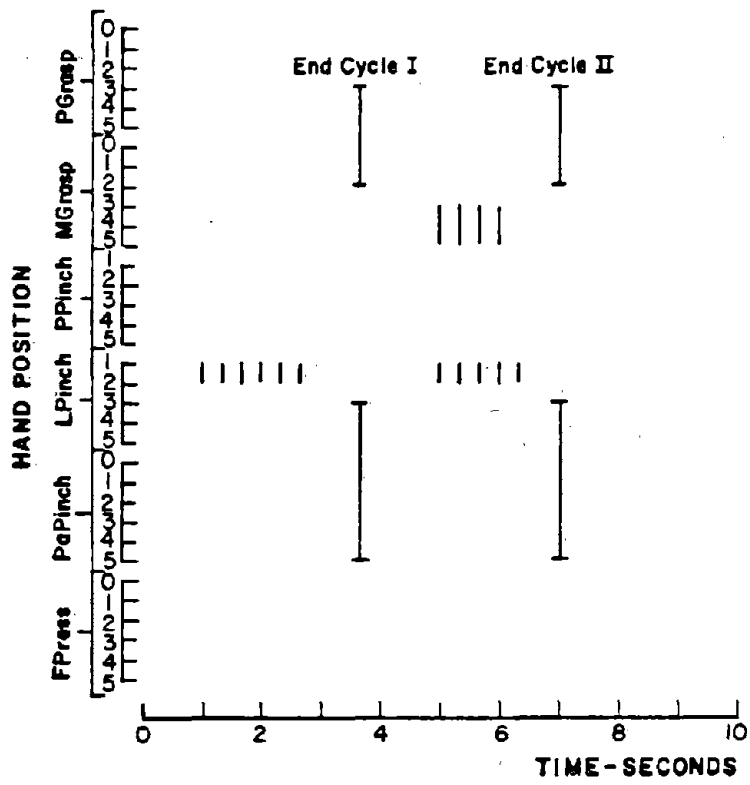


Figure B3.7

## APPENDIX B4

### Thigh Boning

Turkeys hang from an overhead conveyor by their wings and pass by the work station from right to left. The thigh boning station is located at the outside corner of a point where the line changes direction 90 degrees. The thigh bones previously are separated from the turkeys so that when they reach the thigh boning station, the thighs are hanging only by the meat. The left hand (only right-handed operators were studied) is used to hold the thigh for cutting while the right hand is used to hold the knife (see Figure B4.1). The thigh boning knife is held so that, with the forearm held horizontally, the knife is pointed away from the worker with the sharp edge down. Four cuts are required to remove the thigh bone (see Figure B4.1). The first cut is made along the long axis of the thigh bone on the side furthest from the operator. The second cut is made on the side closest to the worker. The third cut completely separates the long axis of the bone from the meat so that it hangs by ligaments and tendons at the end furthest from the turkey. The fourth and final cut is made to completely separate the bone from the turkey. All cuts are made from the turkey towards the worker. The left hand is used to facilitate cutting by twisting the meat away from the incisions. Thigh boners bone one thigh of every other turkey. If seven hours of cutting per shift are assumed, it is estimated that as many as 15,120 cuts are made to bone as many as 3,780 turkeys.

THIGH BONING

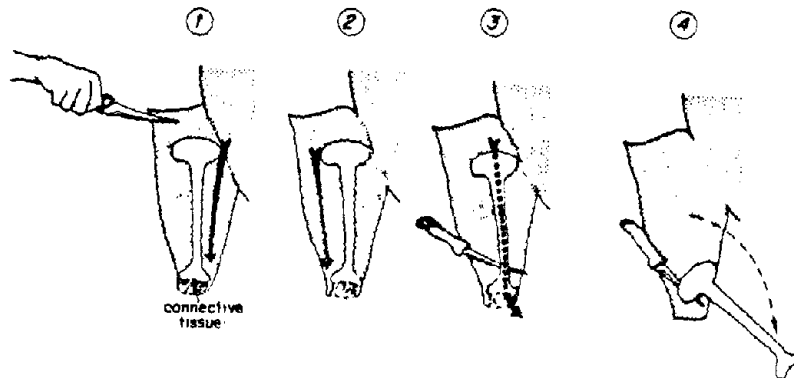


Figure B4.1: The knife design and cutting sequence are shown for boning a right thigh.

Annotated MTM elements and upper extremity postures for two cycles of boning right thighs are shown in Figures B4.2 through B4.7. Joint positions are expressed according to the scheme described in Appendix A.

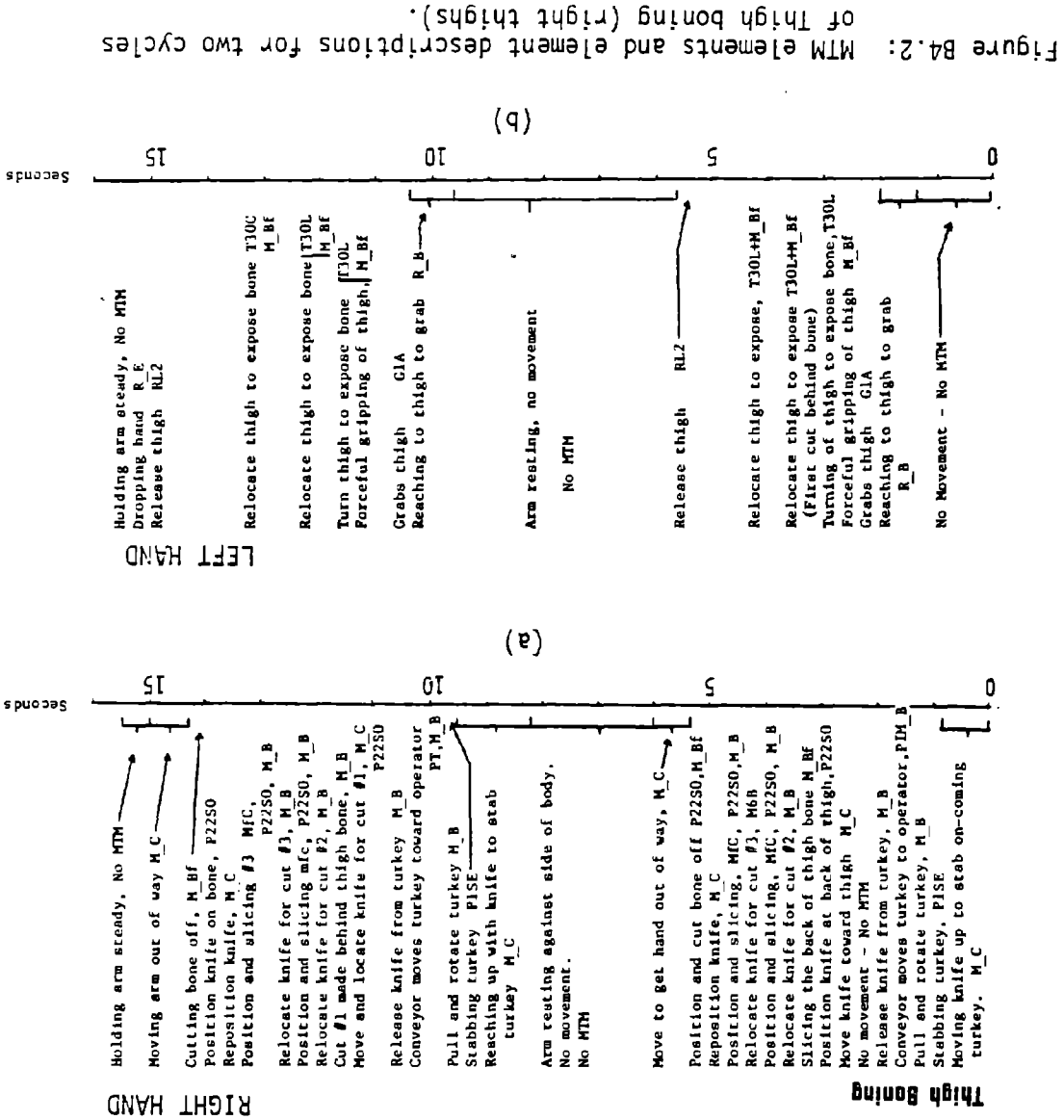


Figure B4.2: MTM elements and element descriptions for two cycles of thigh boning (right thighs).

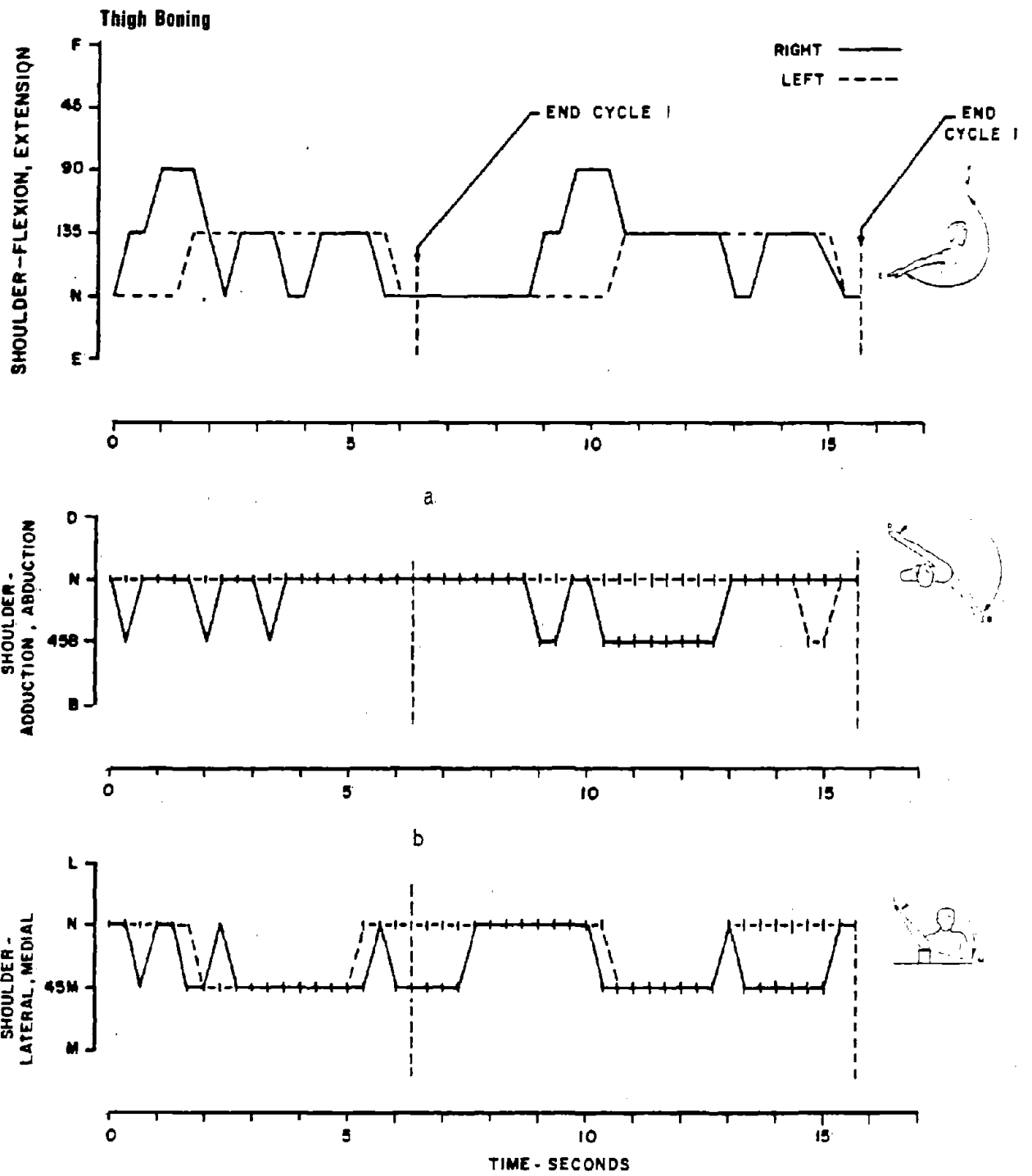


Figure B4.3

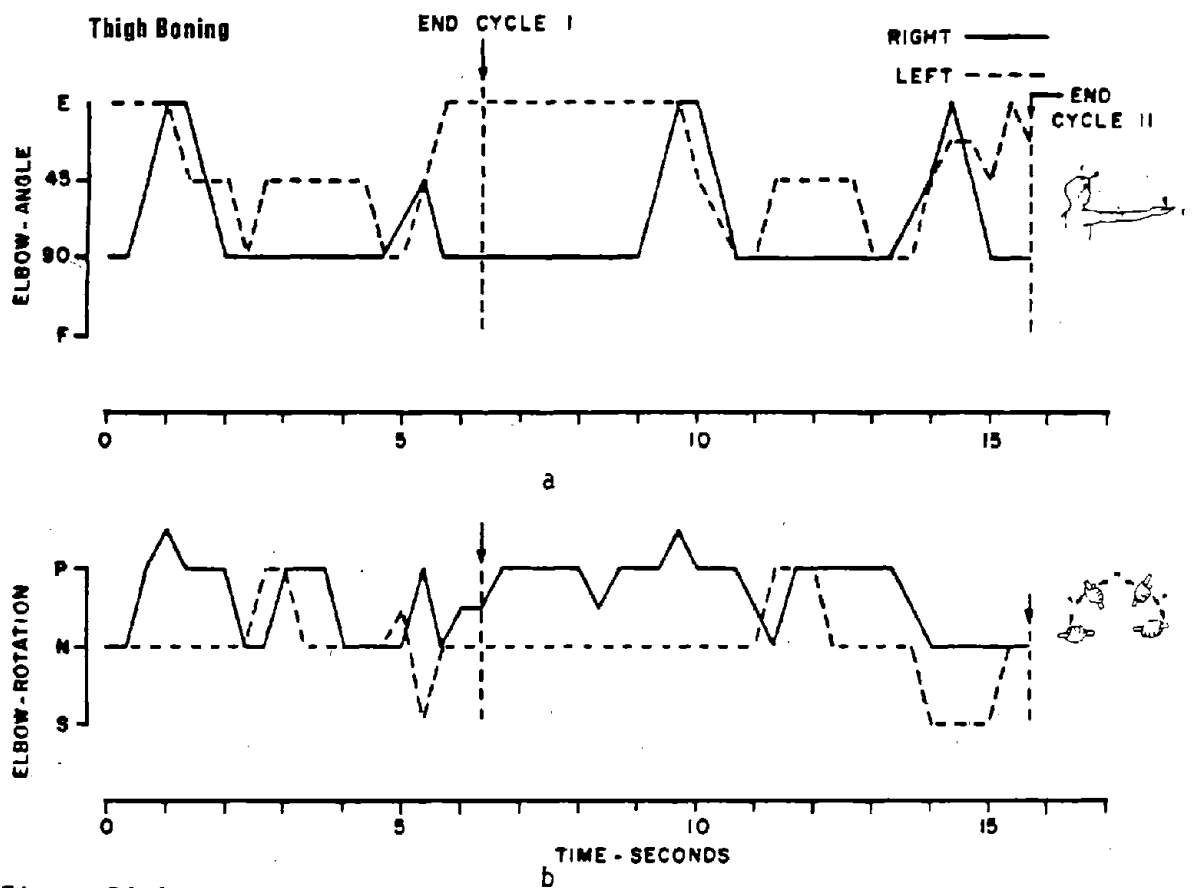


Figure B4.4

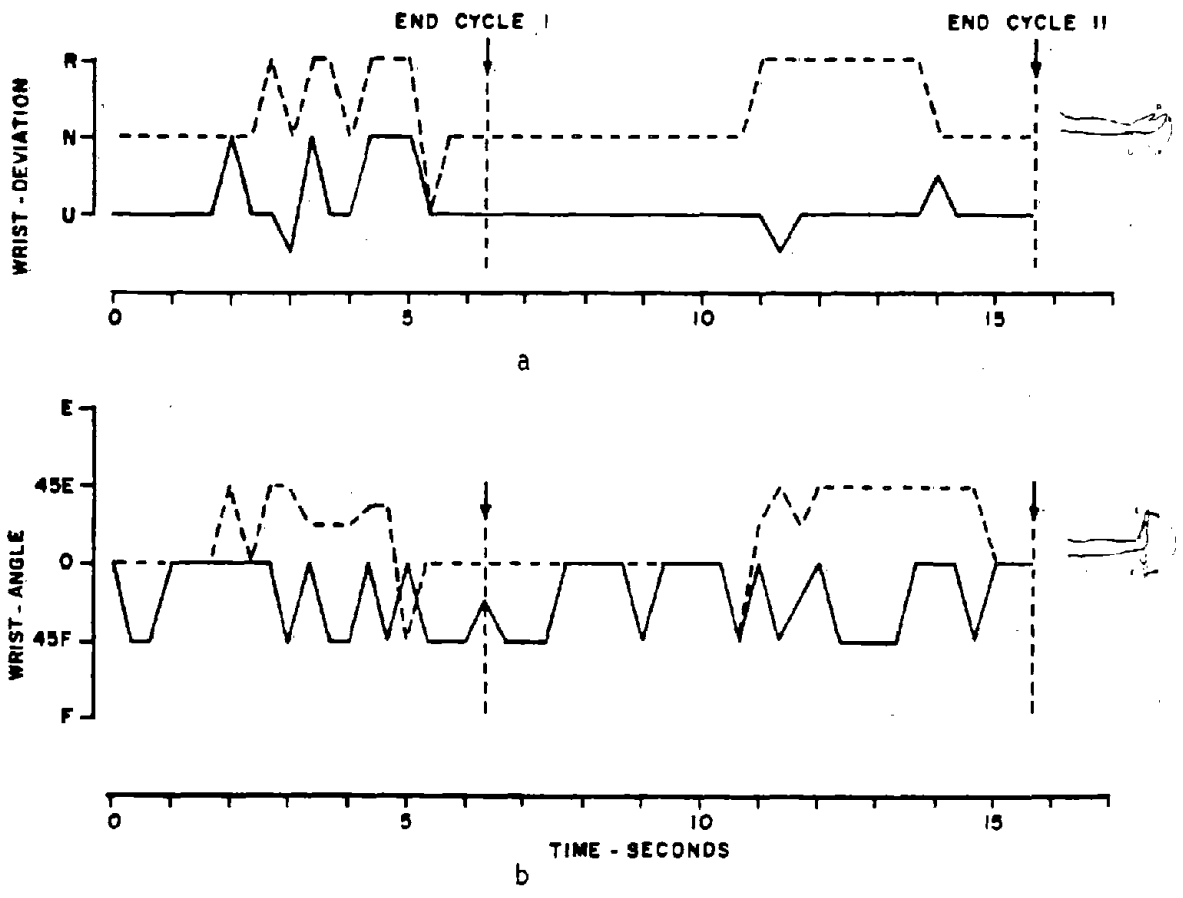


Figure B4.5



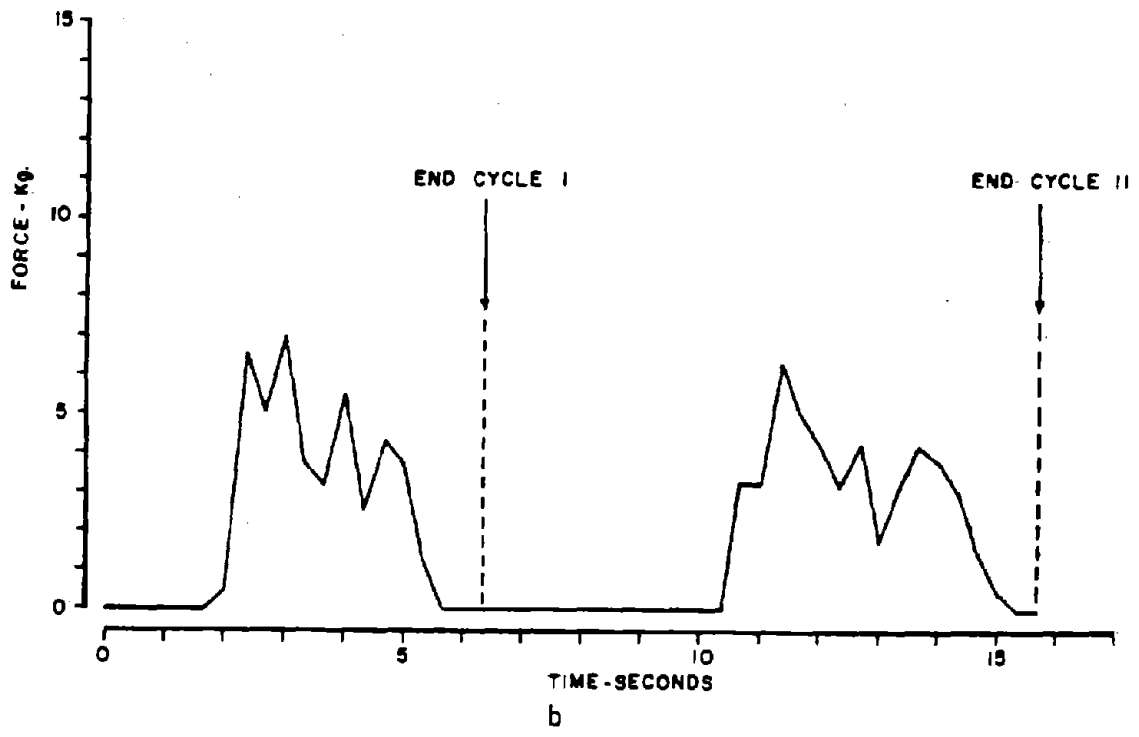
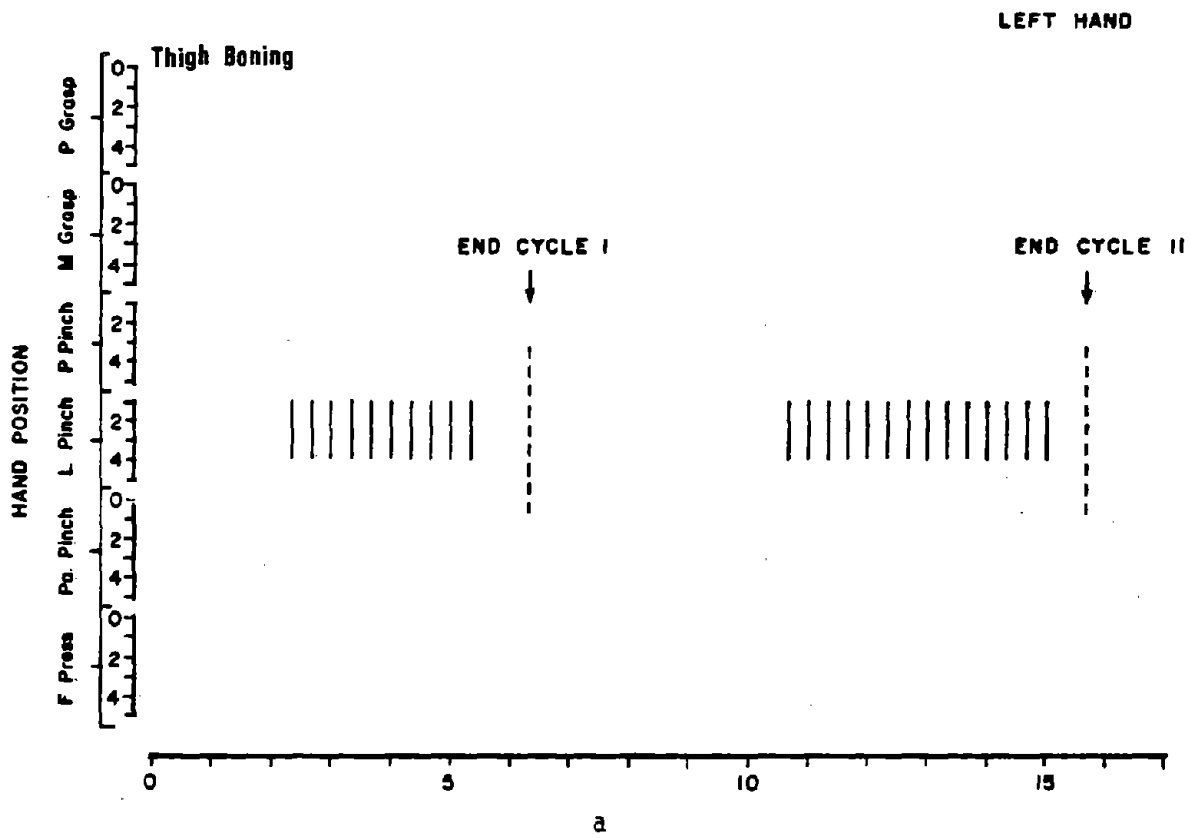


Figure B4.7

## APPENDIX B5

### Thigh Skinning

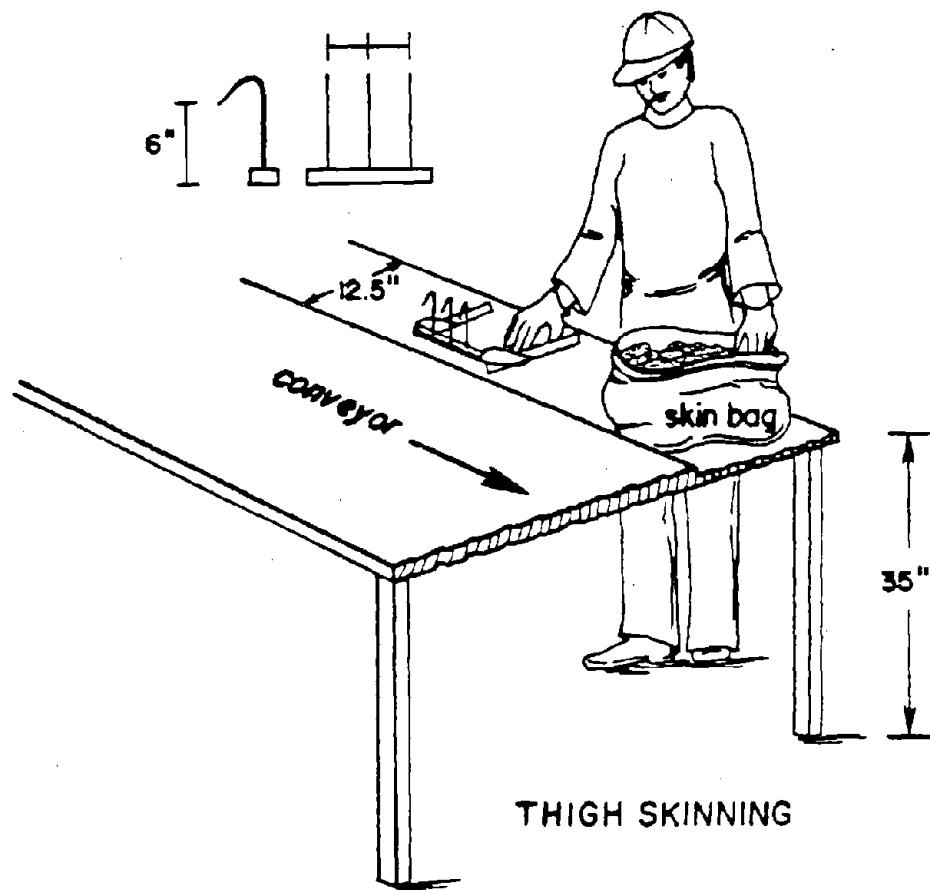
Thighs, previously deboned and separated from the carcass, are transported to the thigh skinning station along conveyor belts (see Figure B5.1). Two methods for skinning thighs were documented.

Method I: The operator picks up a passing thigh, grabs the edge of the skin in the other, and pulls the skin from the thigh. The skin then is placed in a plastic bag and the thigh is placed on the conveyor for further processing.

Method II: The operator picks up two thighs by the skin, one in each hand (see Figure B5.2). The thighs are moved past hooks on the edge of the conveyor (see Figure B5.1) that snags the meat. The skin can then be pulled off from the thigh. The skin is placed in a plastic bag in front of the worker. The process then is repeated with the other hand. Thighs are removed from the hooks and placed back on the conveyor. The production standard for thigh skinning is seven to eight thighs per minute. Persons skinning thighs for 9 hours per shift could skin as many as 4,320. A record rate of over thirty thighs per minute has been reported.

There often is an accumulation of unskinned thighs by the end of the shift so that persons from other jobs help finish skinning at the end of the shift.

Annotated MTM elements and upper extremity postures for skinning four thighs by Method II, with hook, and for skinning one thigh by

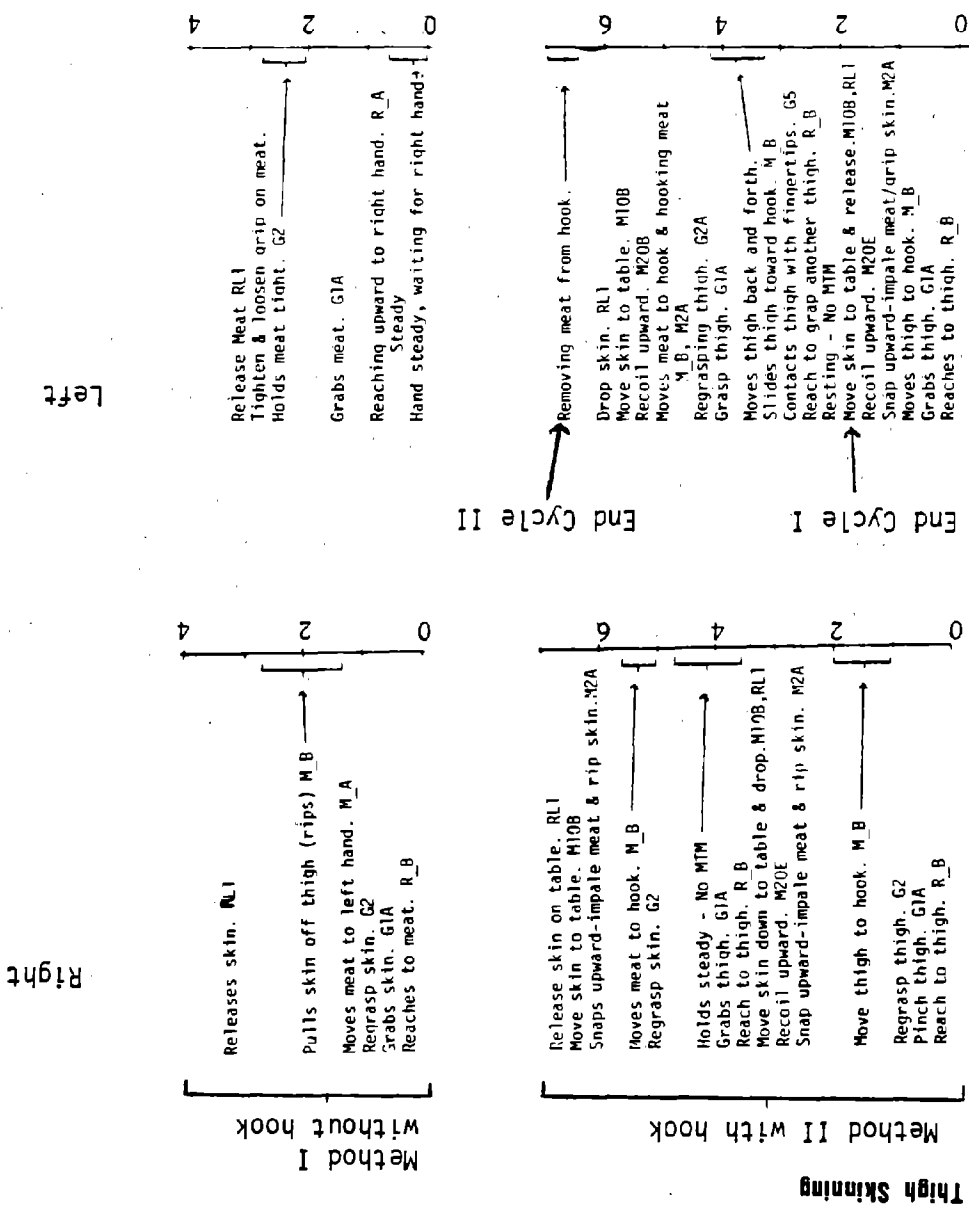


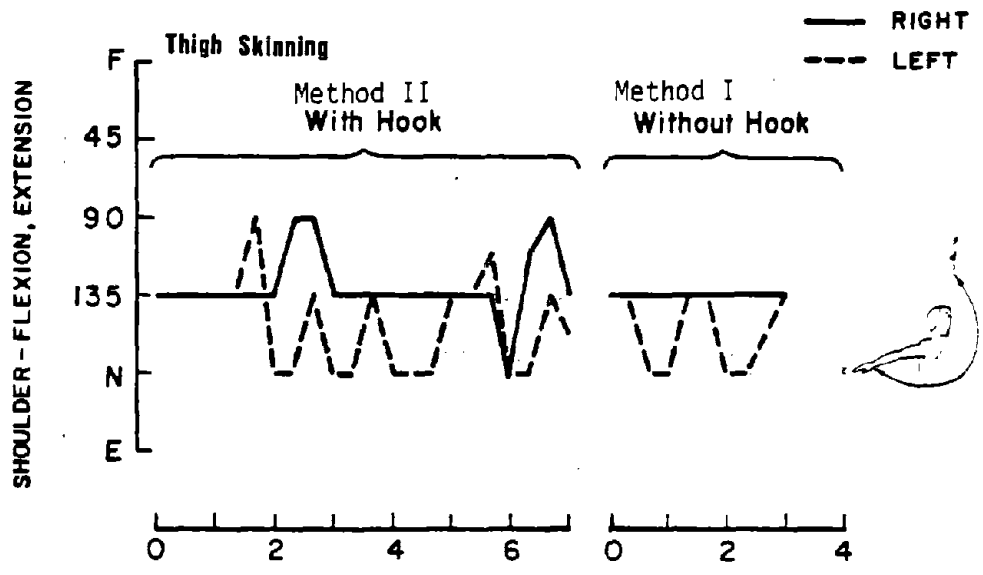
**THIGH SKINNING**

Figure B5.1: The work station used for thigh skinning is shown above. The hooks were used in Method II but not in Method I.

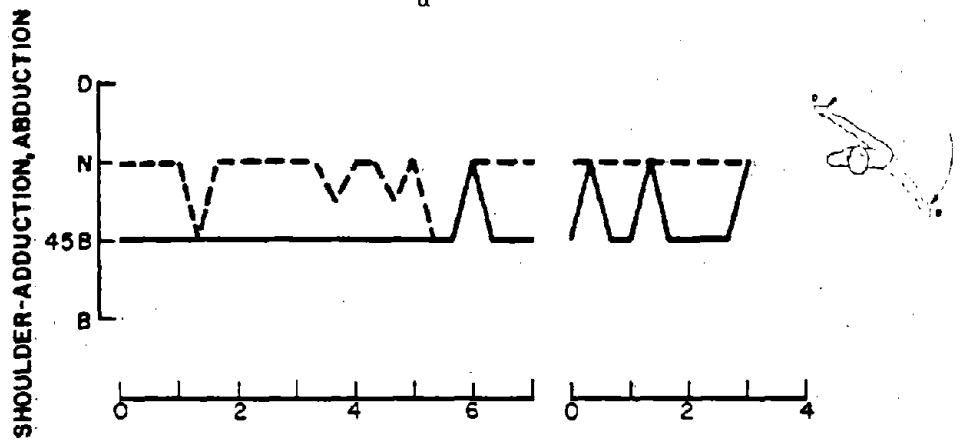
Method I, without hook, are shown in Figures B5.2 through B5.7. Joint positions are expressed according to the scheme described in Appendix A.

Figure B5.2: MTM elements and element descriptions are shown for two cycles of Method I in which four thighs are skinned using a hook and one cycle of Method II in which one thigh is skinned using only the hands.

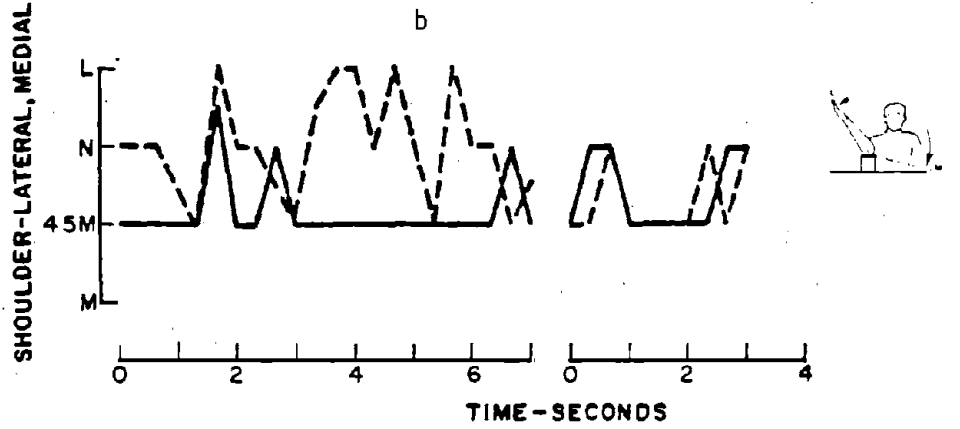




a



b



c

Figure B5.3

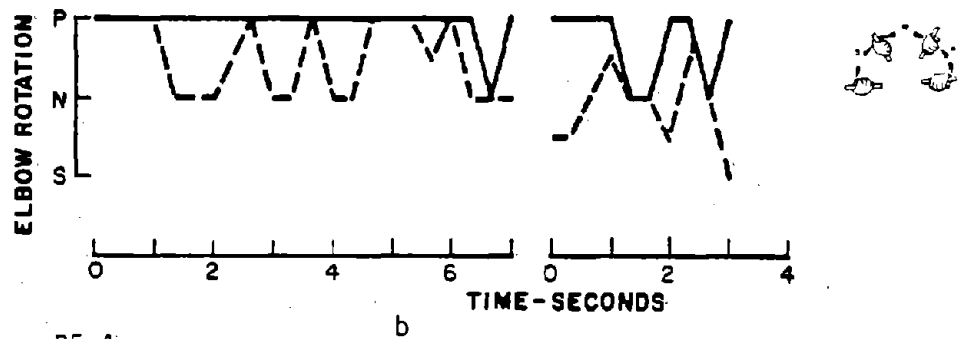
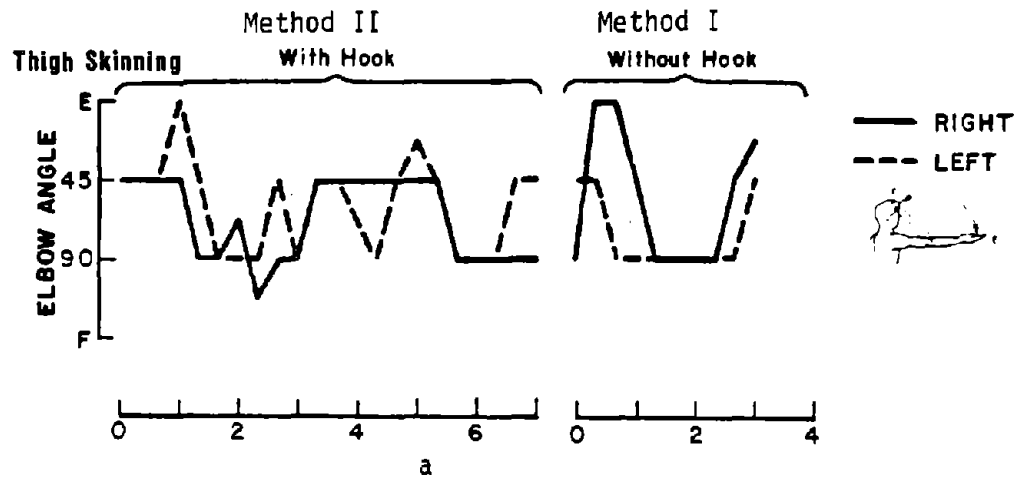


Figure B5.4

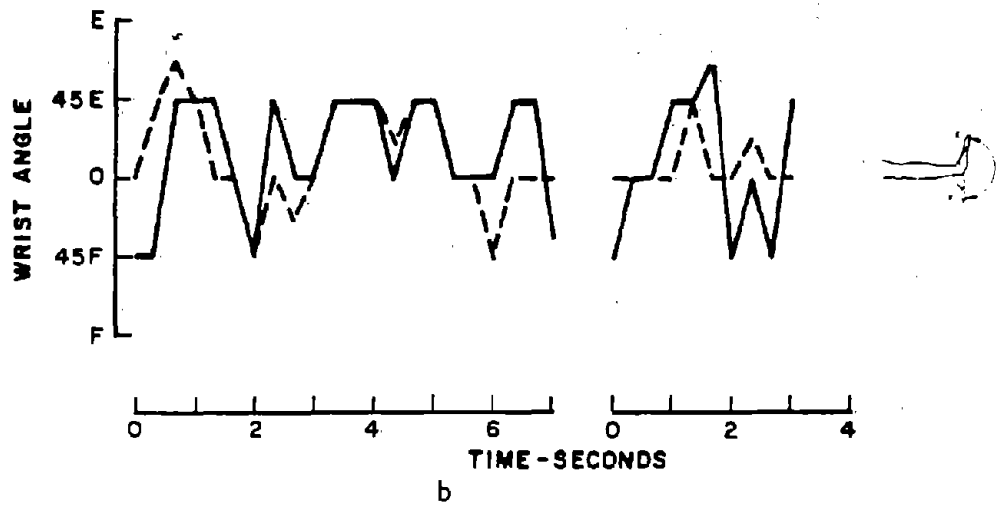
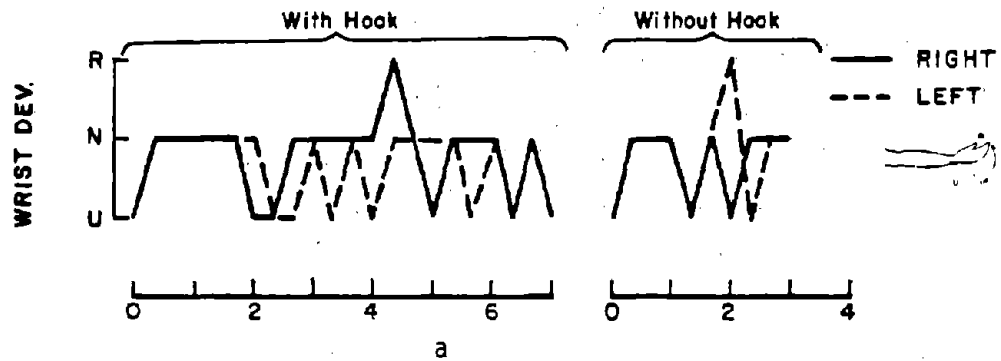
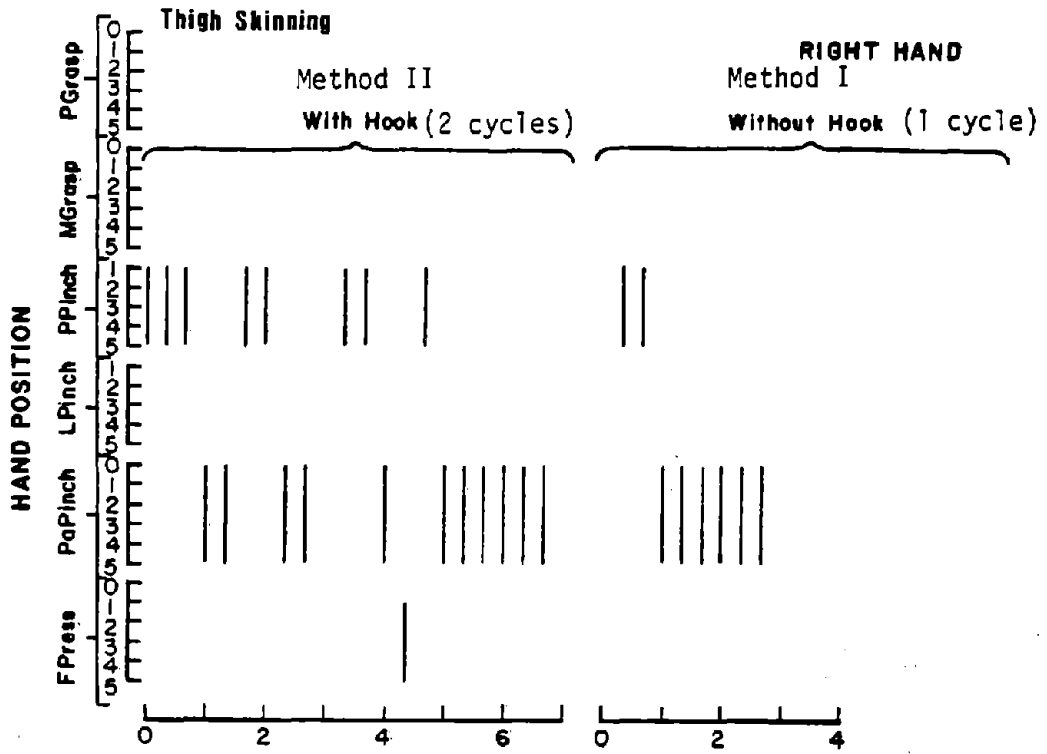
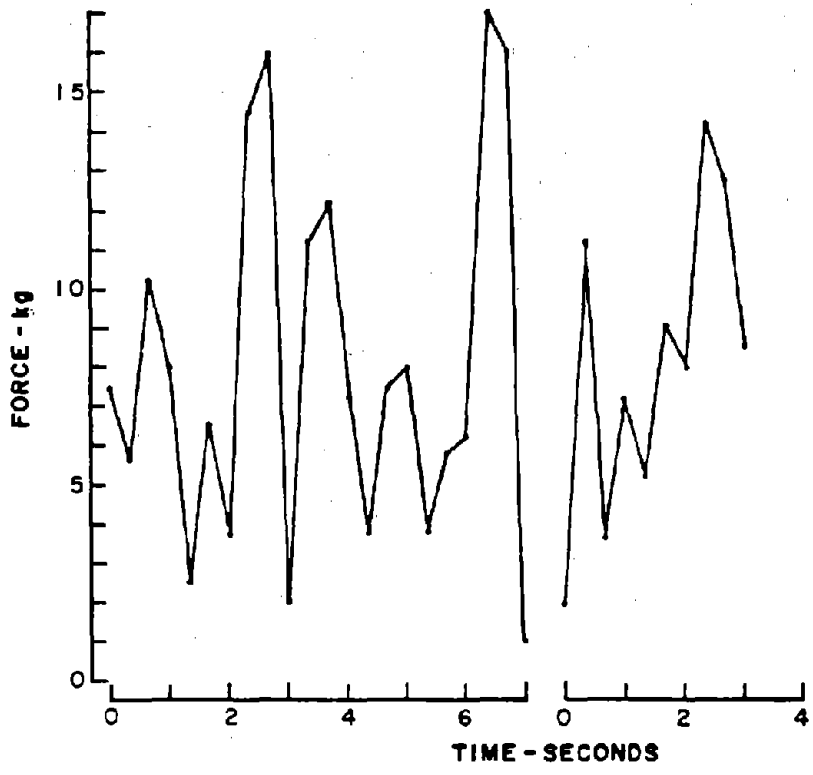


Figure B5.5



a



b

Figure B5.6

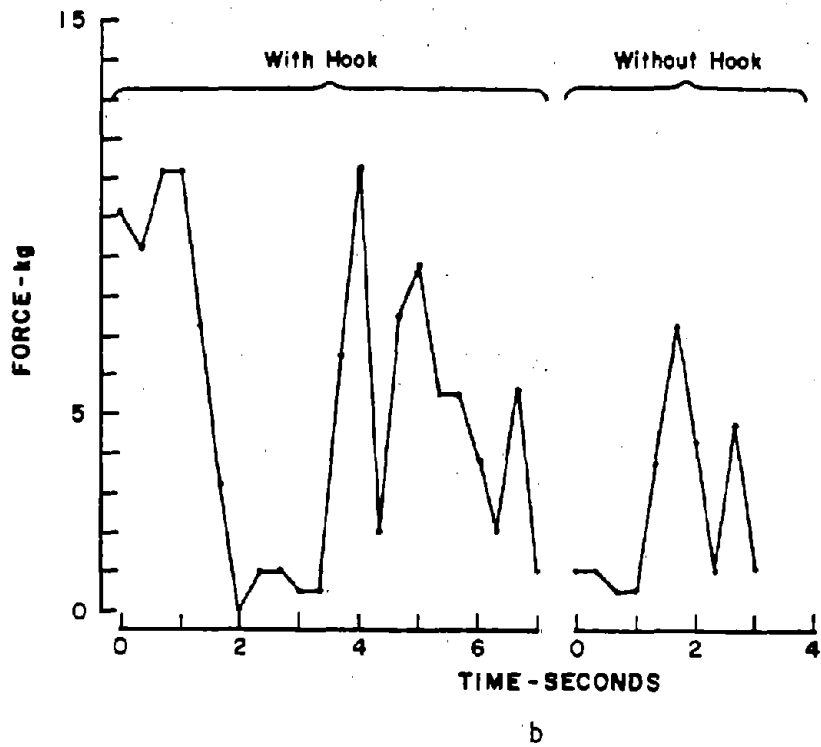
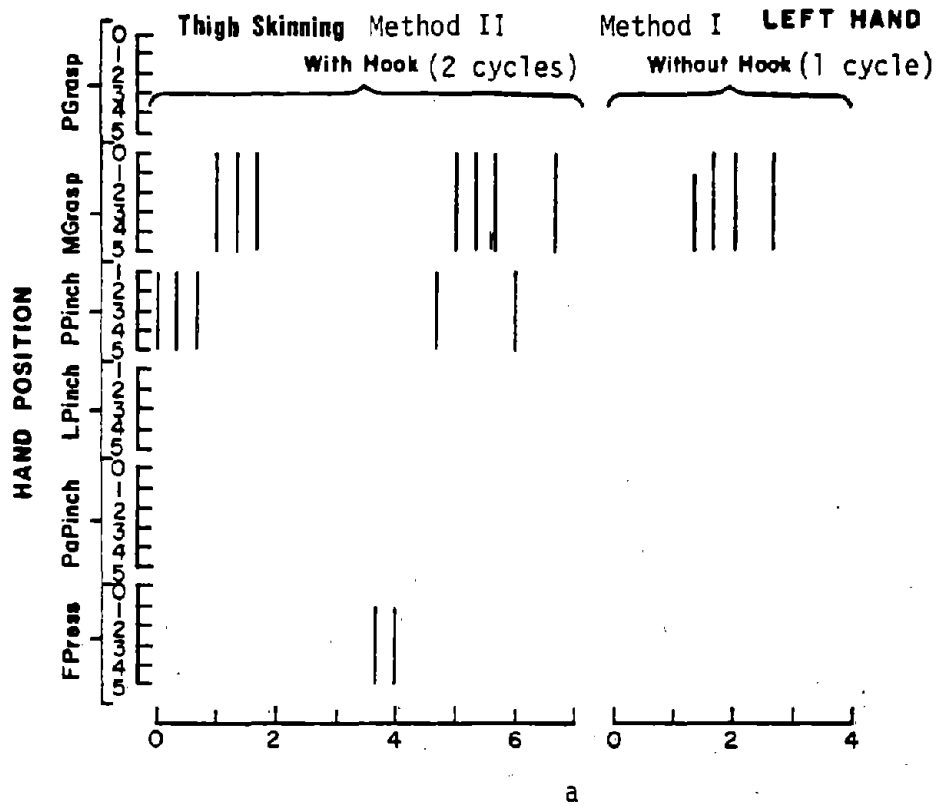


Figure B5.7

APPENDIX C

Job Descriptions and Analyses  
for Panel Plant

Work Methods Analysis for Plant

## APPENDIX C1

### Upholster the Panel

Panels used to partition offices are filled with layers of sound absorbing material and covered by a decorative cloth. Working in pairs, upholsterers perform all the tasks on a work bench shown in Figure C1.1. A steel frame is obtained from a cart by one worker and, with the second partner's help, is laid on the work bench. Panel frames range in size from 42" x 18" to 75" x 45"; all panels are 2½" thick. A rigid fiberglass panel is obtained from a nearby cart and aligned inside the frame. Each partner applies tape to a long side of the panel and an adjacent short side. The tape is cut at each corner by pulling it down sharply over the edge of the frame. The covering is obtained by one of the workers from a nearby rack. The cloth is thrown over the panel with one hand while holding one side with the other hand; together, the workers straighten out the covering by first pulling at the ends with one hand and wiping wrinkles out of the center with their other hand.

A plastic cord is used to anchor the fabric in a groove around the periphery of the frame. A reciprocating palm hammer (see Figure C1.1) is held in one hand while the cord is held in the other. The binding is aligned at one corner and the palm hammer is positioned over it. Working opposite one another, the partners simultaneously insert the cord to anchor the fabric starting with the short sides (from corner 1 to 2 and 4 to 3 - Figure C1.1) and finishing with the long sides (from

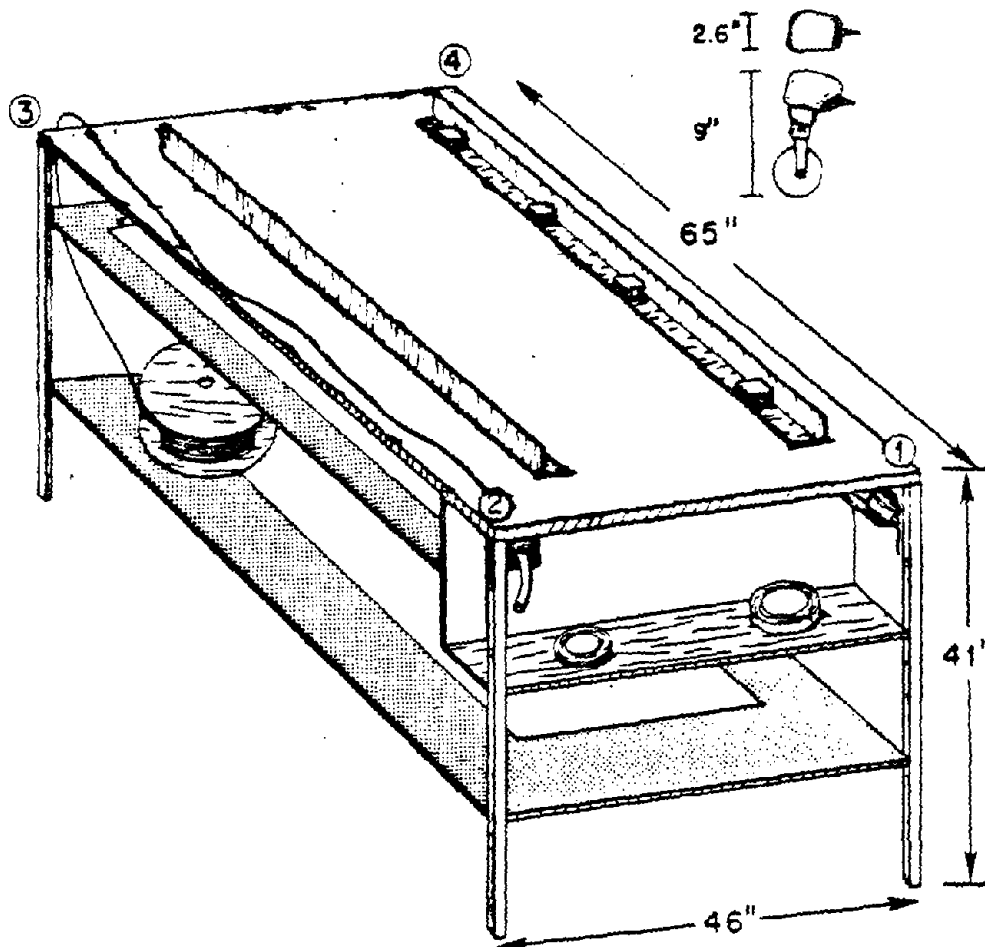


Figure C1.1: The work station and palm hammer used for upholstering panels are shown above.

corner 2 to 3 and 4 to 1). At completion, the cord is cut by pulling the loose end perpendicular to the groove under the blade of the palm hammer. The palm hammers and binding are returned to the end of the bench (between corner 1 and 2).

Scissors are used to remove the loose edge of the fabric. Starting with the short ends (Corner #1 to #2 and Corner #3 to #4, see Figure C1.1) the loose fabric is held tight with one hand and the open scissors are forced along the cord to make the cut. The scissors are not open and closed but instead are used like a knife edge. The workers continue from the short sides to the adjacent long sides.

The frame is turned over and two pieces of soft fiberglass and a piece of cardboard are obtained from nearby racks. One piece of the soft fiberglass is placed into the frame followed by the cardboard and the second piece of soft fiberglass. Finally, a piece of rigid fiberglass is placed on top. Another piece of fabric is attached following the procedure described above to complete the panel. The completed panel is placed on a cart for transport to the final assembly line.

Annotated MTM elements and upper extremity postures are shown for upholstering one panel. Joint positions are expressed according to the scheme described in Appendix A.

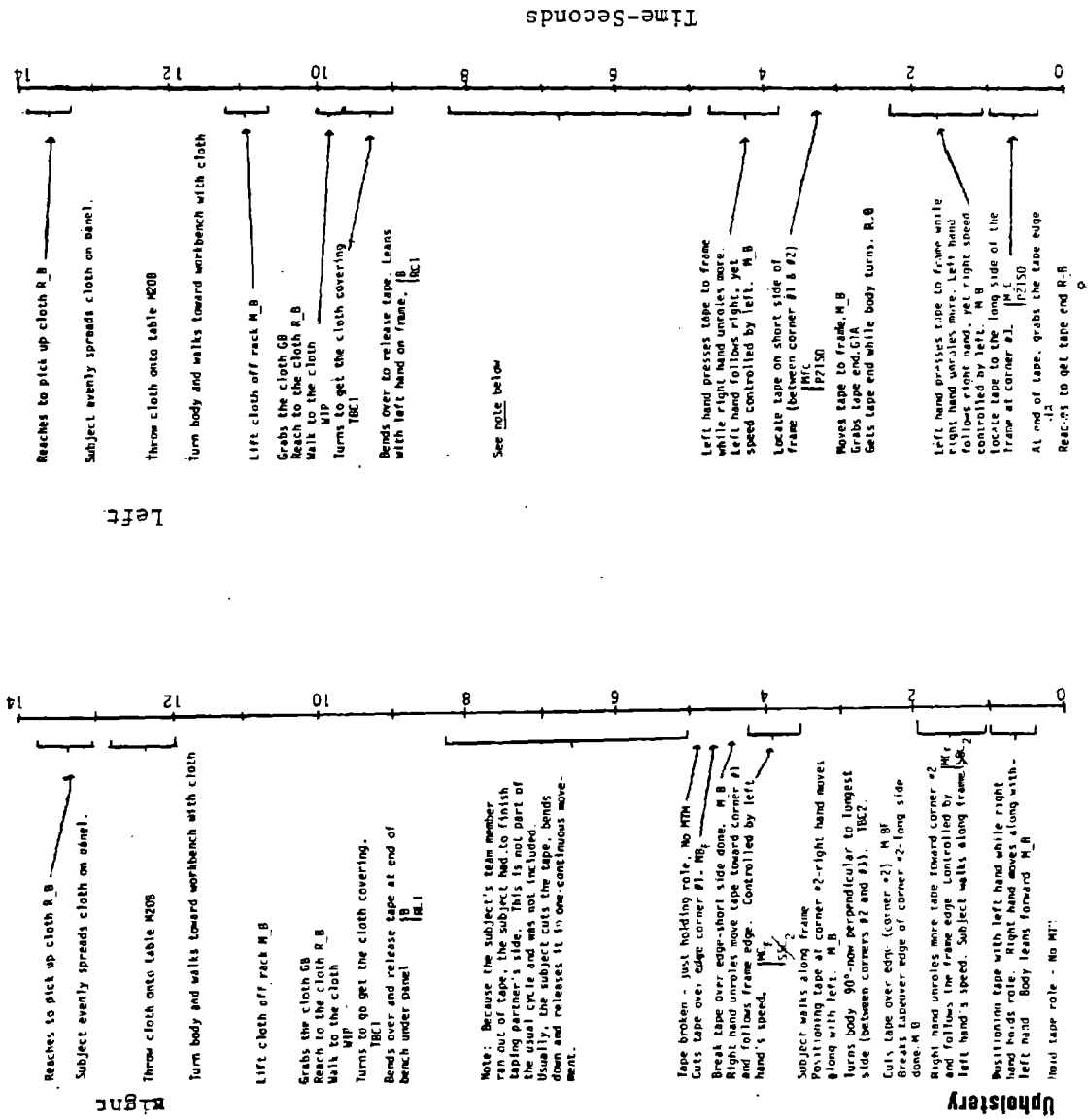


Figure C1.2

Upholstery

See note below

Note: Because the subject's team member ran out of tape, the subject had to finish taping partner's side. This is not part of the usual cycle and was not included. Usually, the subject cuts the tape, bends down and releases it in one continuous movement.

Right

Turns corner #3 while right hand still binding long side.

TBCZ

Binding long side (from corner #2 to corner #3). The process is the same as the short side. Near the end of the run (at corner #3), the subject must turn his body and keep binding at the same time.

PT M\_C T M\_B

Note: the subject shuffles his feet rather than actually walks.

At corner #2, turns body from short side to long side of panel.

TBCZ

Hammer binding shortside (from corner #1 to corner #2). There is process time involved in allowing the hammer enough time to push the cord into the slot. Subject walks along the side of panel.

PT M\_C T M\_B

Force hammer in to start tool.

M\_B

M\_C

Locate tool over binding. P23550

M\_B

Move tool back slightly. MTC

Pushes hammer in to make crevice for binding.

M\_B

Walk to corner #1 of panel on short side. MTP

M\_B

Adjust tool position in hand.

M\_B

Grab hammer. Bends body. G1A, B

M\_B

Reaching to get palm. Hammer. R, B

Release hand from cloth. RLZ

M\_B

Slide hand on top of cloth to smooth on to panel. M10B.

Hands contact center of cloth. G5

M\_B

Reach to center of cloth. R, A

M\_B

Release cloth. RL1

M\_B

Pull cloth outward. M, B

M\_B

Slide and tug on cloth to straighten out. M, B

M\_B

Grabs cloth. G1B

Left

Turns corner #3 while left hand lifts binding.

TBCZ

Binding the long side (from corner #2 to corner #3), the process is the same as the short side. Near the end of the run (at corner #3), the subject must lift the binding cord up to keep it tight. He does not tug on the cloth anymore.

PT M\_C

Turning Corner

Left hand holds binding in place as hammer forces it into place. The left hand also smooths out the cloth by slowly pulling out on cloth during the binding process.

PT M\_C

Hold binding in place

M\_C

Set binding in crevice. P23550

M\_C

Locate binding near corner #1. M\_C

----- Walking -----

Pull on cord to get some slack. M, B

M\_B

Grabs binding cord. G1A

M\_B

Reaches to binding cord near corner #2. R, B

M\_B

Release hand from cloth. RLZ

M\_B

Slide hand on top of cloth to smooth on to panel. M10B.

M\_B

Hands contact center of cloth. G5

M\_B

Reach to center of cloth. R, A

M\_B

Release cloth. RL1

M\_B

Pull cloth outward. M, B

M\_B

Slide cloth and tug on cloth to straighten out. M, B

M\_B

Grabs cloth. G1B

Time-Seconds

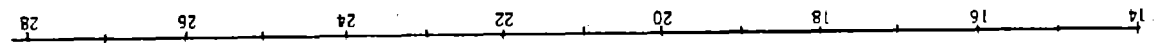
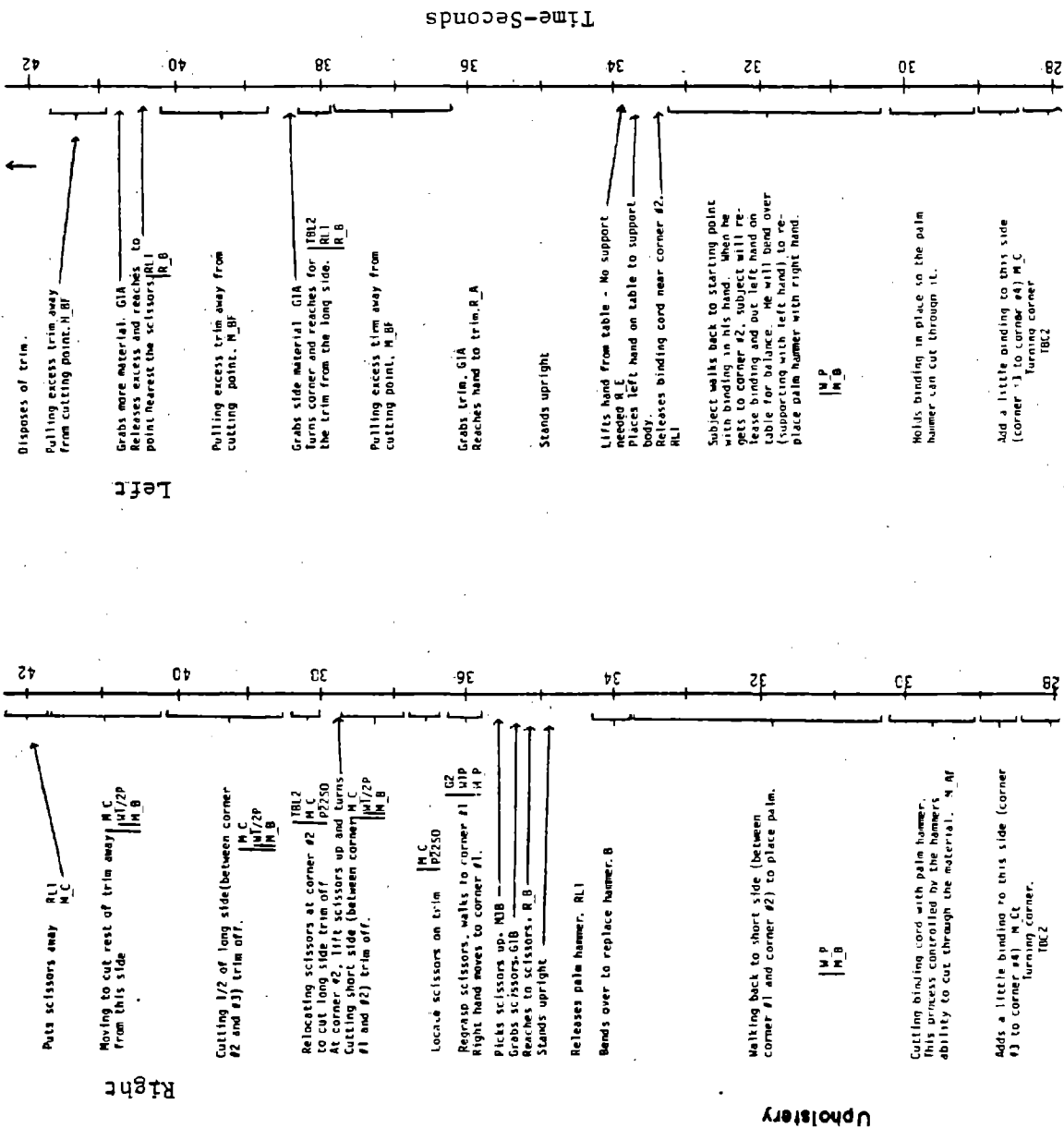
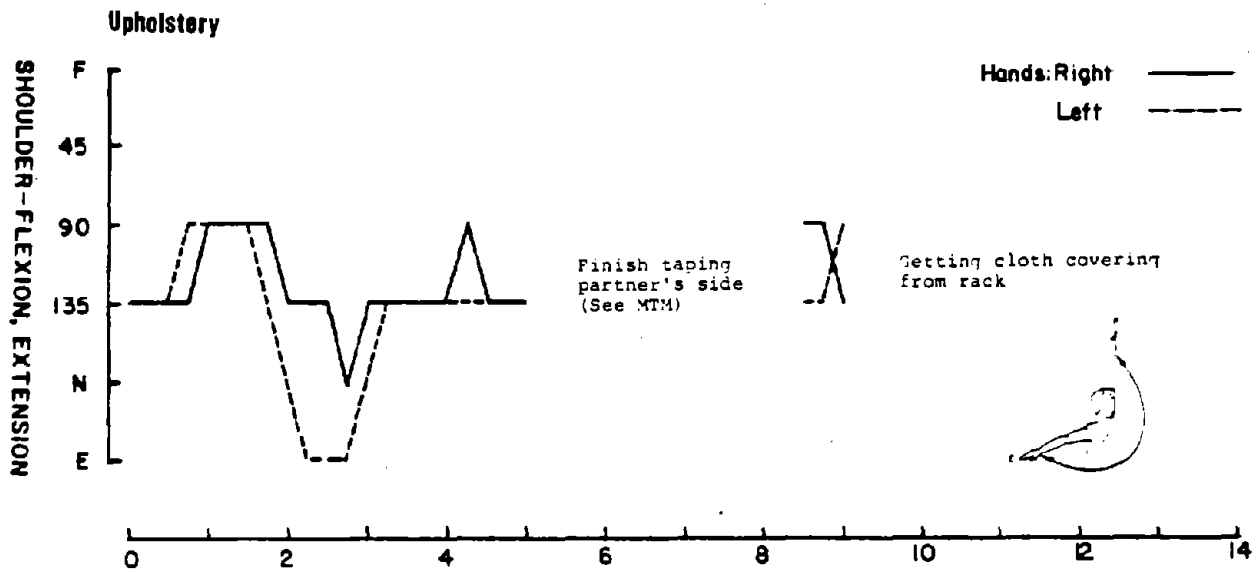


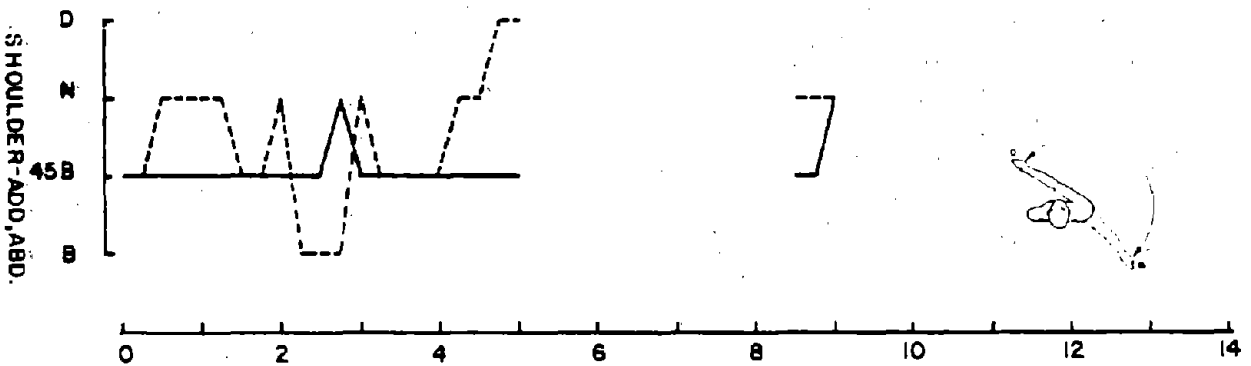
Figure C1.2 Continued.

Figure C1.2 Continued.

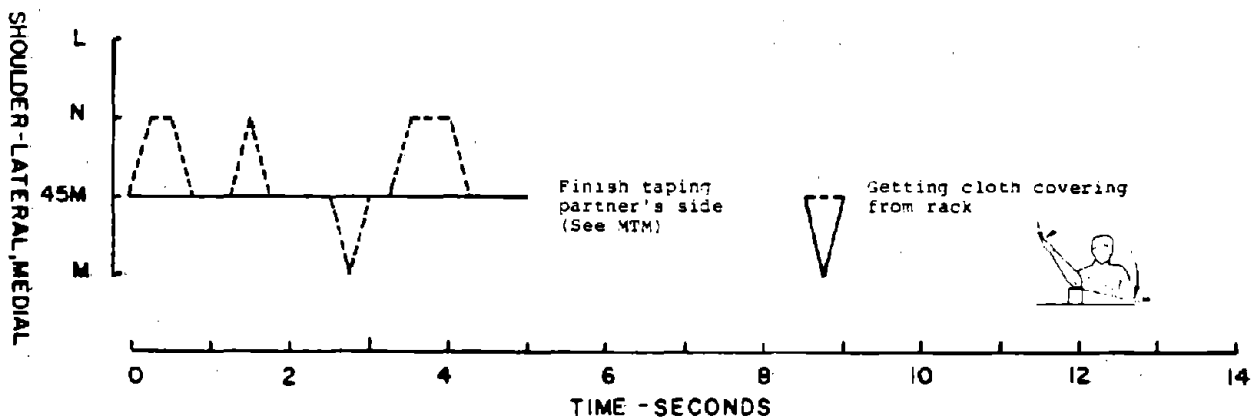




a



b



c

Figure C1.3.

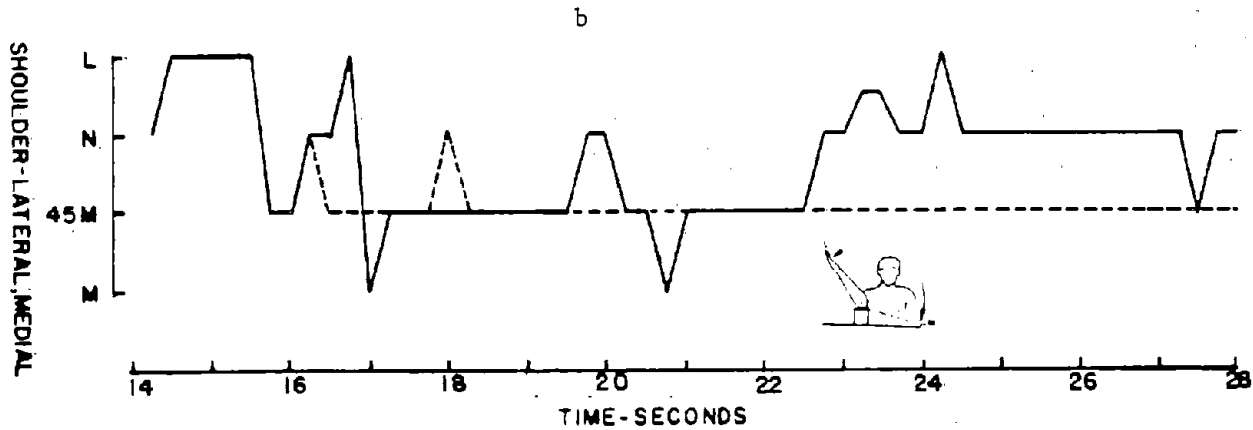
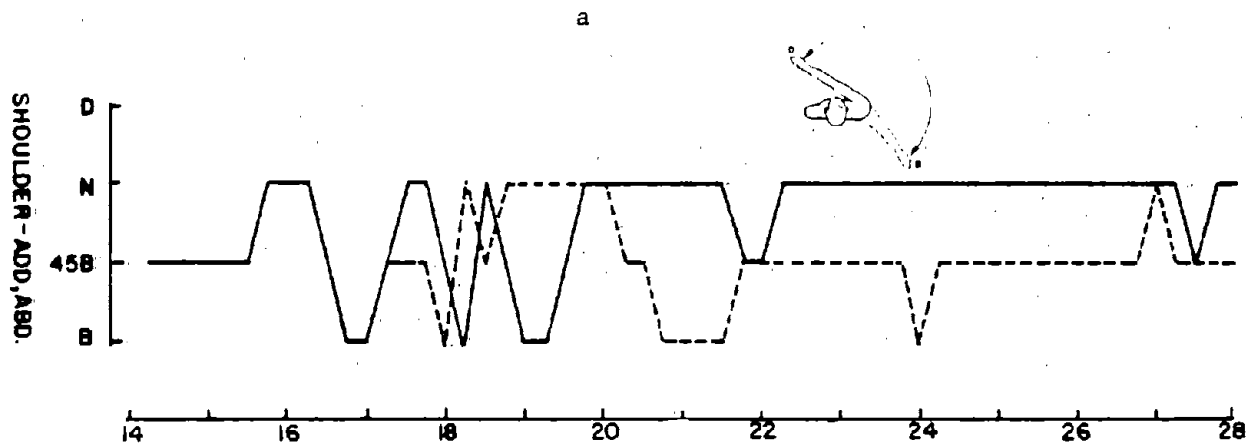
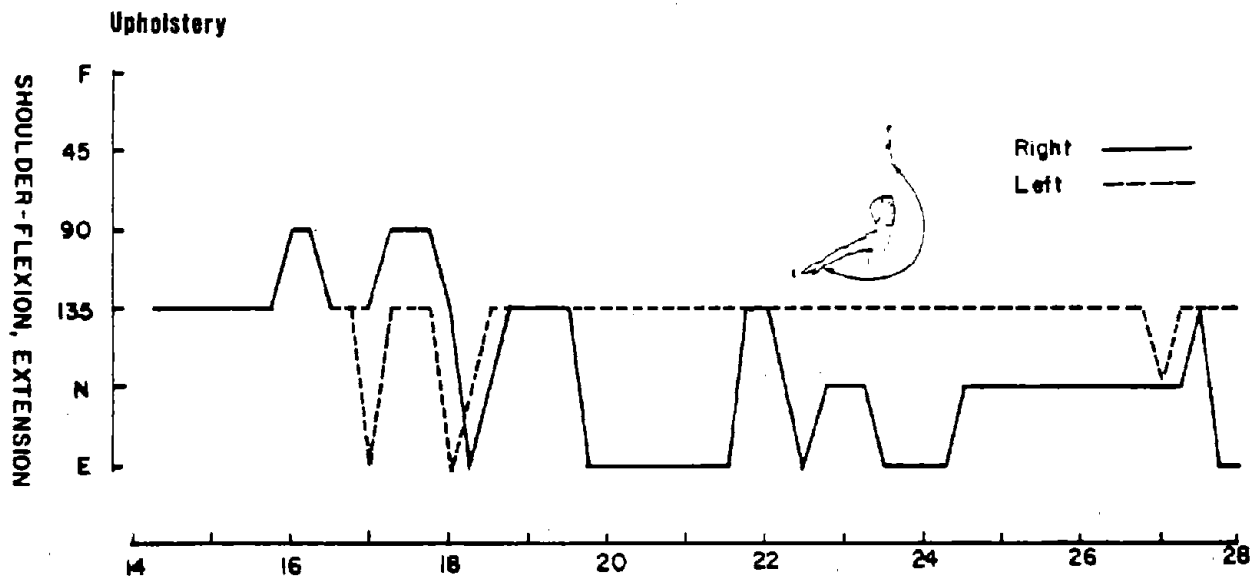


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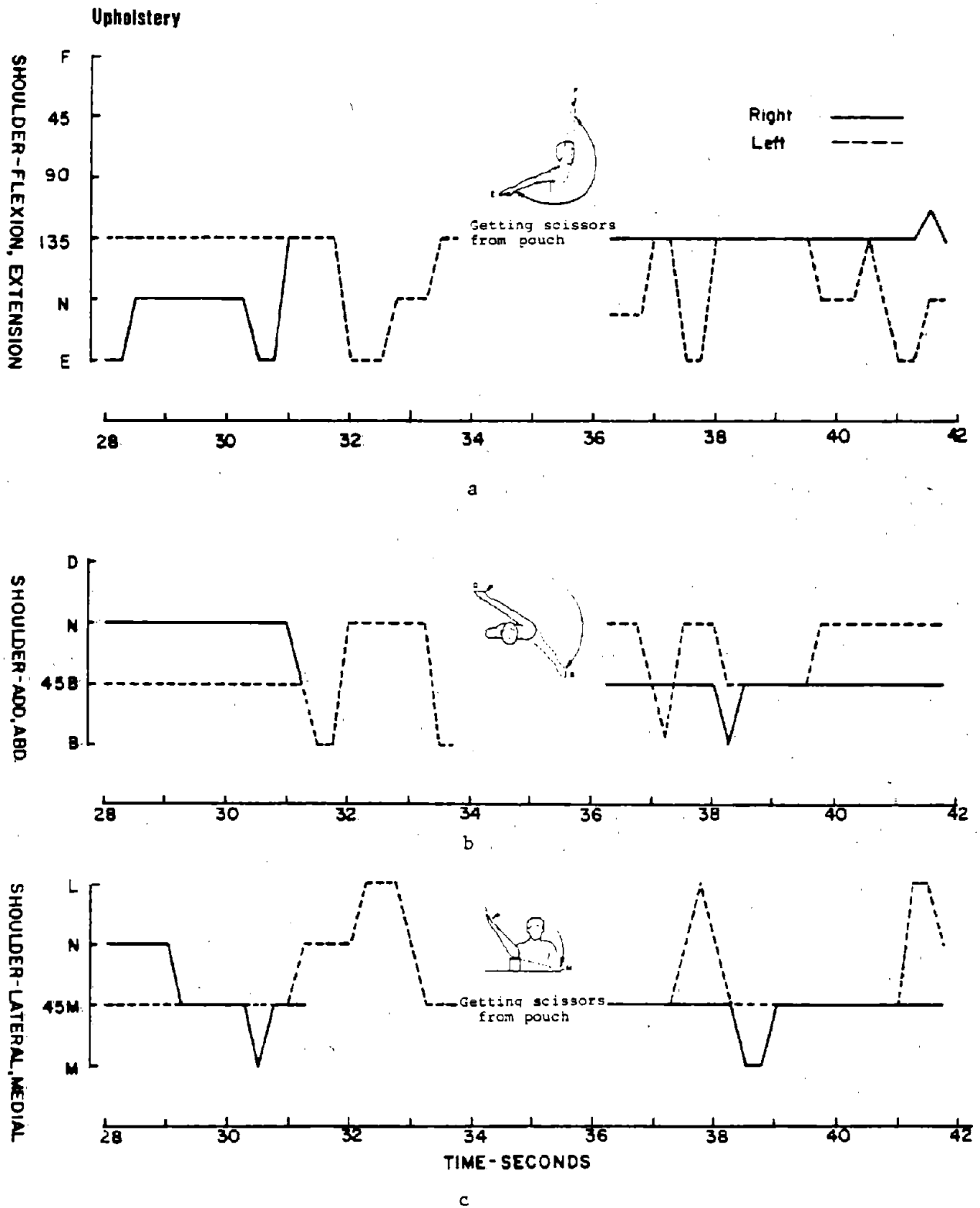


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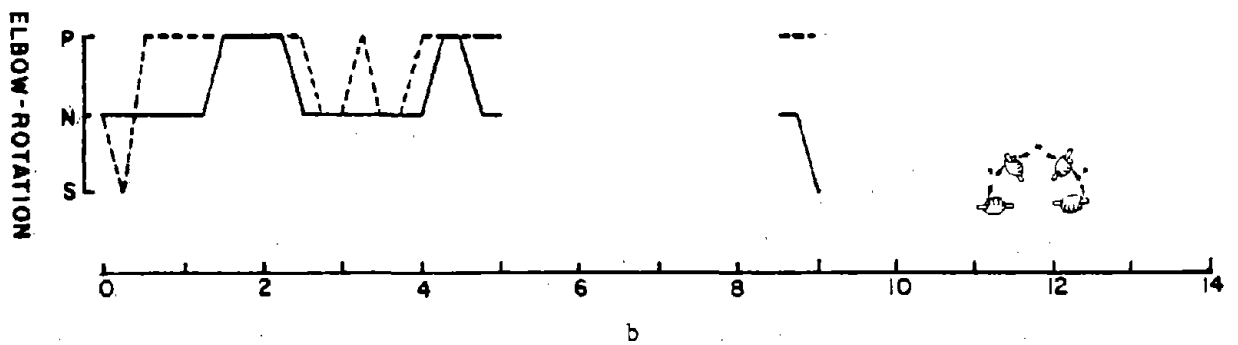
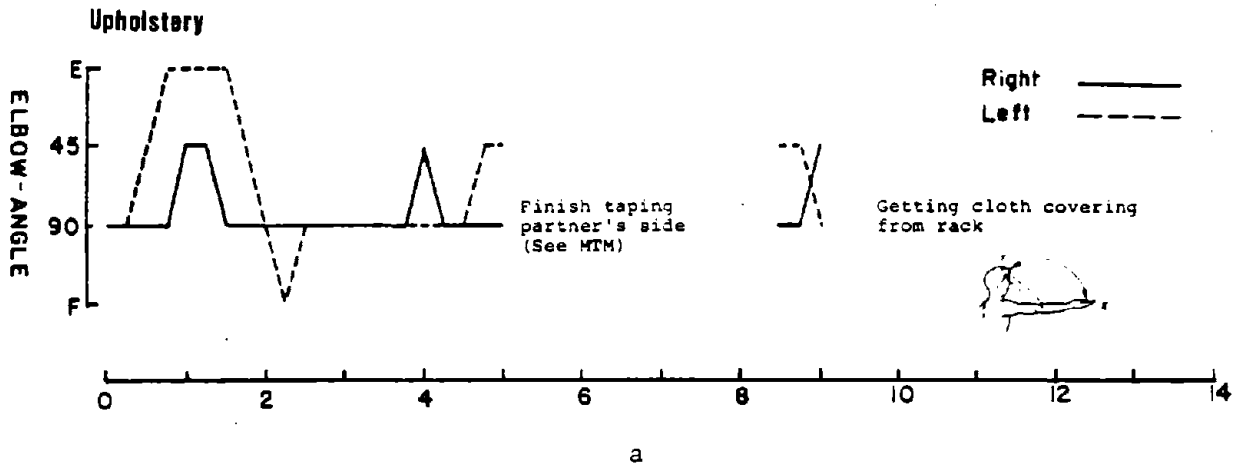


Figure C1.4

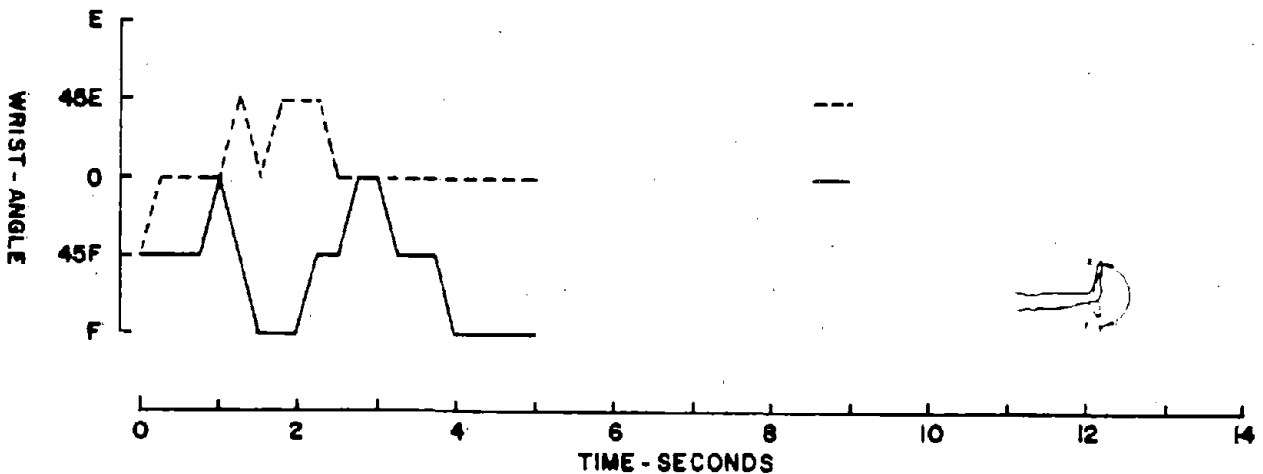
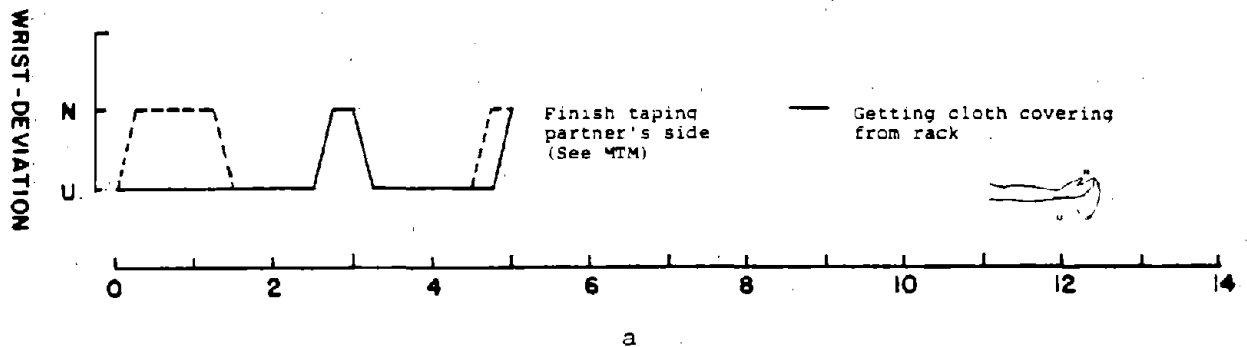


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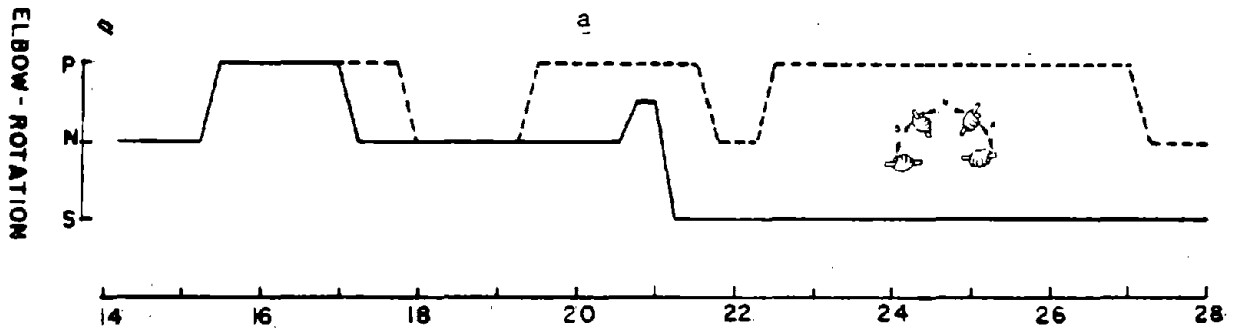
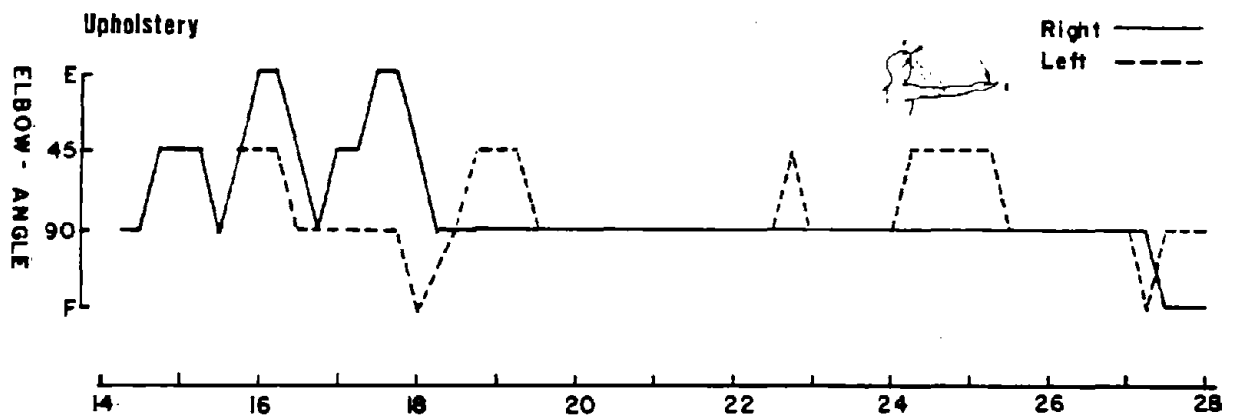


Figure C1.4 Continued.

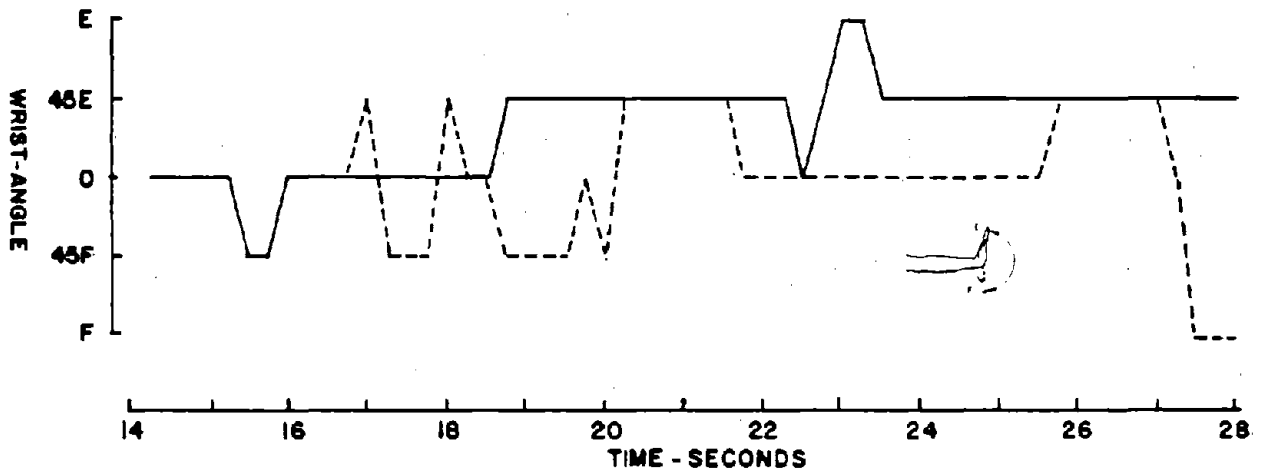
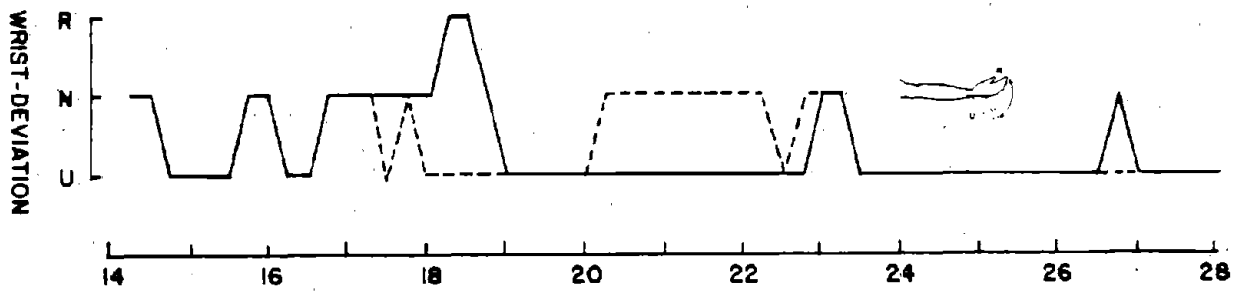


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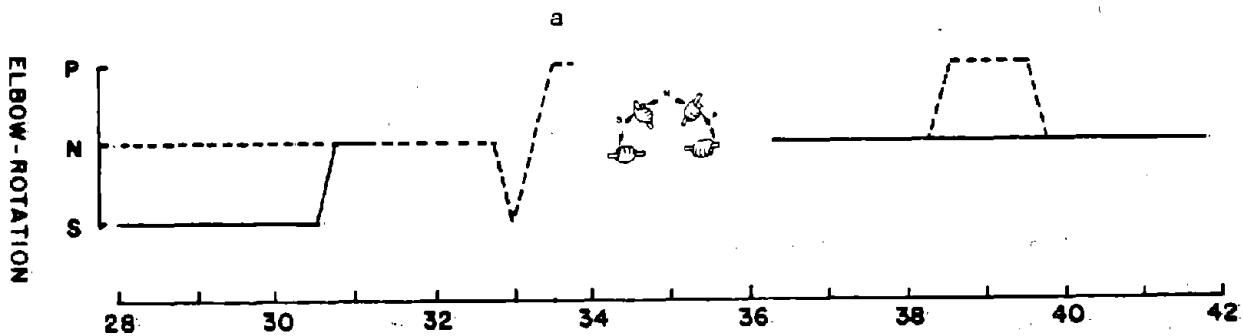
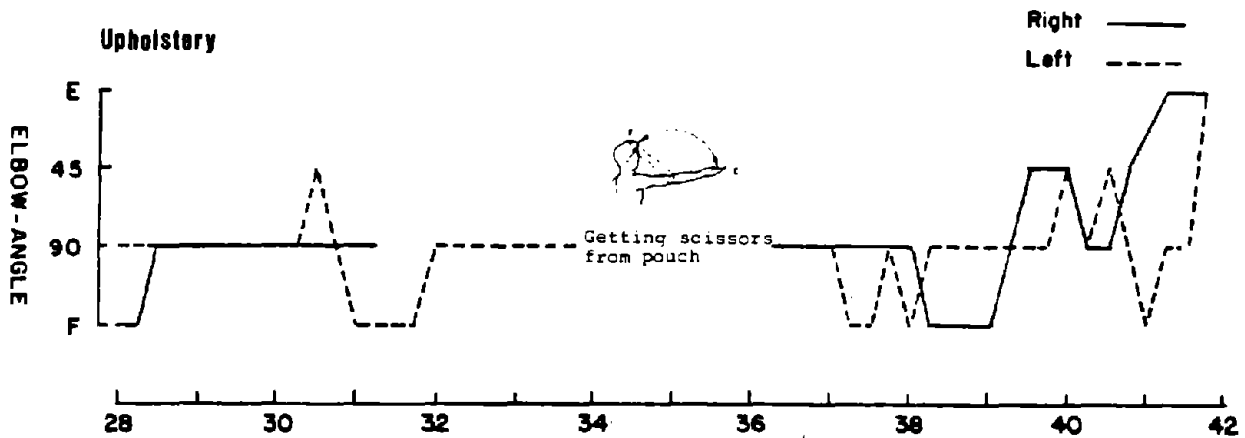


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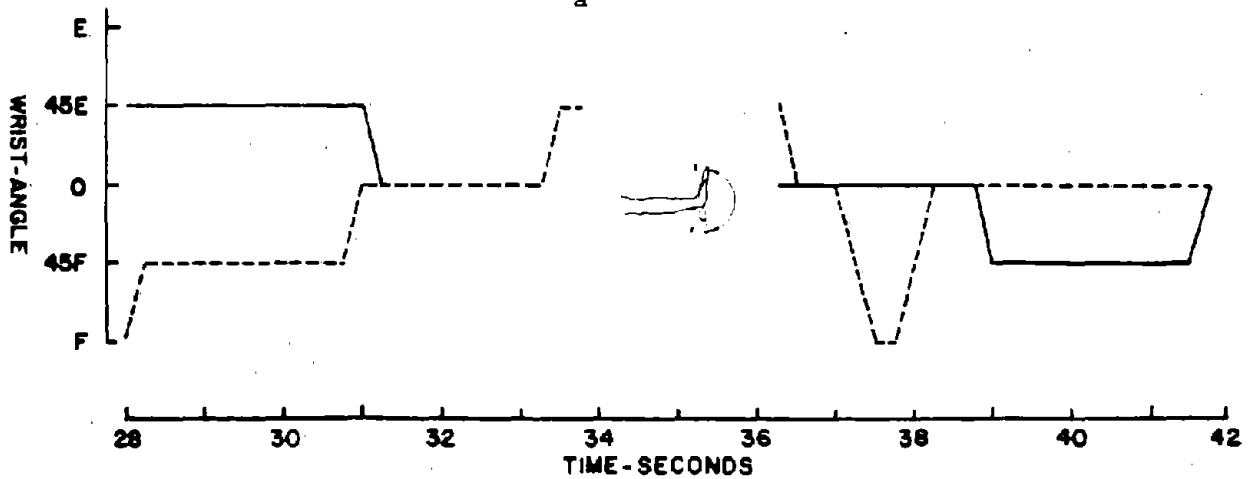
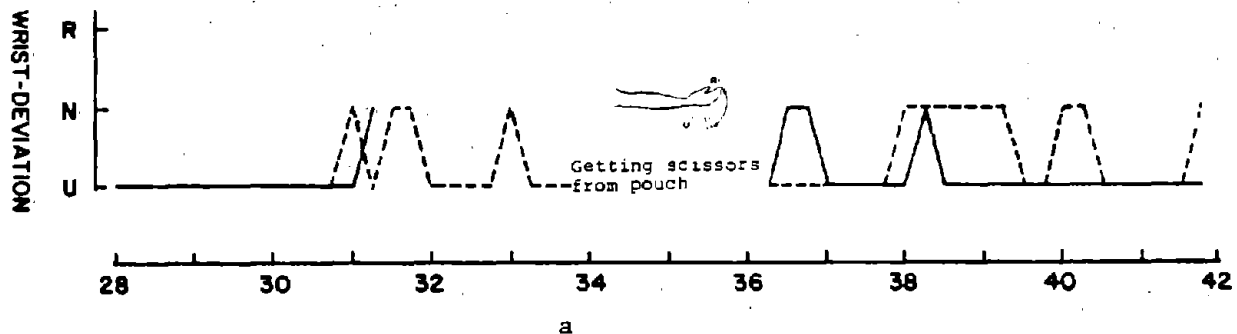
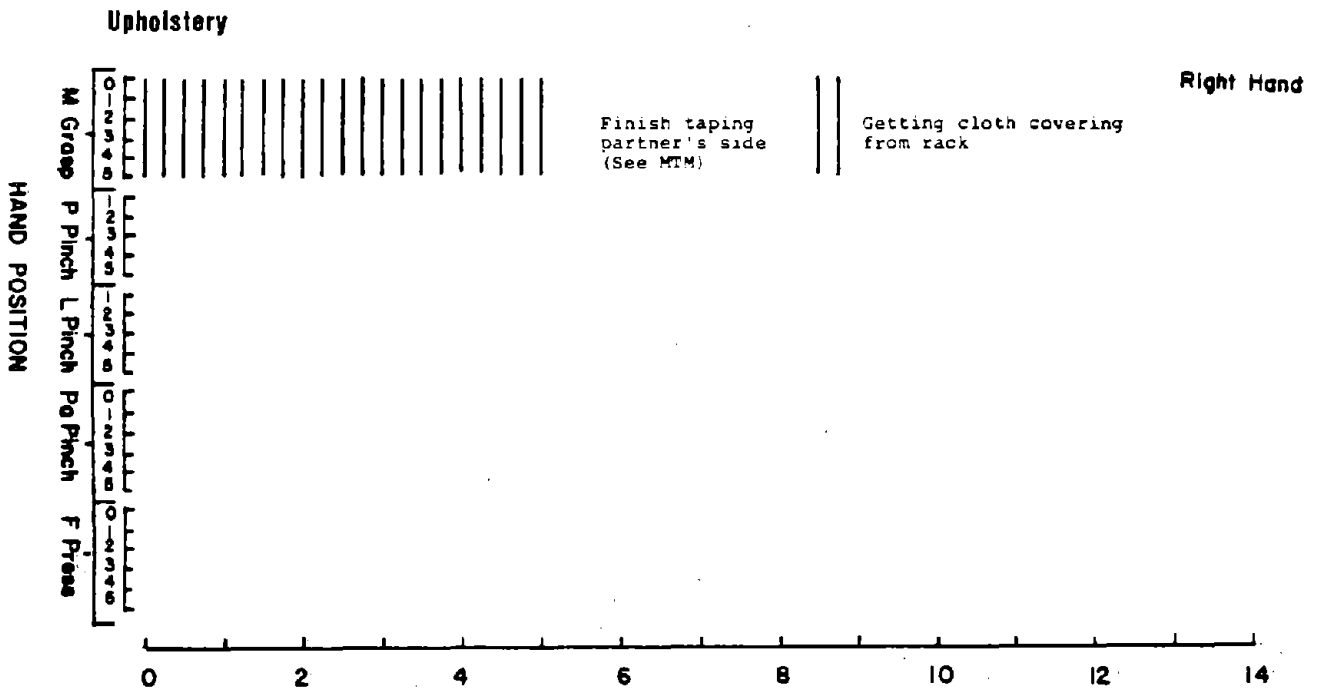
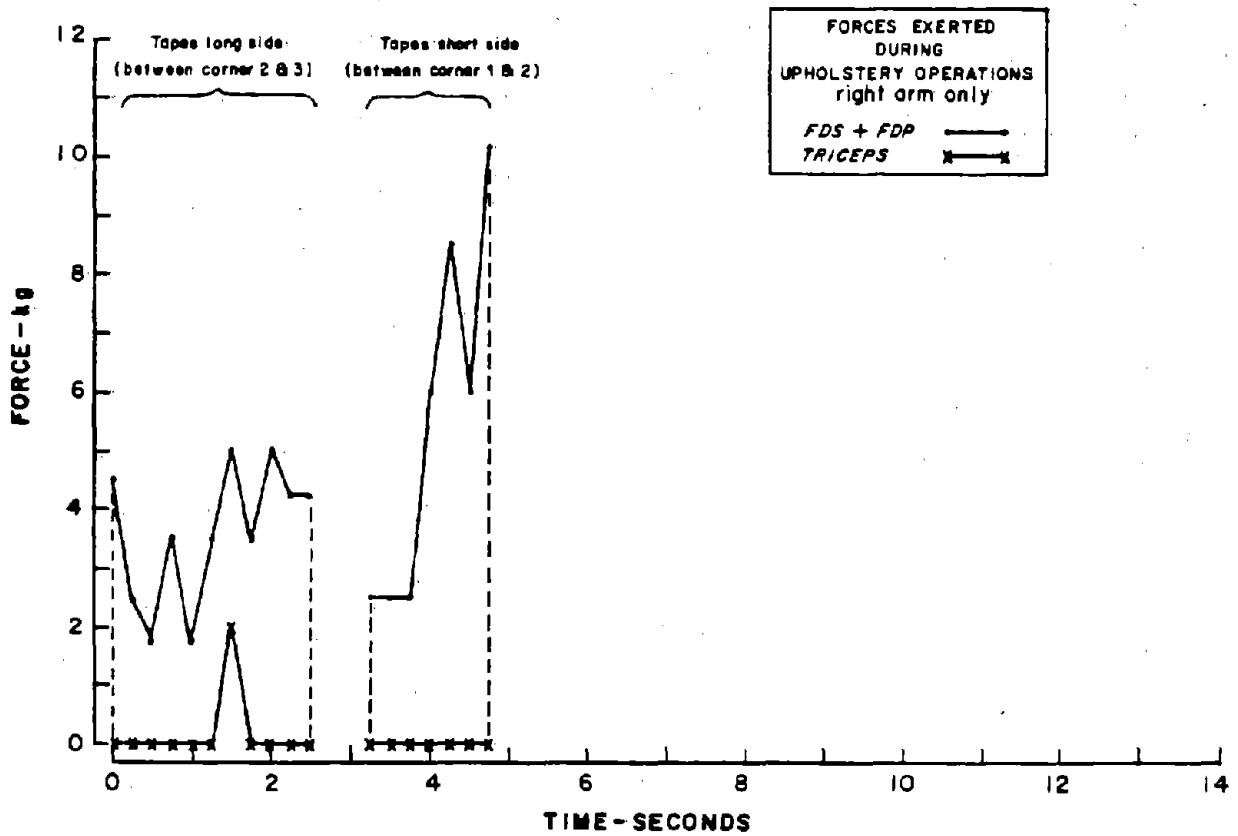


Figure C1.5 Continued.



a



b

Figure C1.6.

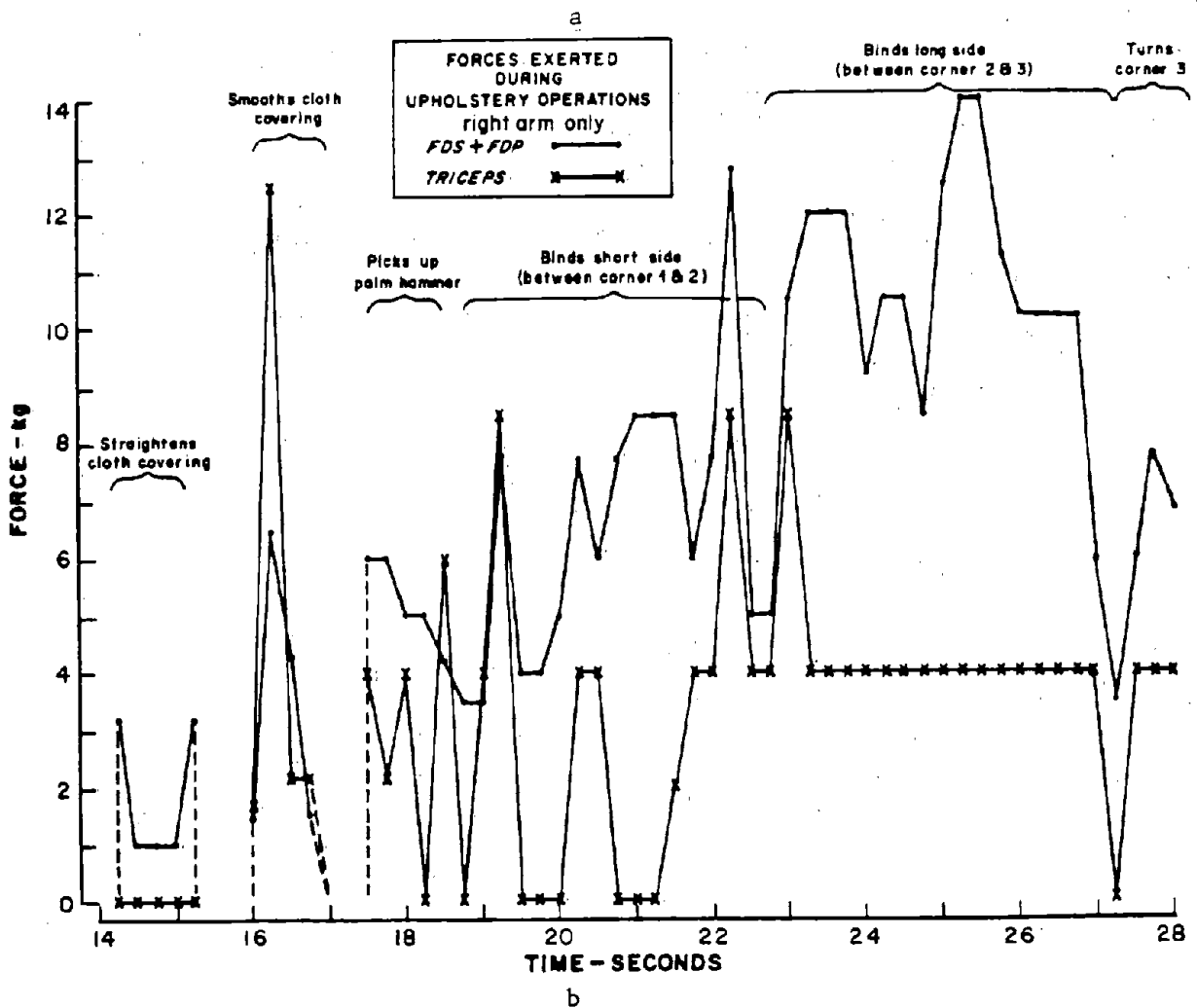
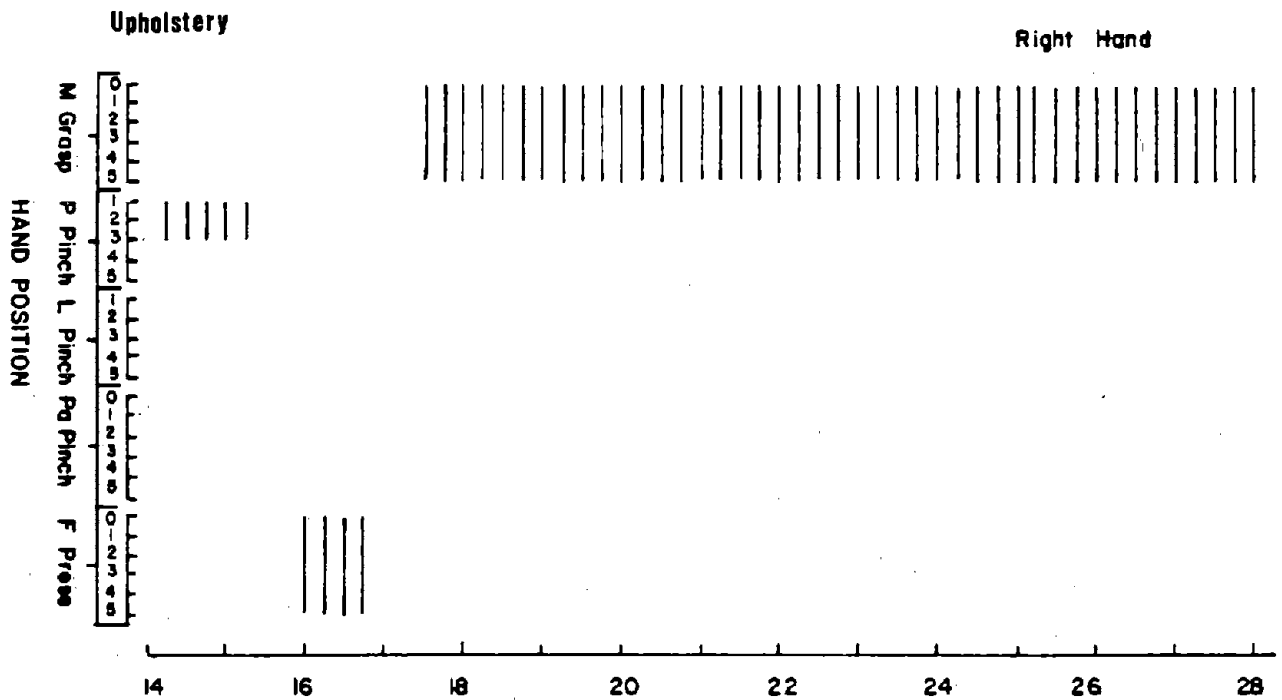
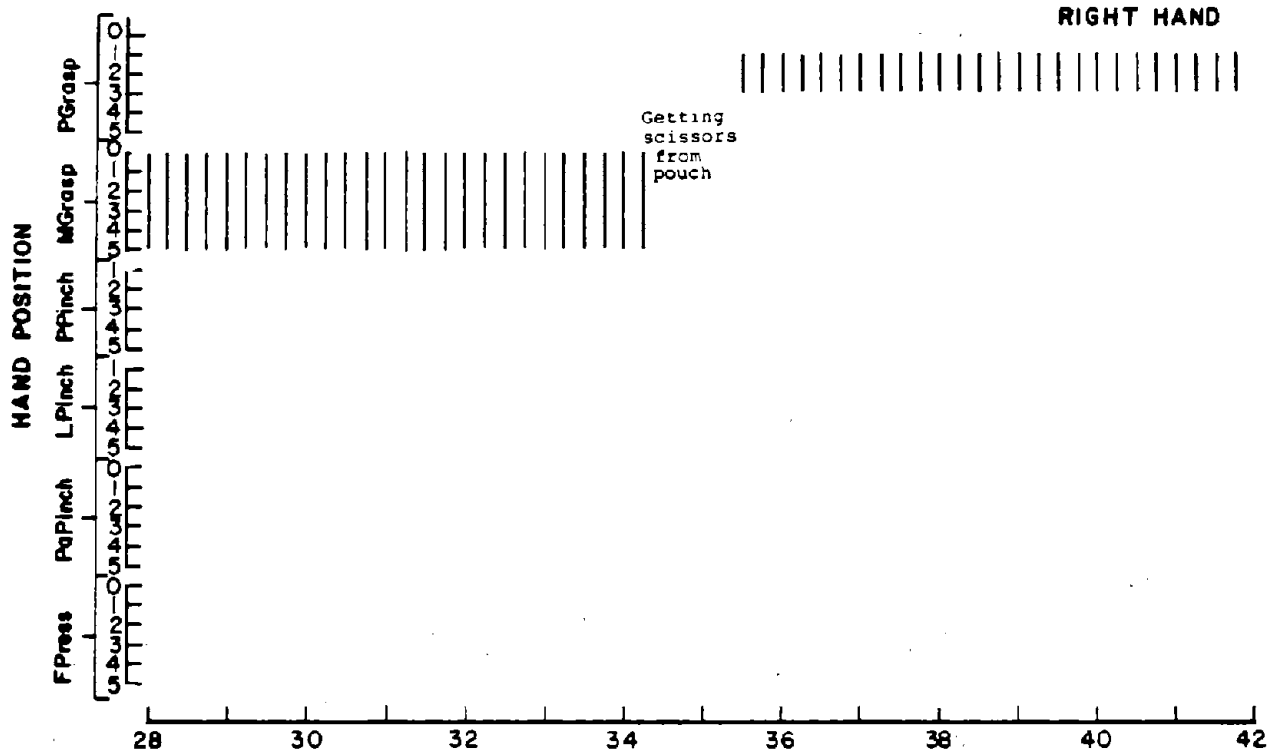


Figure C1.6 Continued.

Upholstery



Binds part of third side.  
(between corner 3 & 4) Cut binding cord

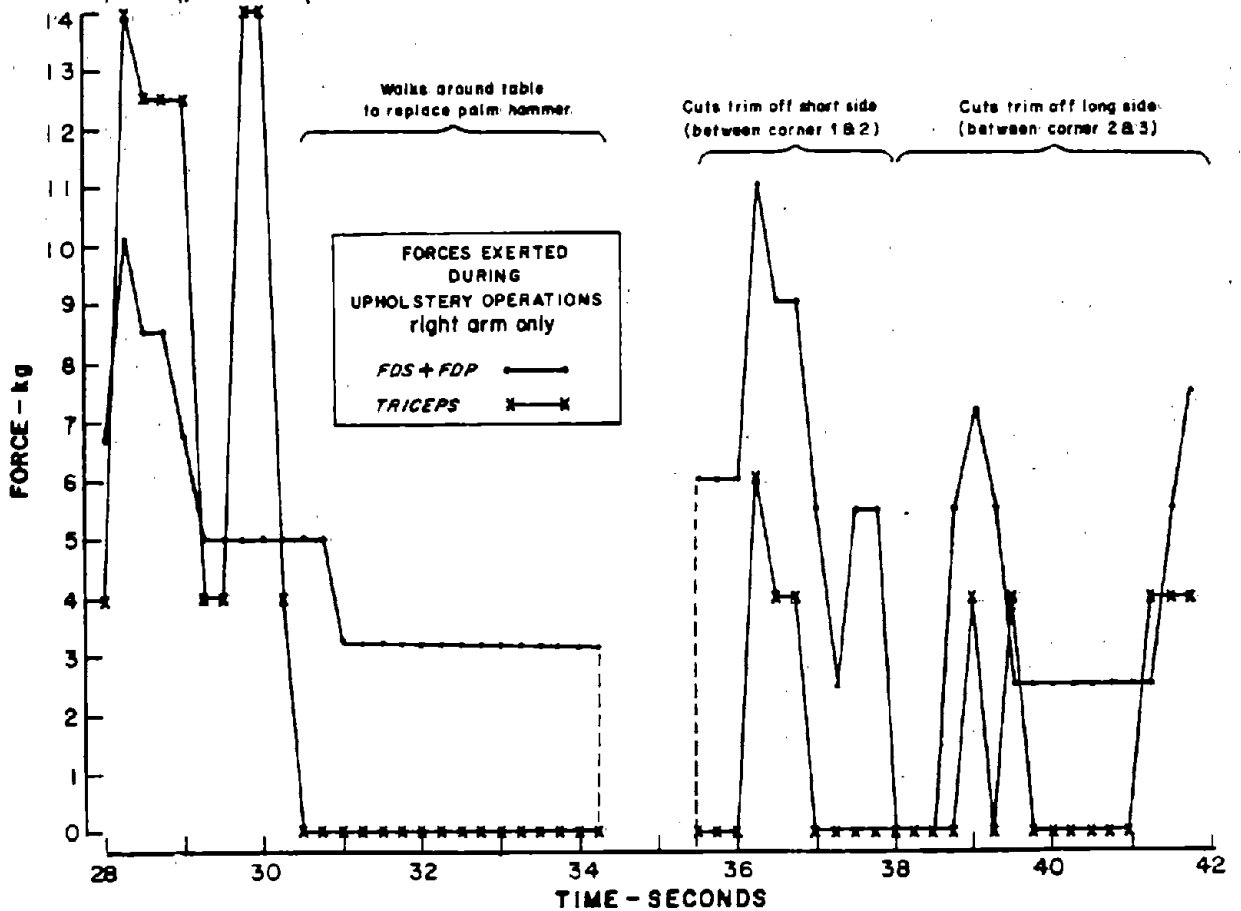


Figure C1.6 Continued.

**Upholstery**

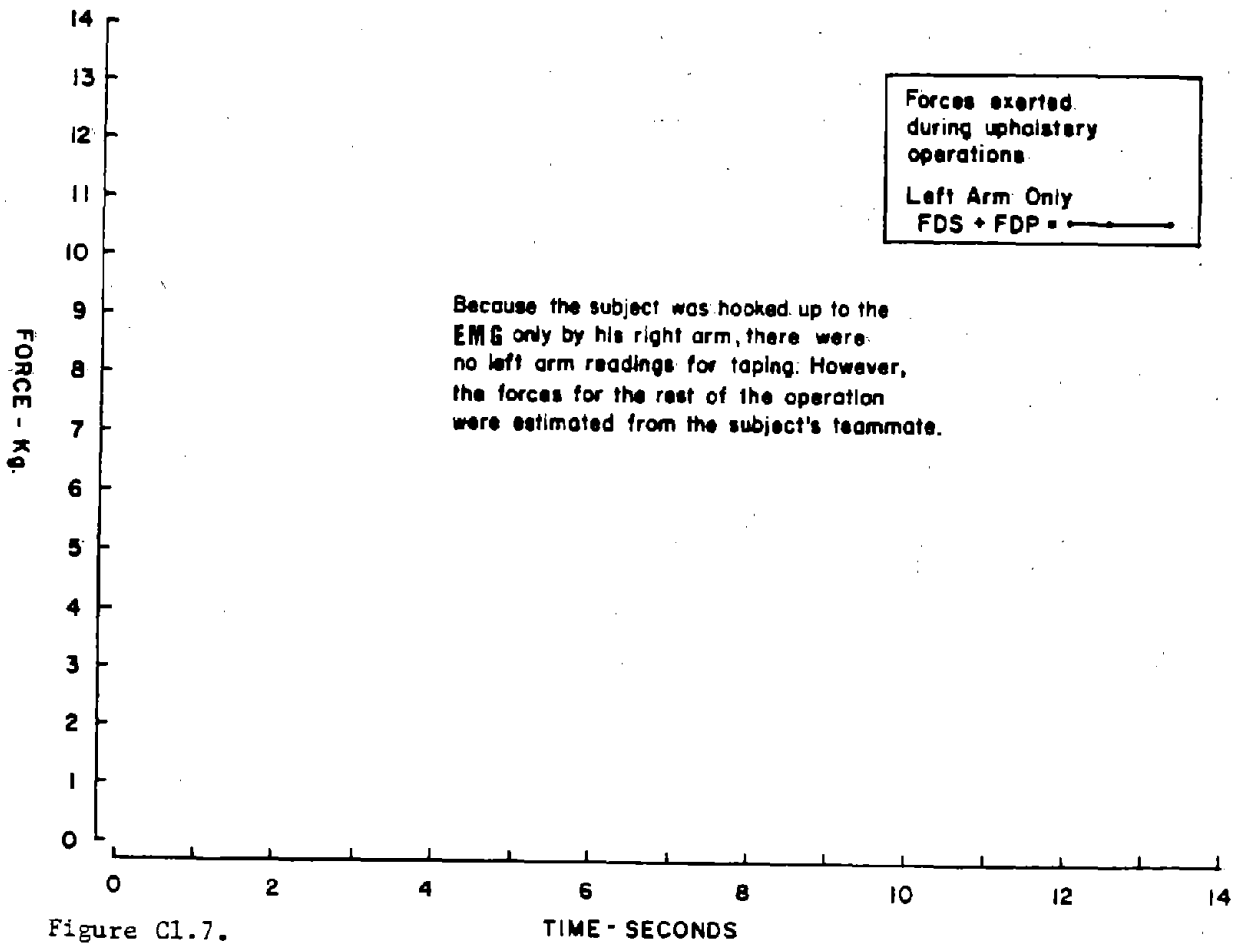
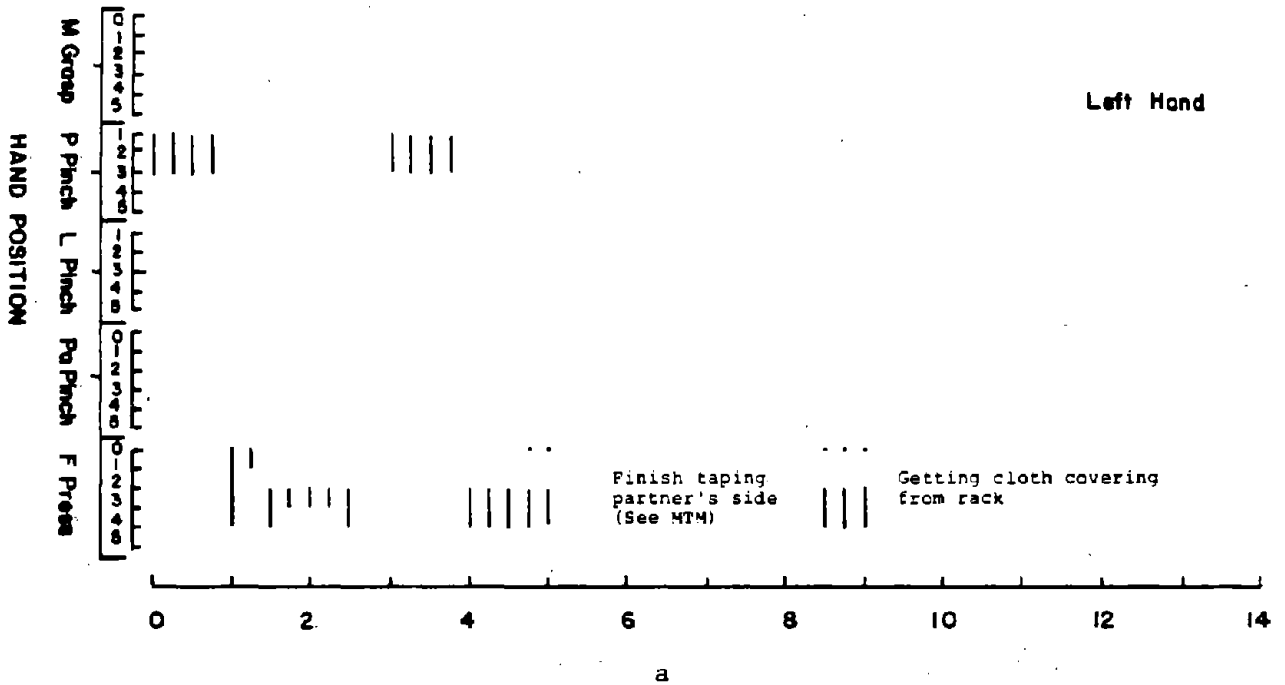


Figure C1.7.

b

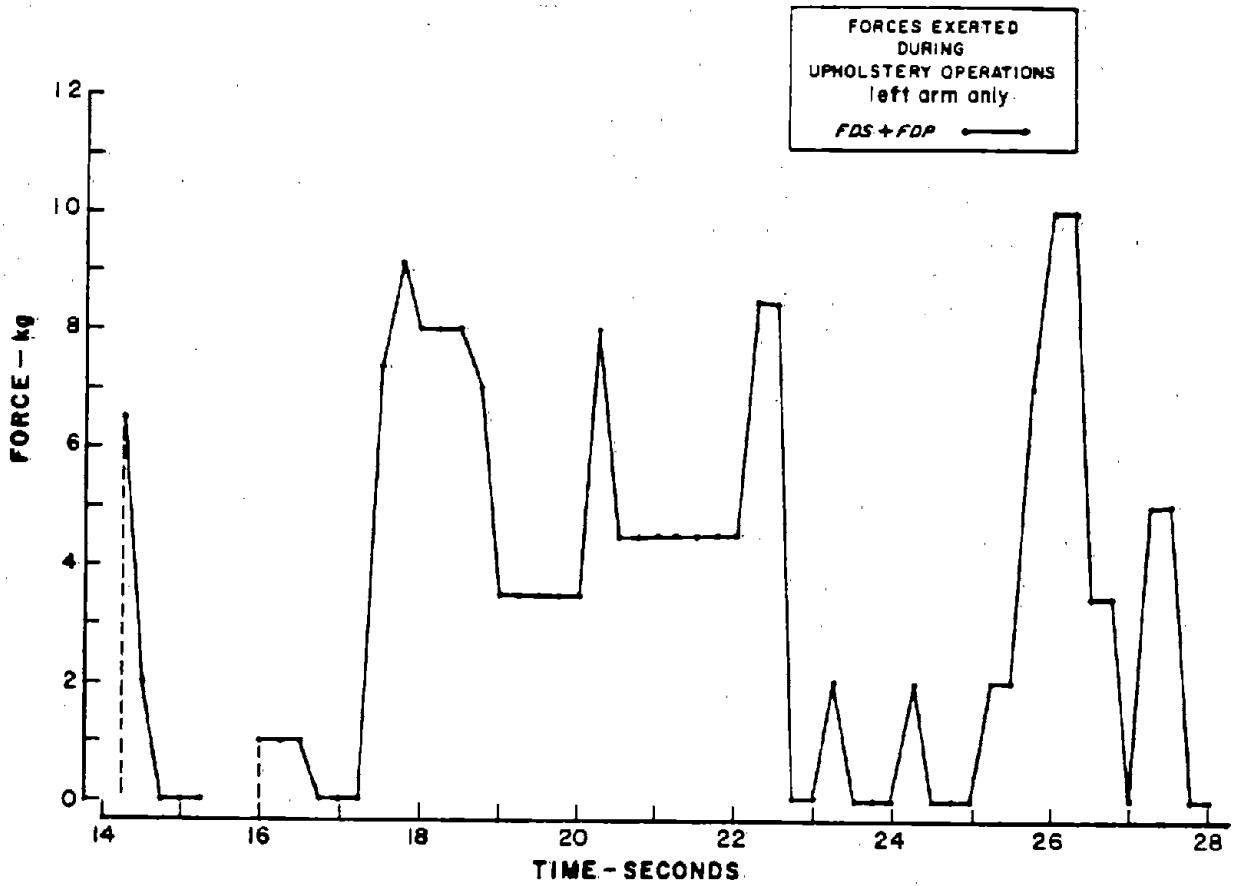
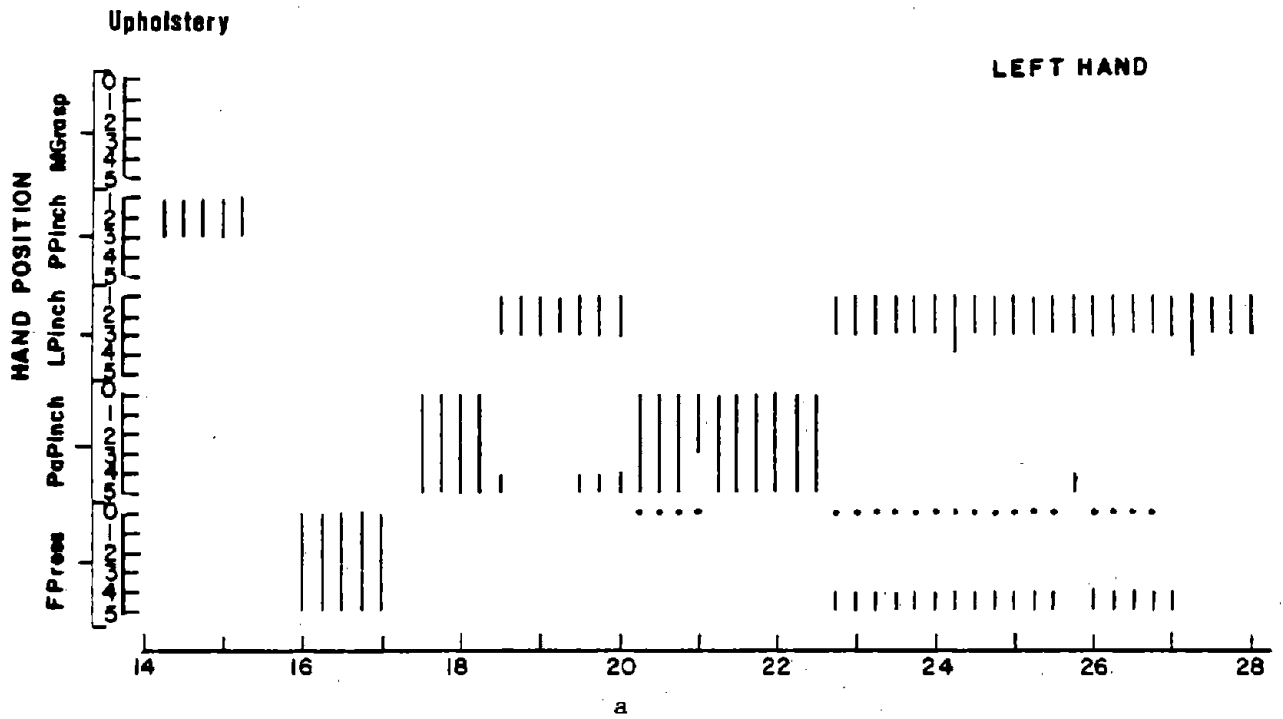
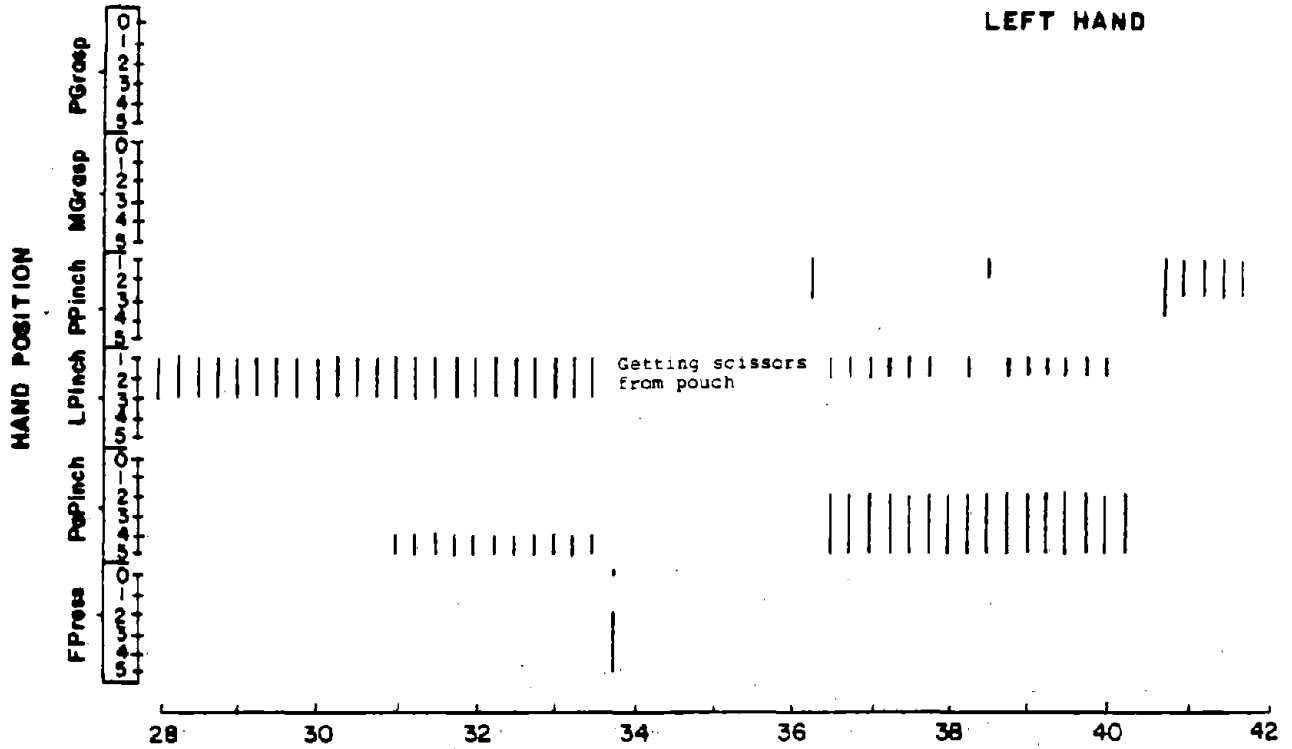
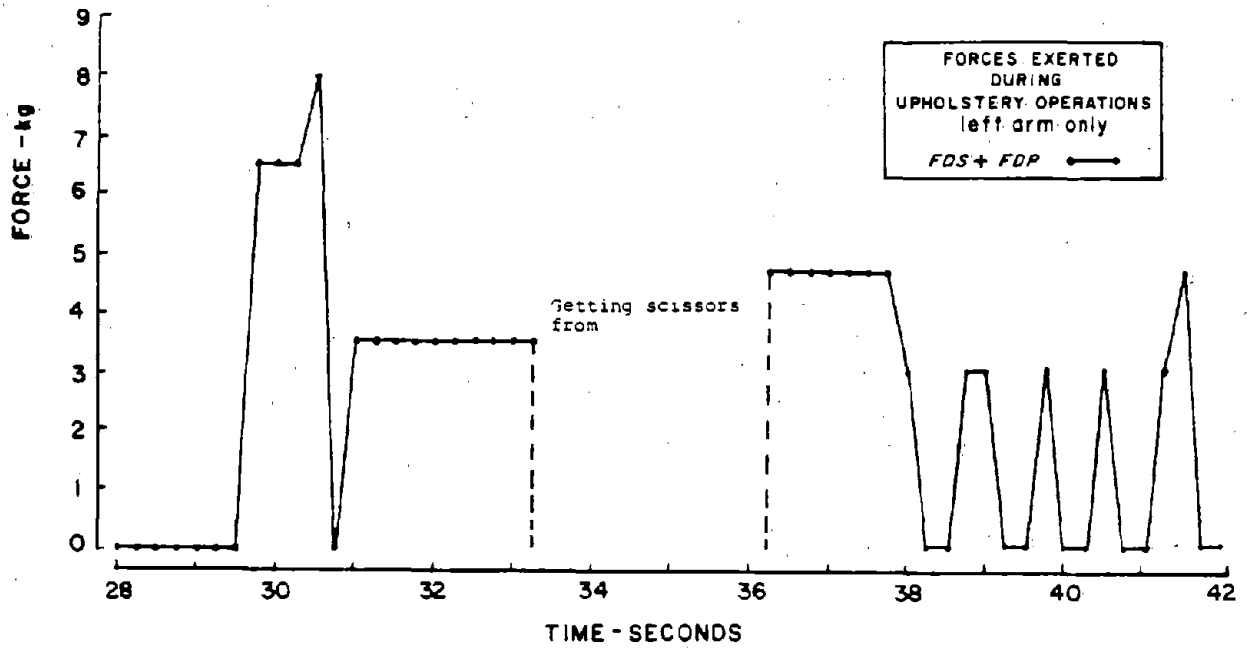


Figure Cl.7 Continued.

Upholstery



a



b

Figure C1.7 Continued.

## APPENDIX C2

### Assembly

Working in two-man teams, assemblers each perform the same tasks on one long and one short edge of the panel. First, supplies to start the cycle are collected by one assembler while the second gets a panel and places it on the work table. Second, the facing strips are placed on the panel, and a black gasket is obtained from under the panel and placed on the strip. A pneumatic gun and screws are picked up from near corner 2 (see Figure C2.1). The gun is loaded and screws are placed through the strip and gasket; the strip is supported with the gun. The strip and gasket is then screwed to the edge of the panel near corner 3 (see Figure C2.1). Walking to corner 2, a second screw is inserted for support. The upholstery edge is then tucked behind the strip and gasket starting at corner 2 along the upper surface to corner 3 and back on the lower surface. The gun is used to place one screw in corner 2; walking to corner 2, four screws are inserted from corner 3 to corner 2. A knife is used to repeat the upholstery tuck as before.

The assembler walks to supply and gets two small black brackets; the gun is used to screw one into the top near corner 2 and the second near corner 1. Screws are picked up from supply and two are placed into the edge of corner 1, the procedure then is repeated at corner 2. The assembler returns to supply, gets an adapter, and fits it to the gun. A screw is put into the top at corner 1 first, then corner 2.

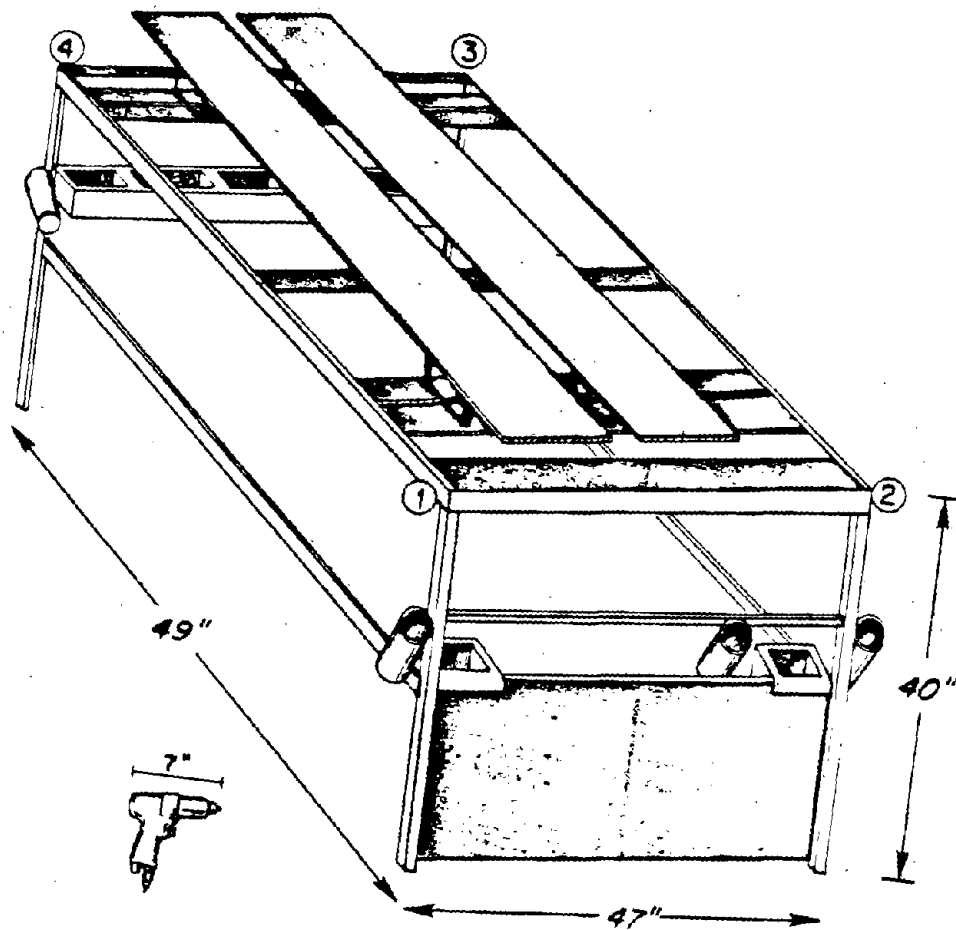
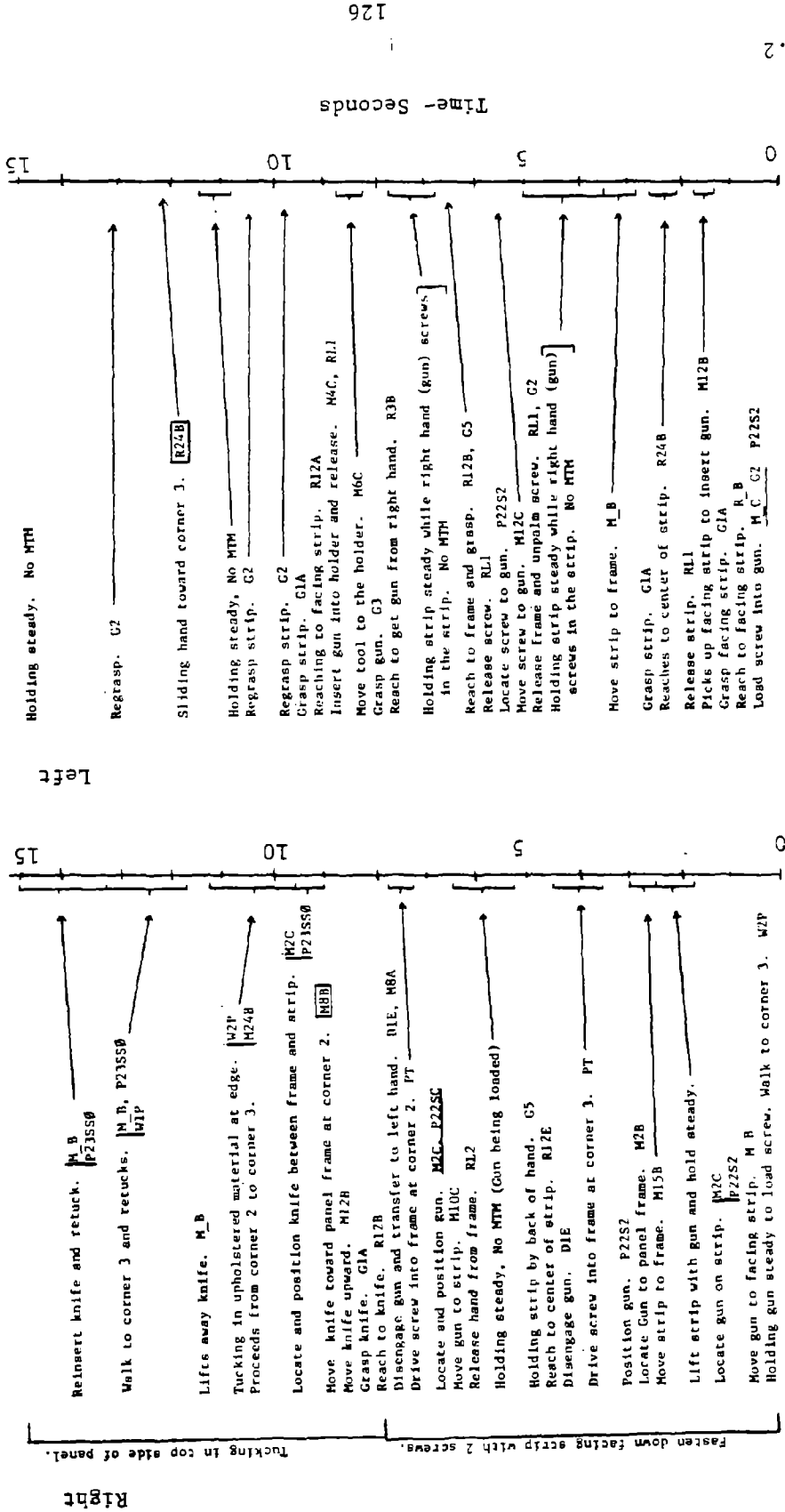


Figure C2.1: A typical power screwdriver and the work station used for panel assembly are shown above.

Picking up a finish strip from supply, the worker walks to the edge to fit the strip. The finish strip is held in place with one hand while he reaches for the gun and tightens a retaining screw on the top edge at corner 2. A top finishing strip is obtained from supply and shaped into place. With tape from supply, corners 1 and 2 are secured. The top of the panel is lifted from the work table and placed in storage. End of cycle.

Annotated MTM elements and upper extremity postures are shown for one cycle of panel assembly. Joint positions are expressed according to the scheme described in Appendix A.



Right

Tucking in top side of panel.  
Fasten down facing strip with 2 screws.

Left

Time - Seconds

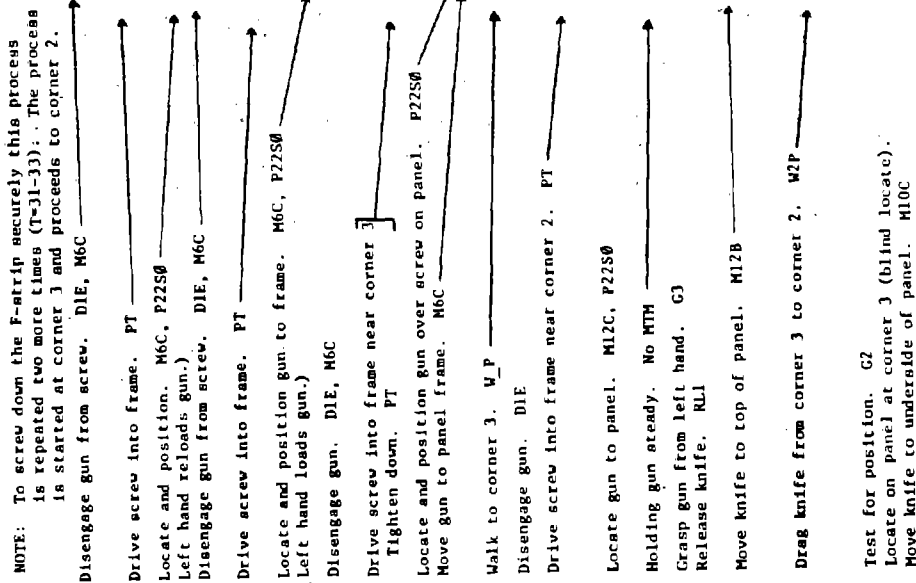
Figure C2.2

Assembly

Right

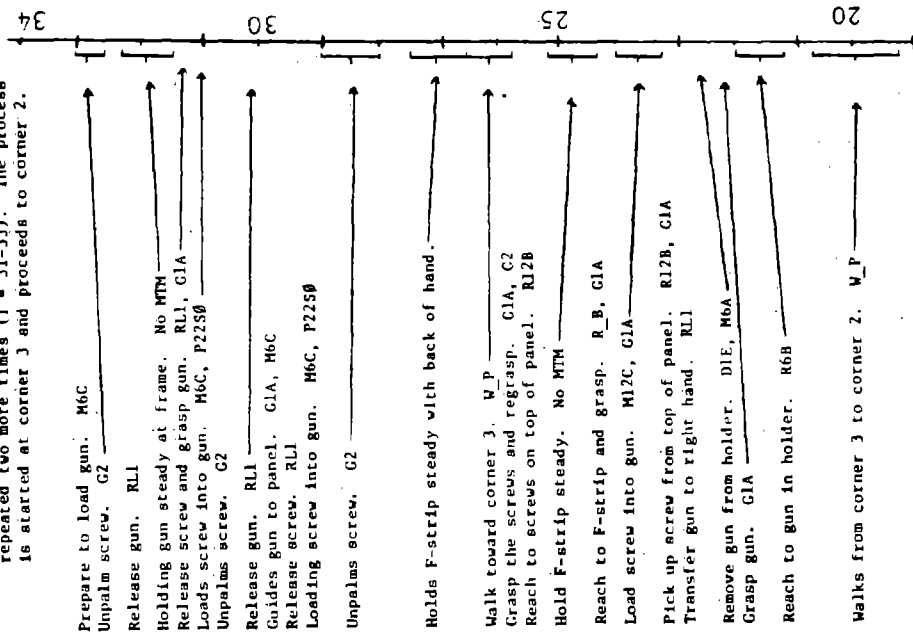
Securing the facing strip with the rest of the screws.

Tuck bottom side of panel



Left

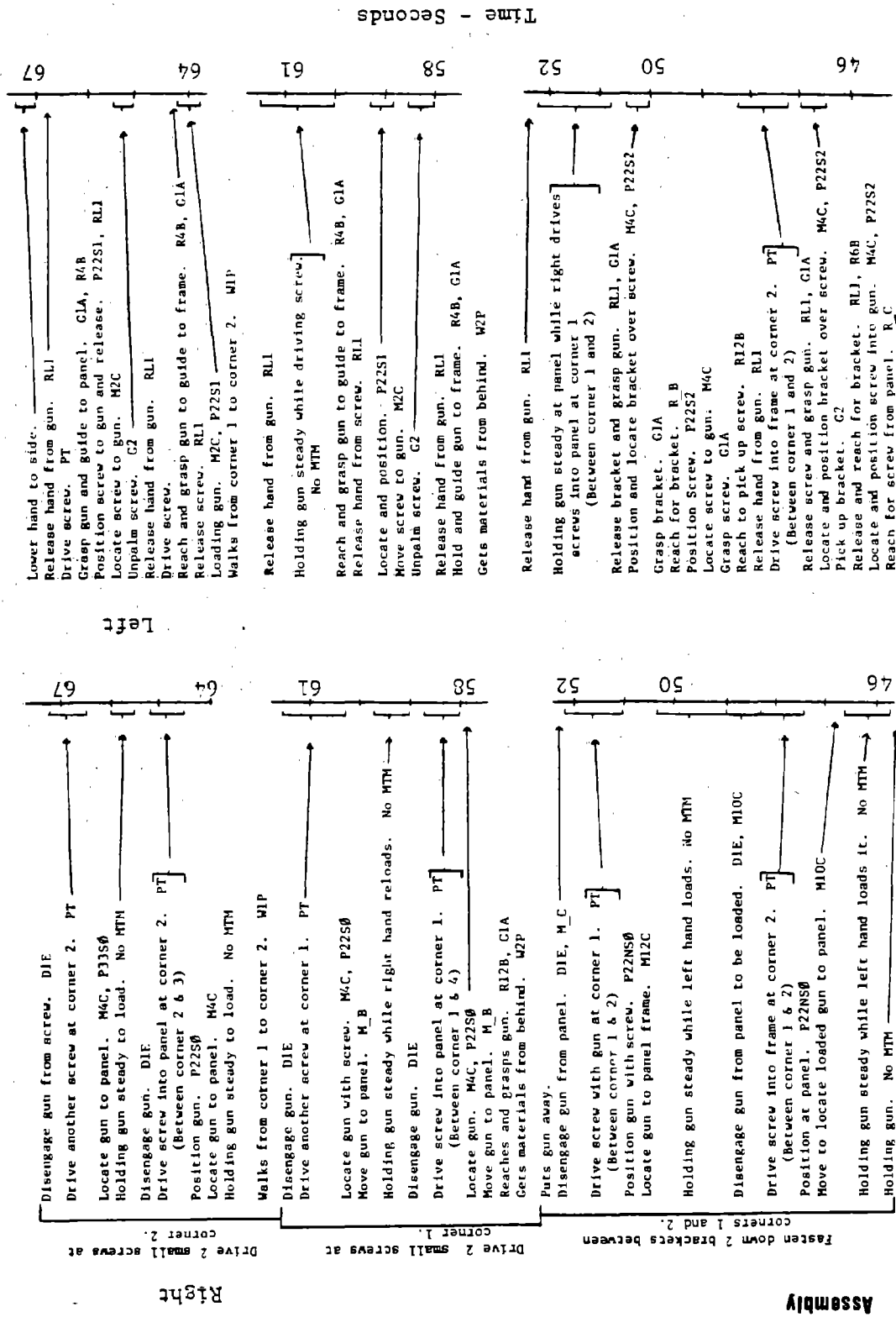
NOTE: To screw down F-strip securely, this process is repeated two more times (T = 31-33). The process is started at corner 3 and proceeds to corner 2.



Time - Seconds

Figure C2.2 (cont.)

Figure C2.2 (cont.)



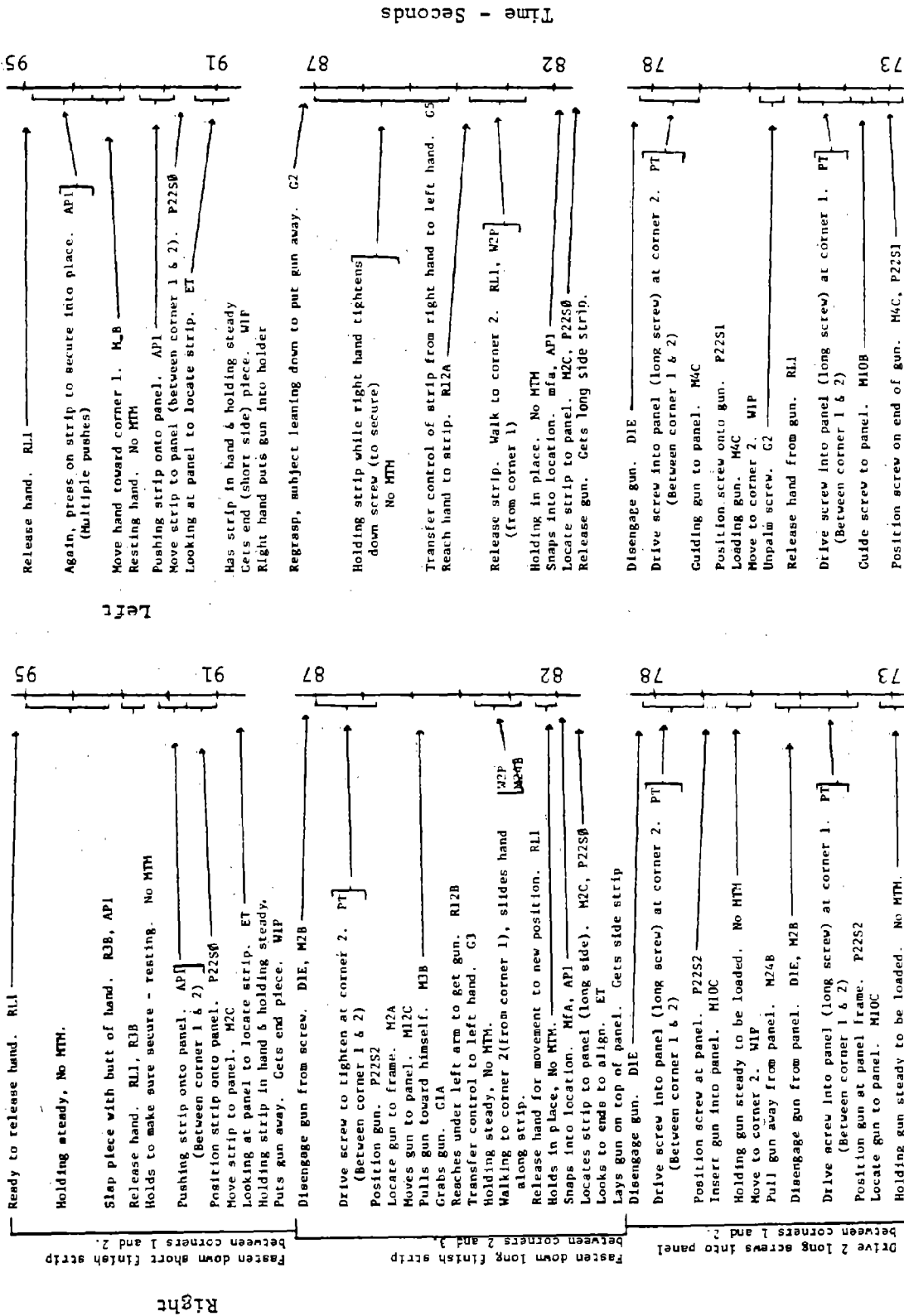


Figure C2.2 (cont.)

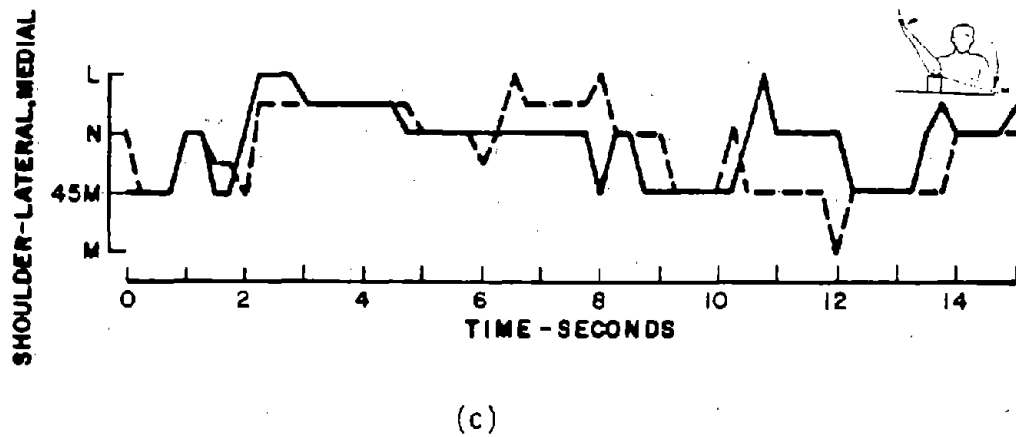
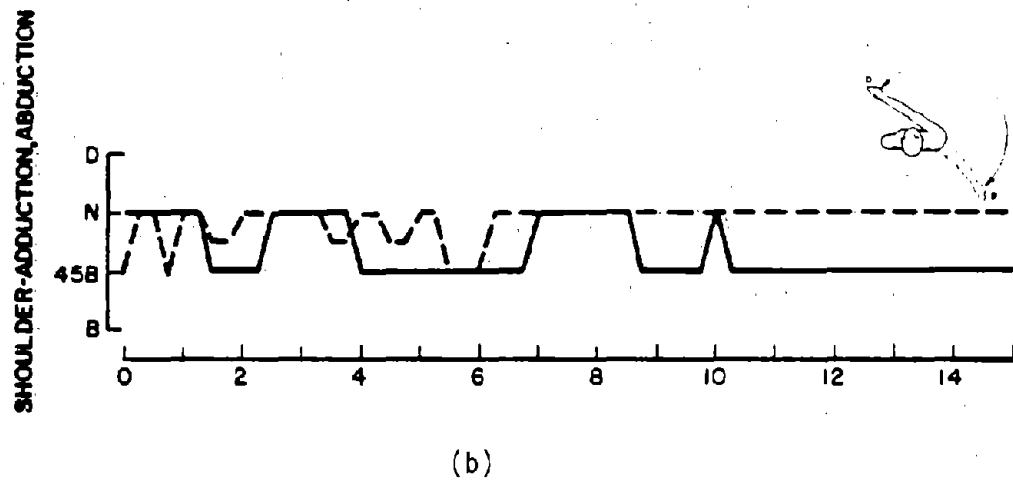
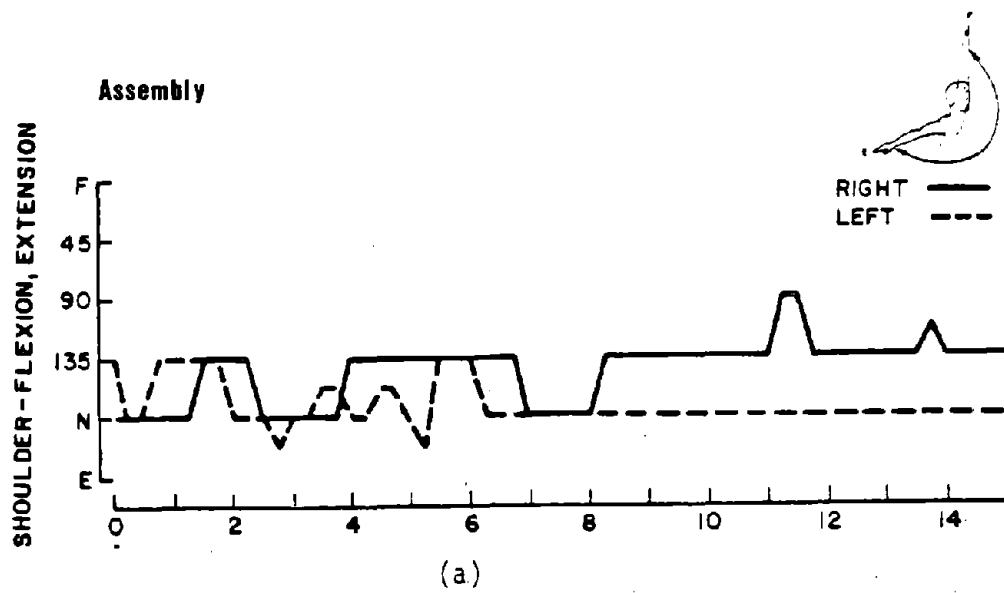
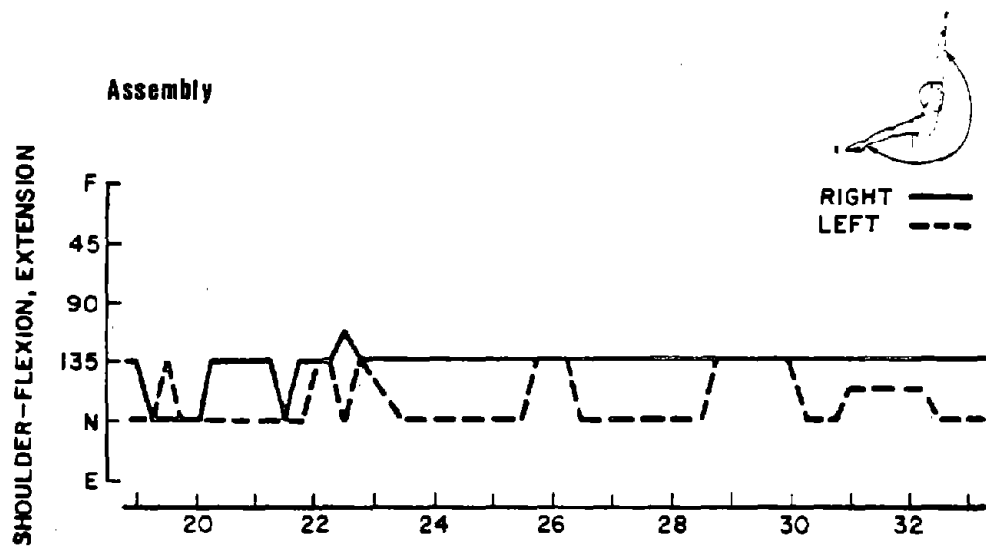
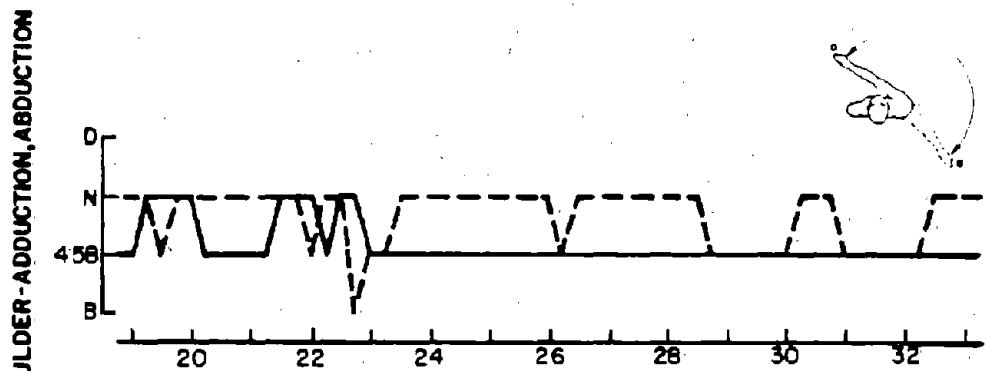


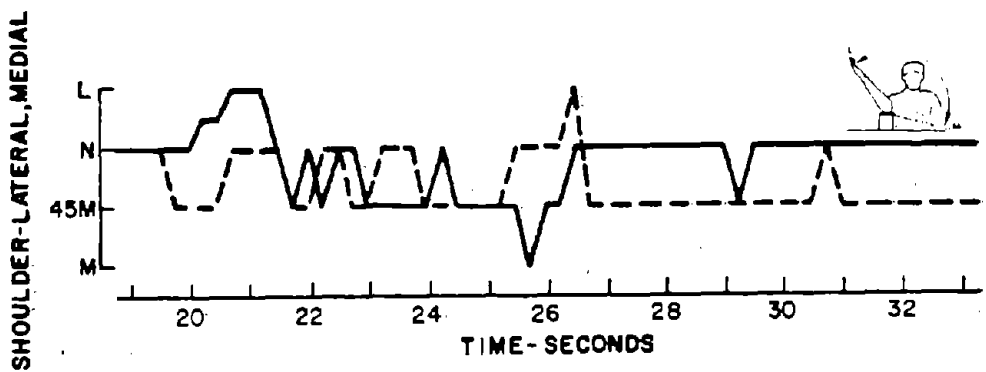
Figure C2.3



(a)



(b)



(c)

Figure C2.3 cont.

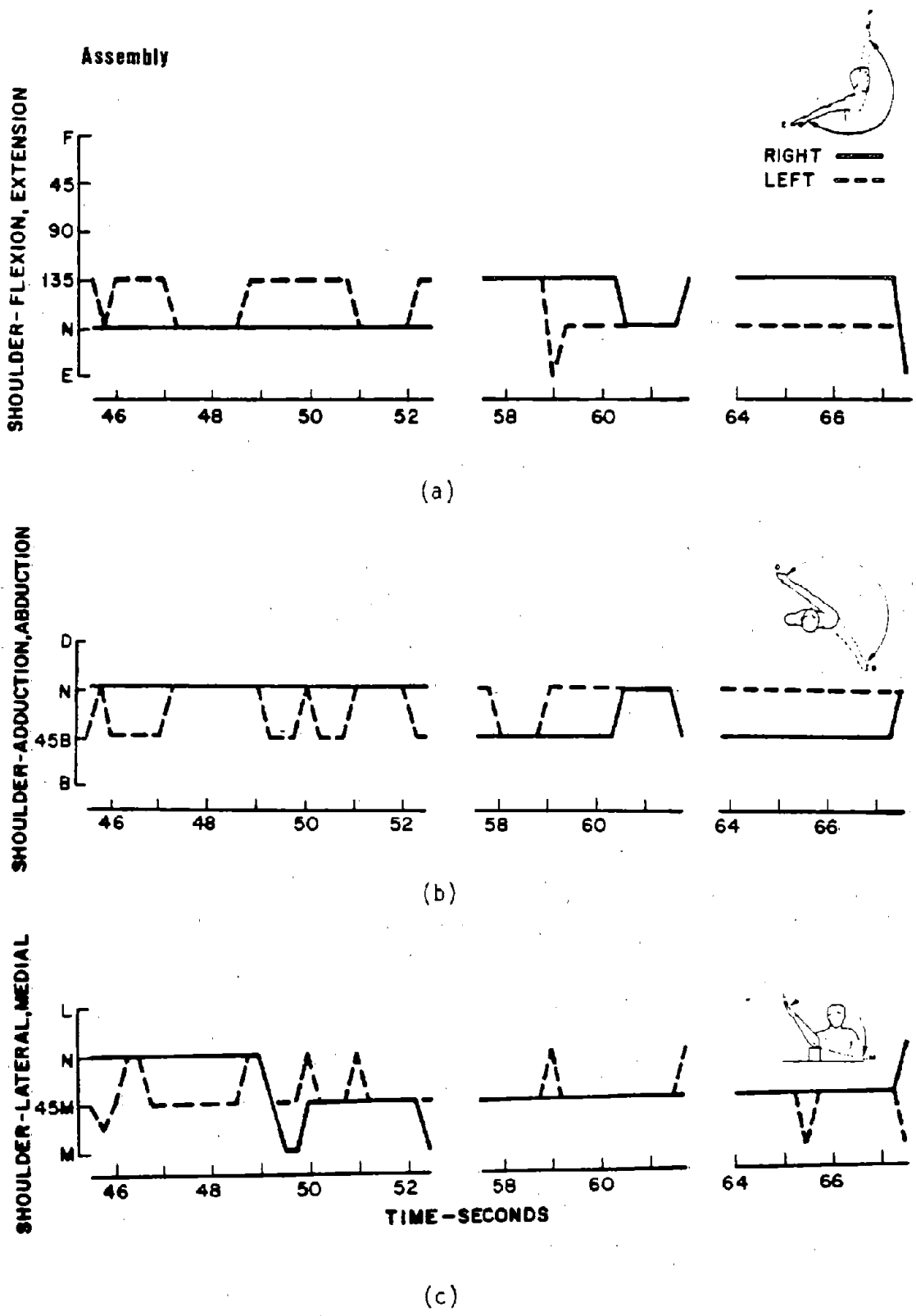


Figure C2.3 cont.

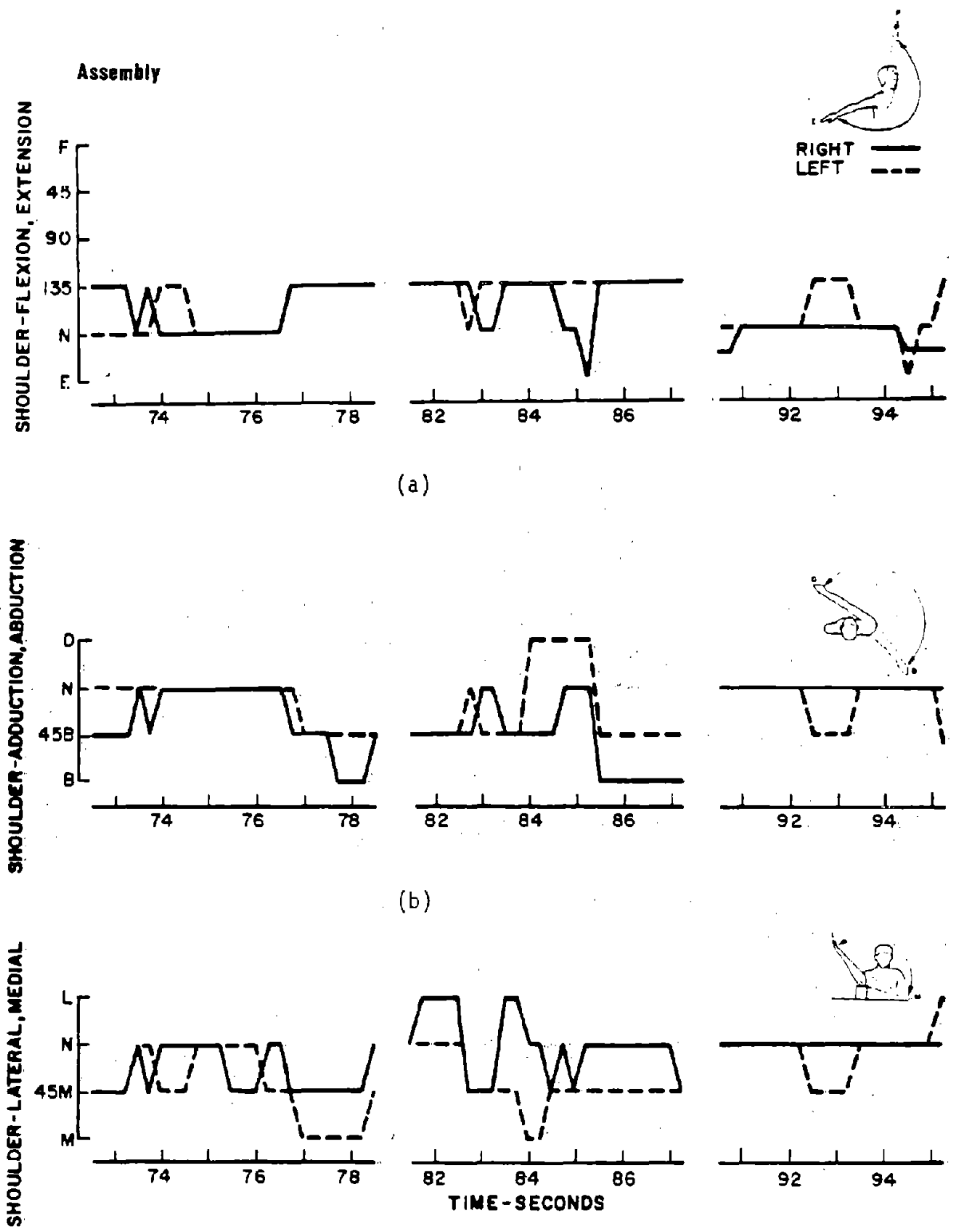


Figure C2.3 cont.

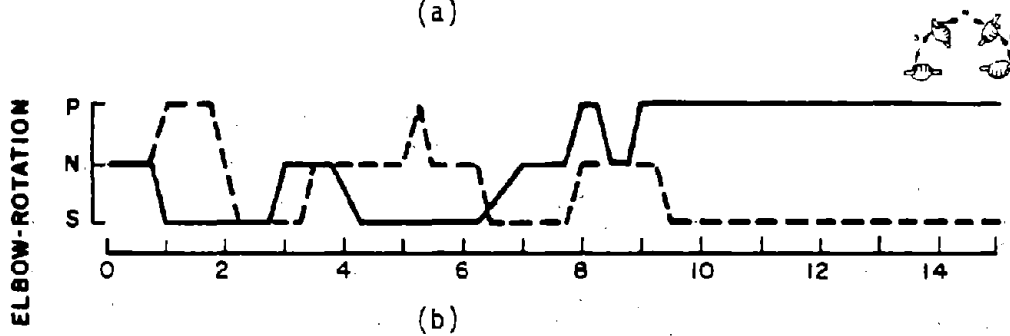
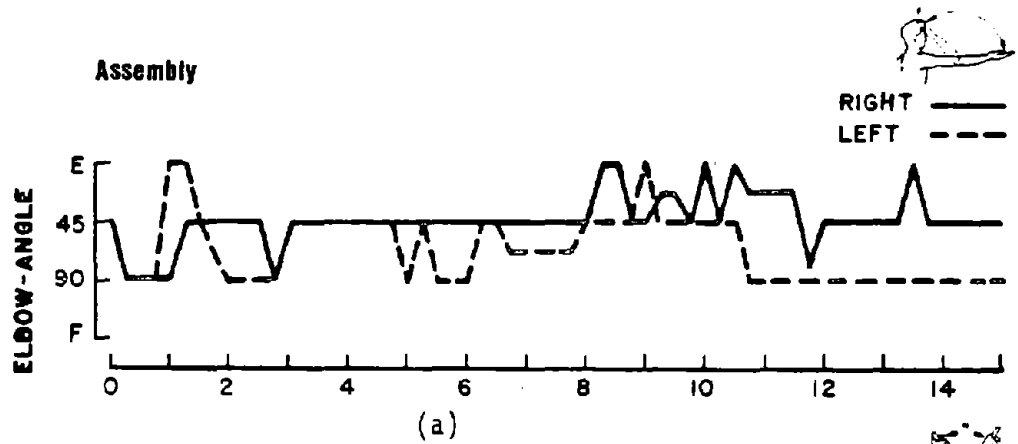


Figure C2.4

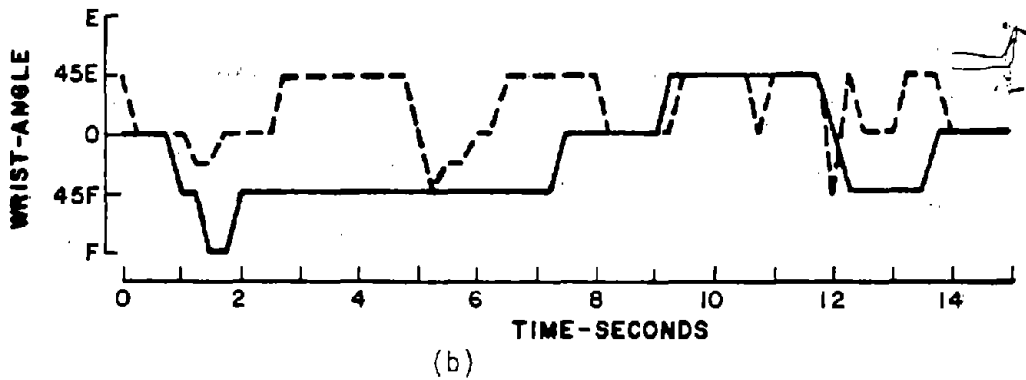
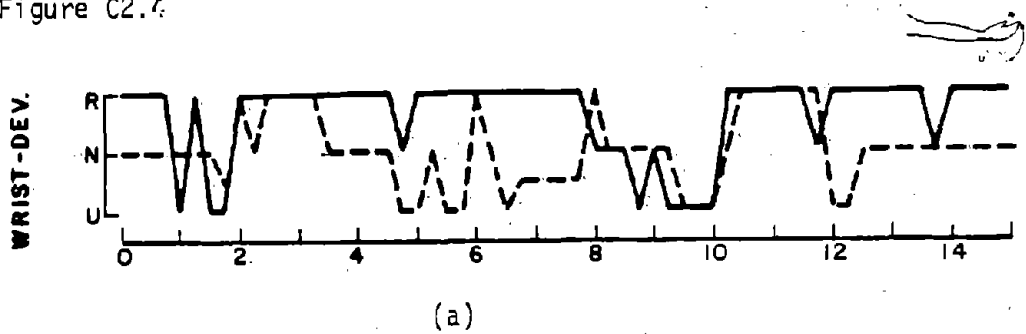


Figure C2.5

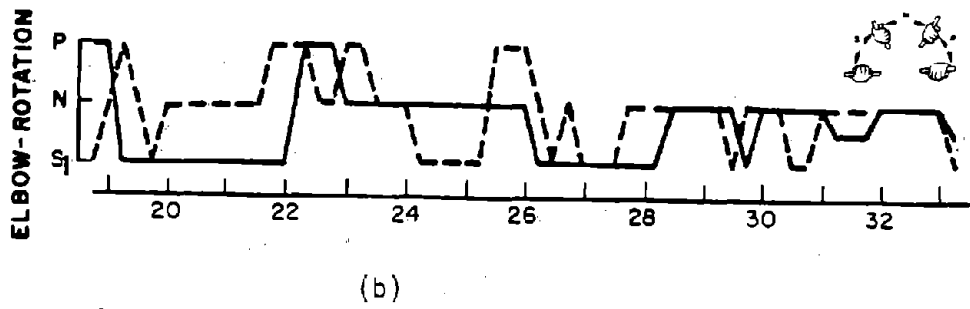
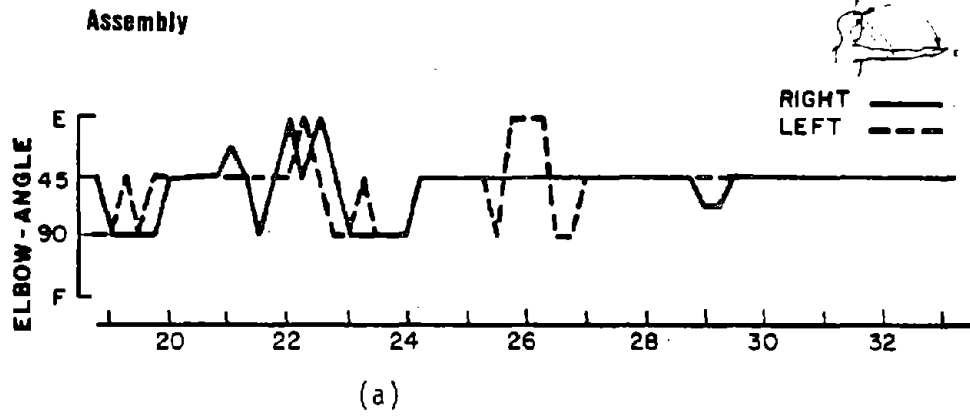


Figure C2.4 cont.

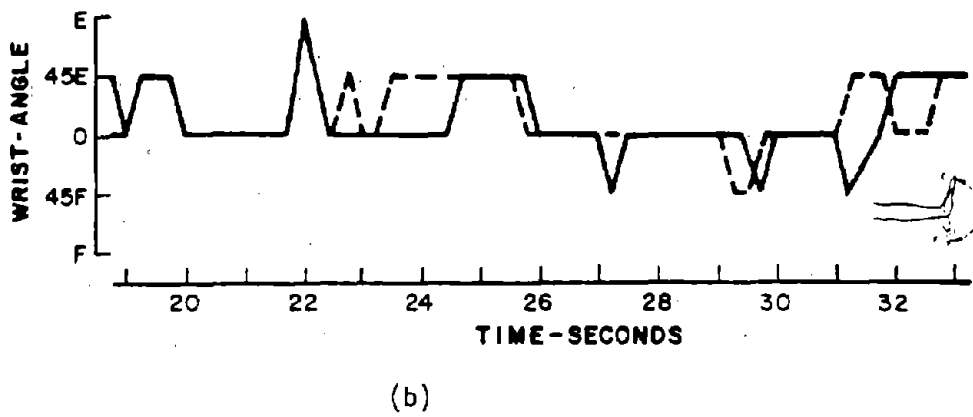
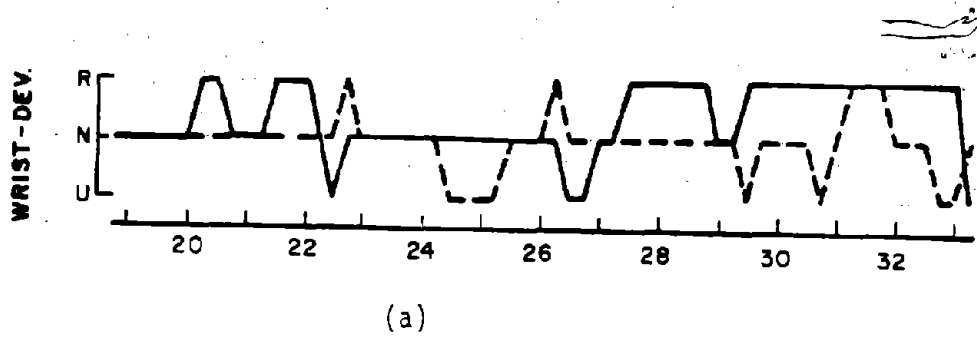
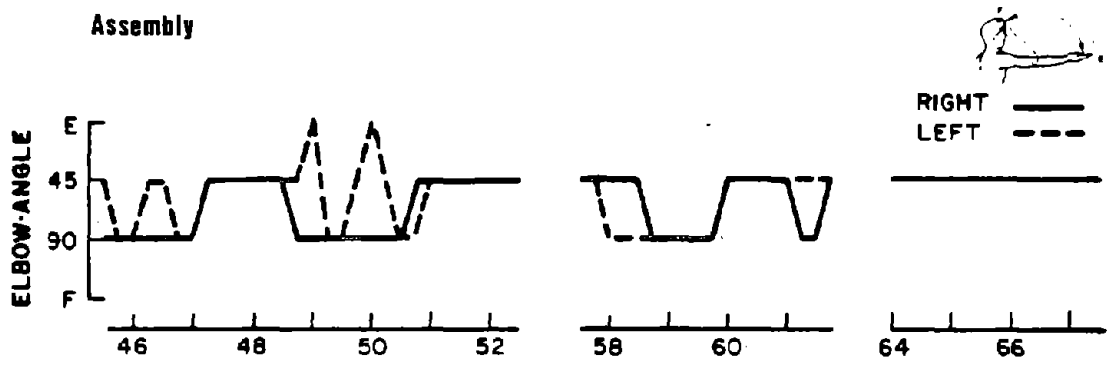
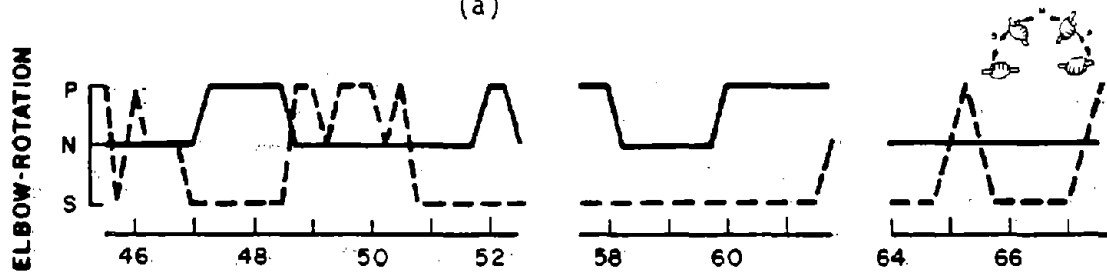


Figure C2.5 cont.

Assembly

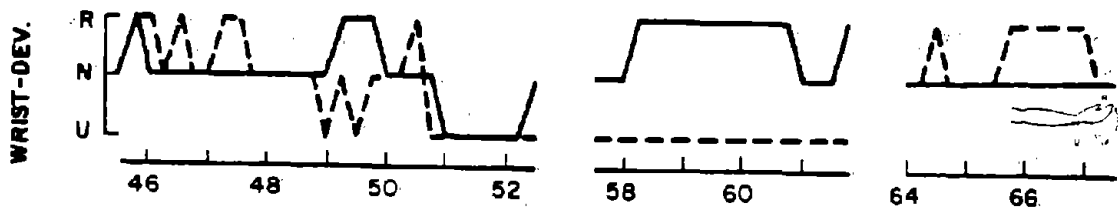


(a)

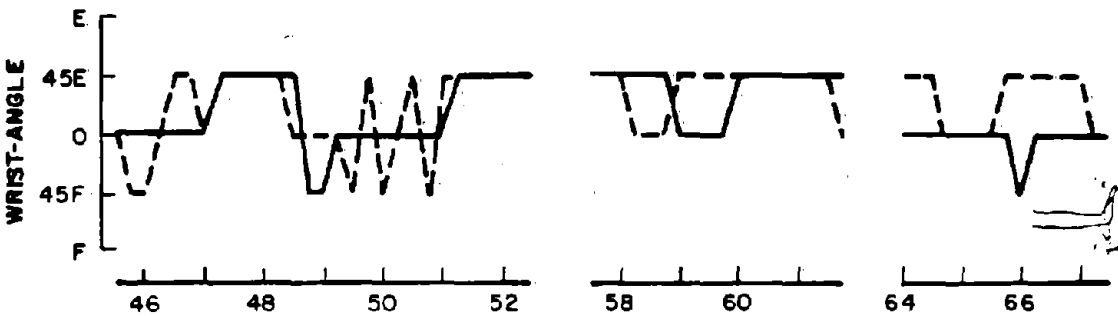


(b)

Figure C2.4 cont.



(a)



(b)

Figure C2.5 cont.

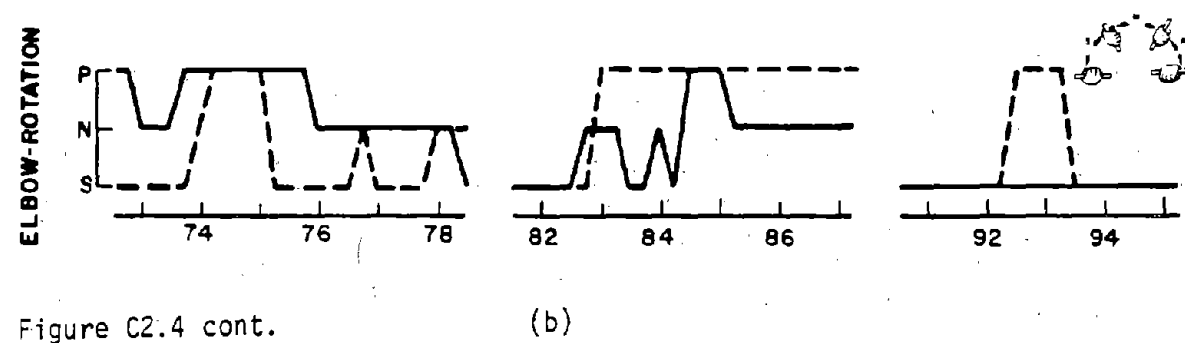
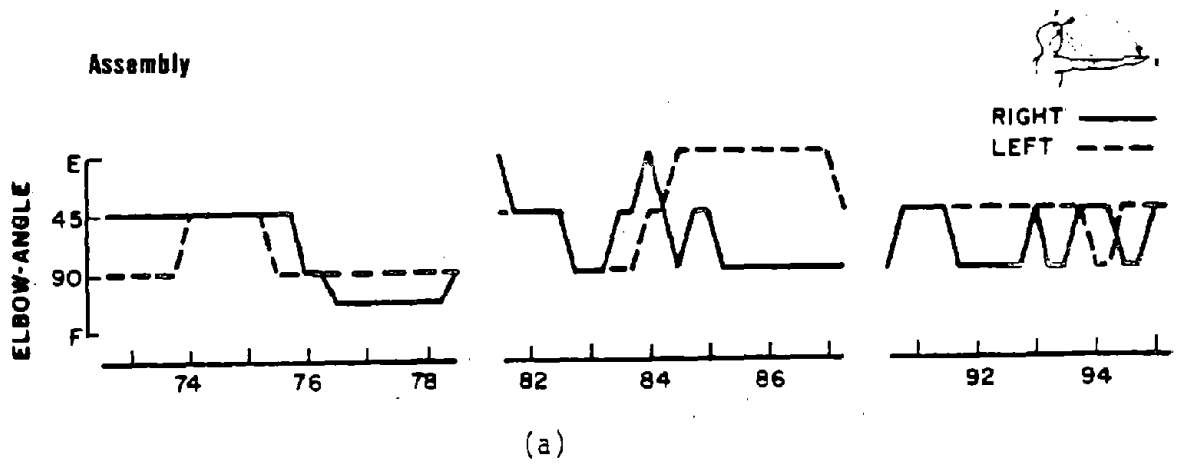


Figure C2.4 cont.

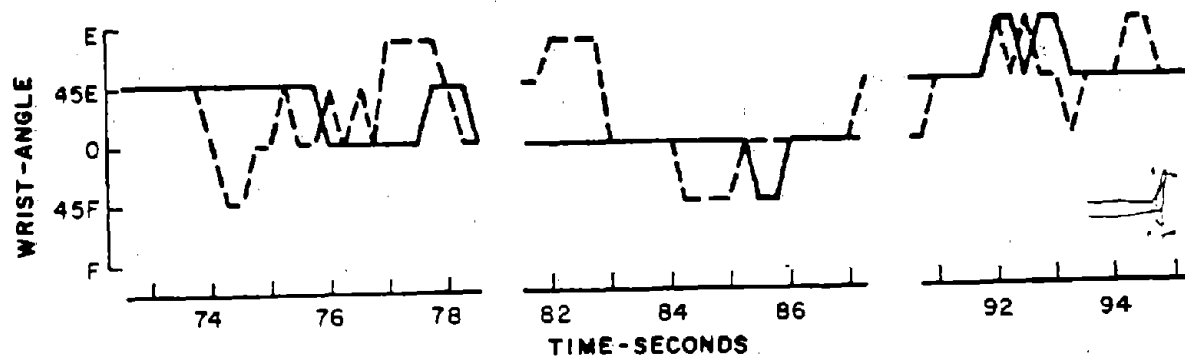
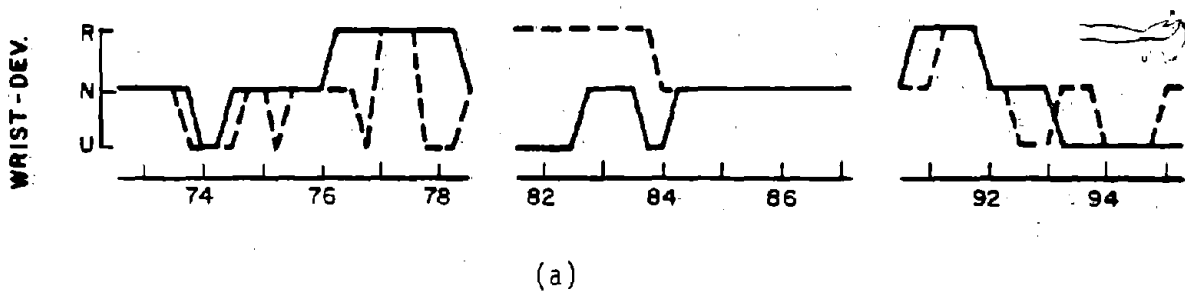
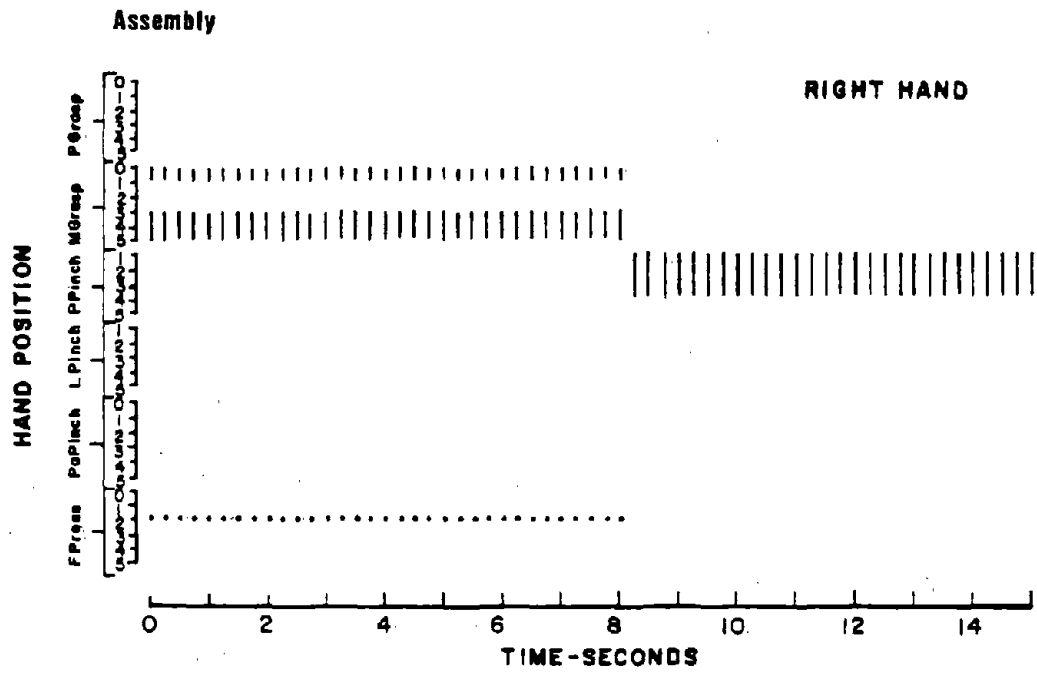
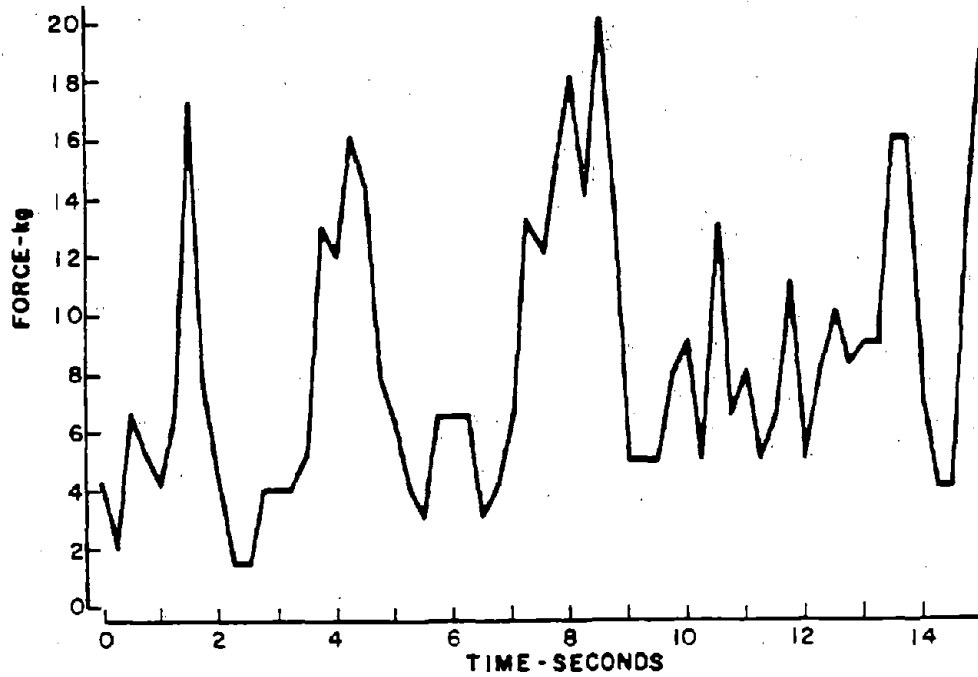


Figure C2.5 cont.

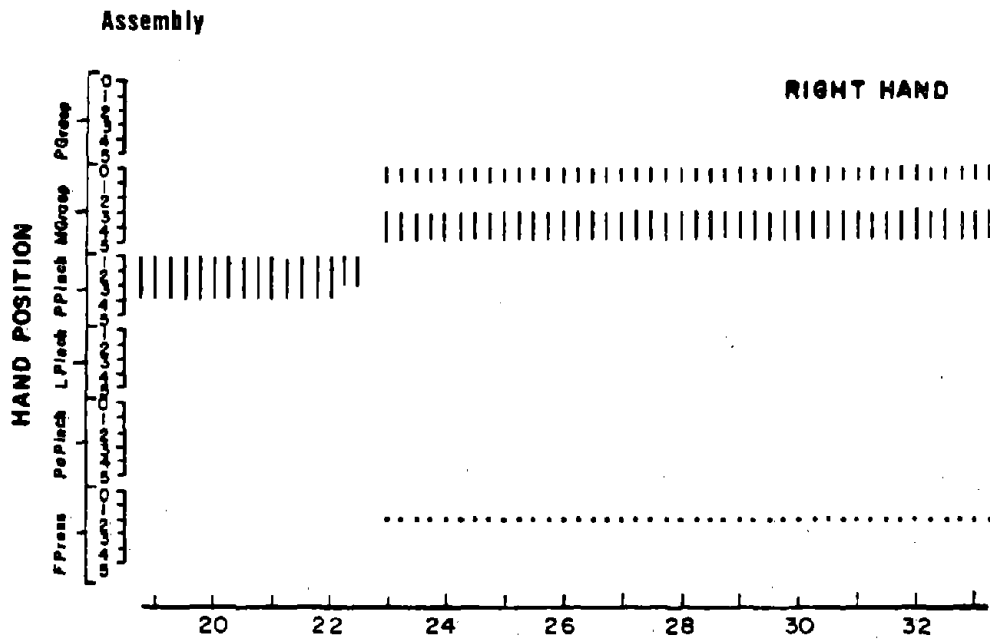


(a)

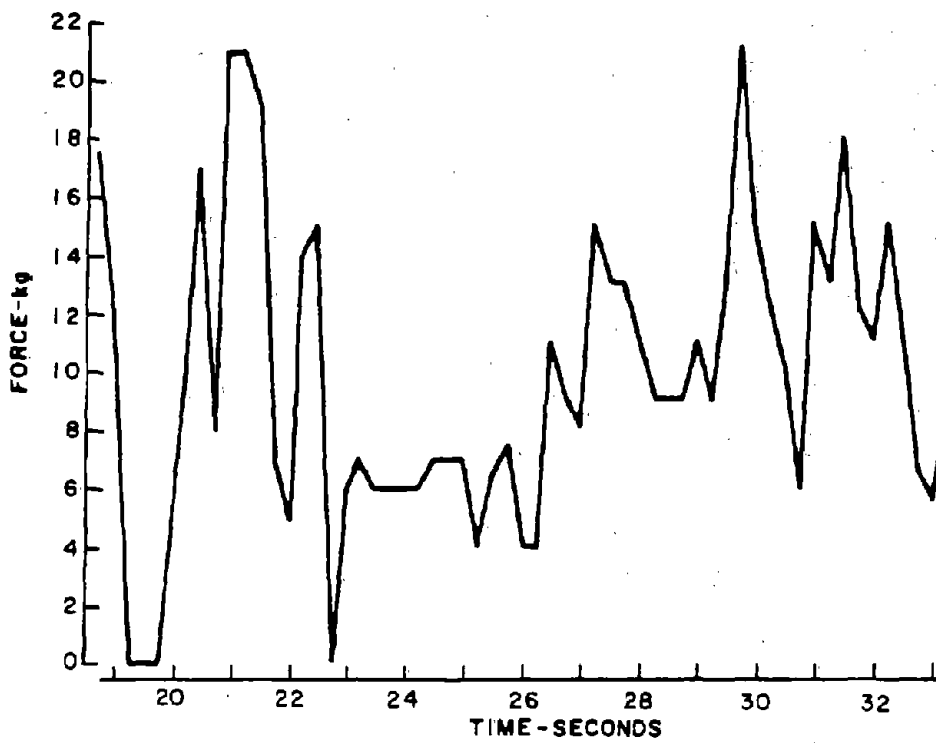


(b)

Figure C2.6



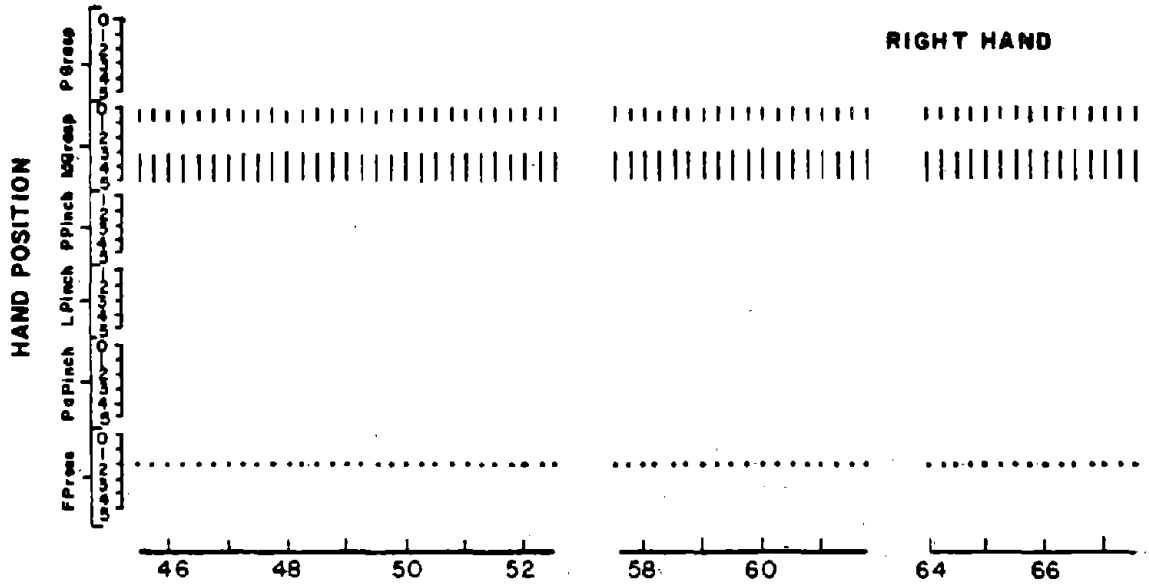
(a)



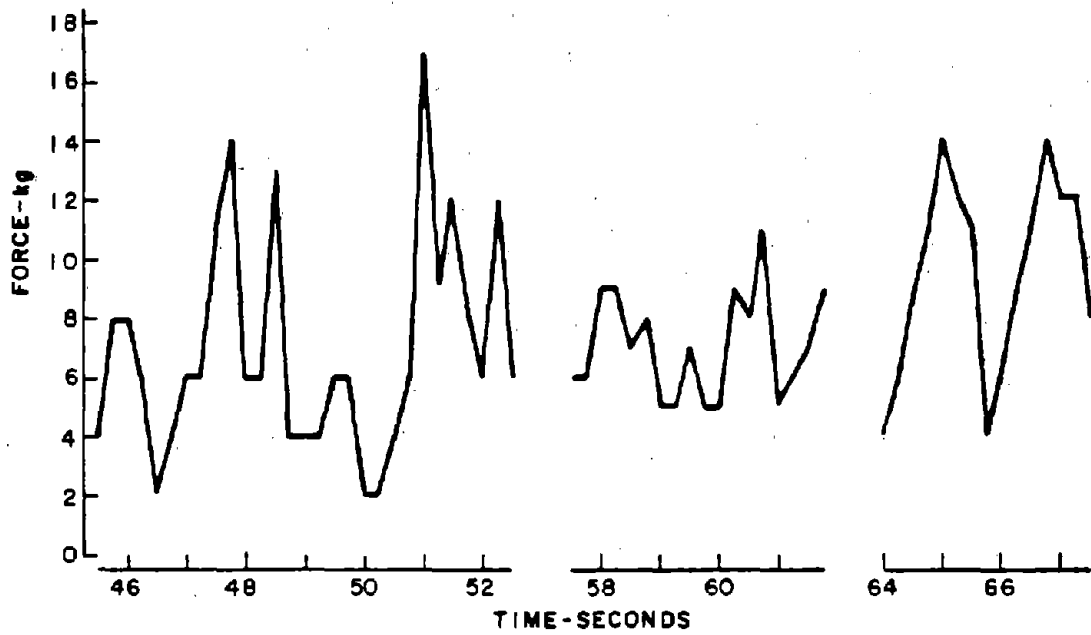
(b)

Figure C2.6 cont.

Assembly

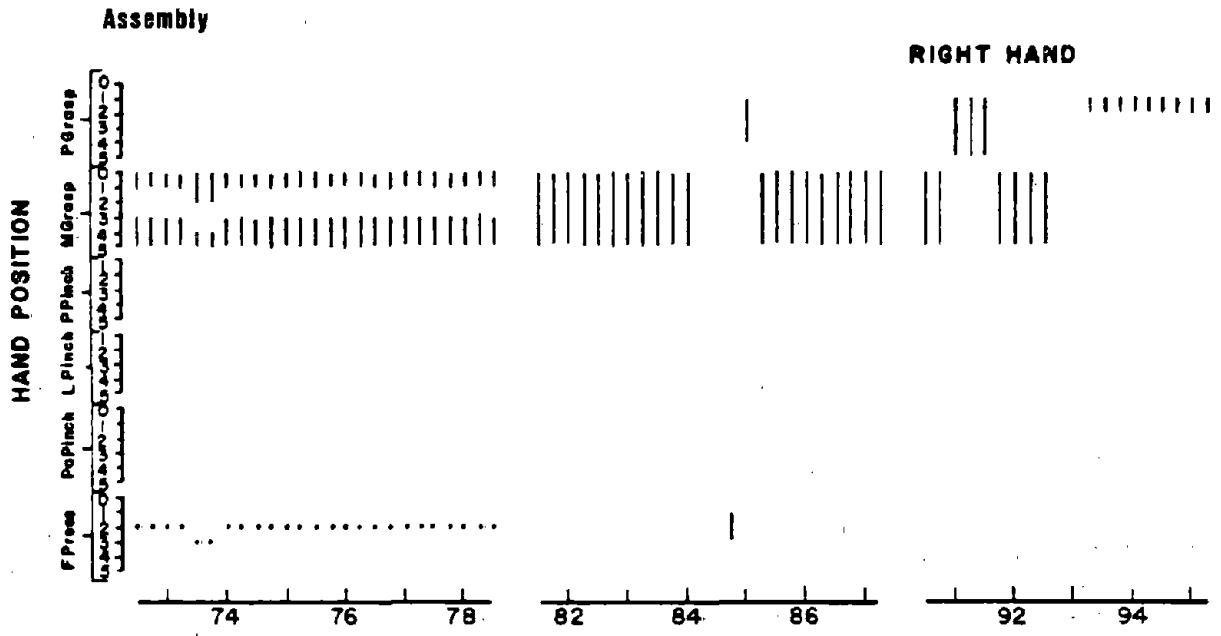


(a)

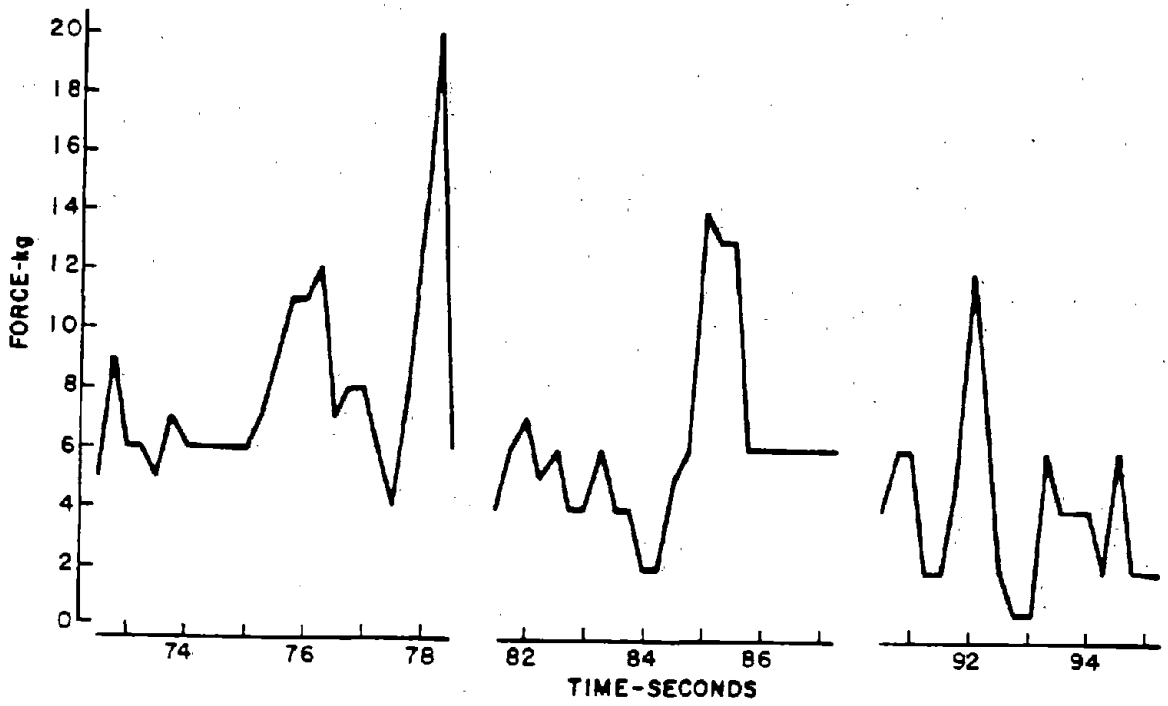


(b)

Figure C2.6 cont.

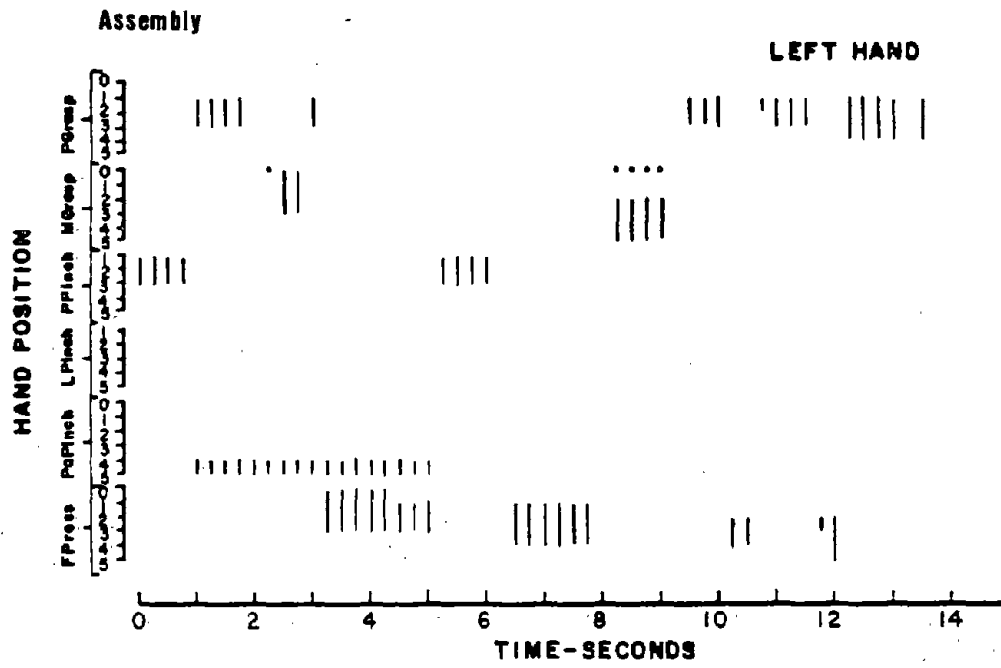


(a)



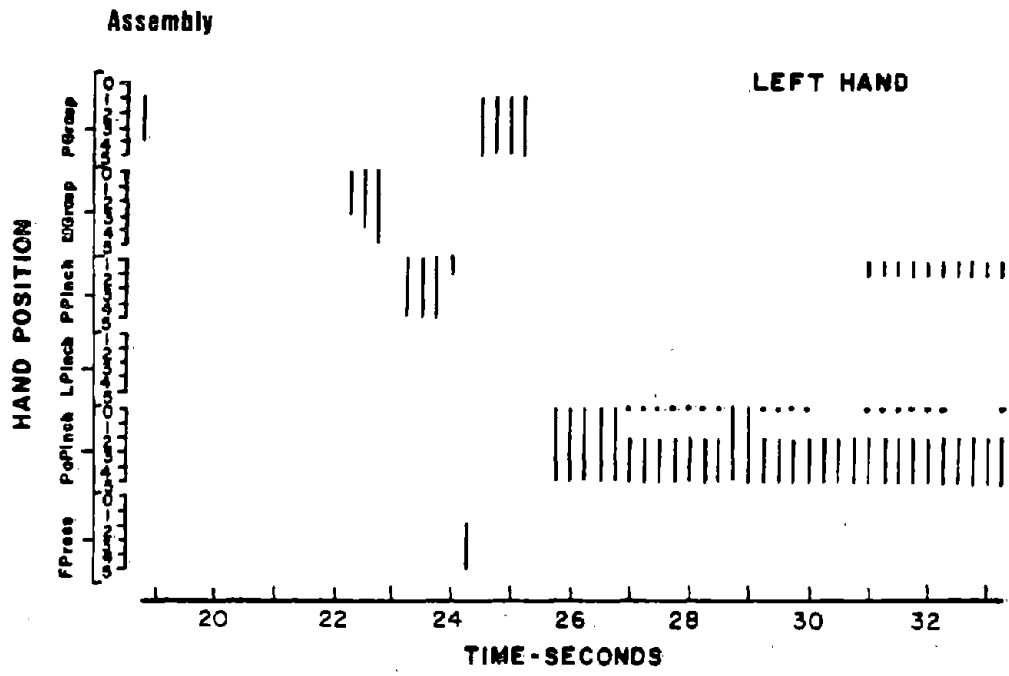
(b)

Figure C2.6 cont.



(a)

Figure C2.7



(a)

Figure C2.7 cont.

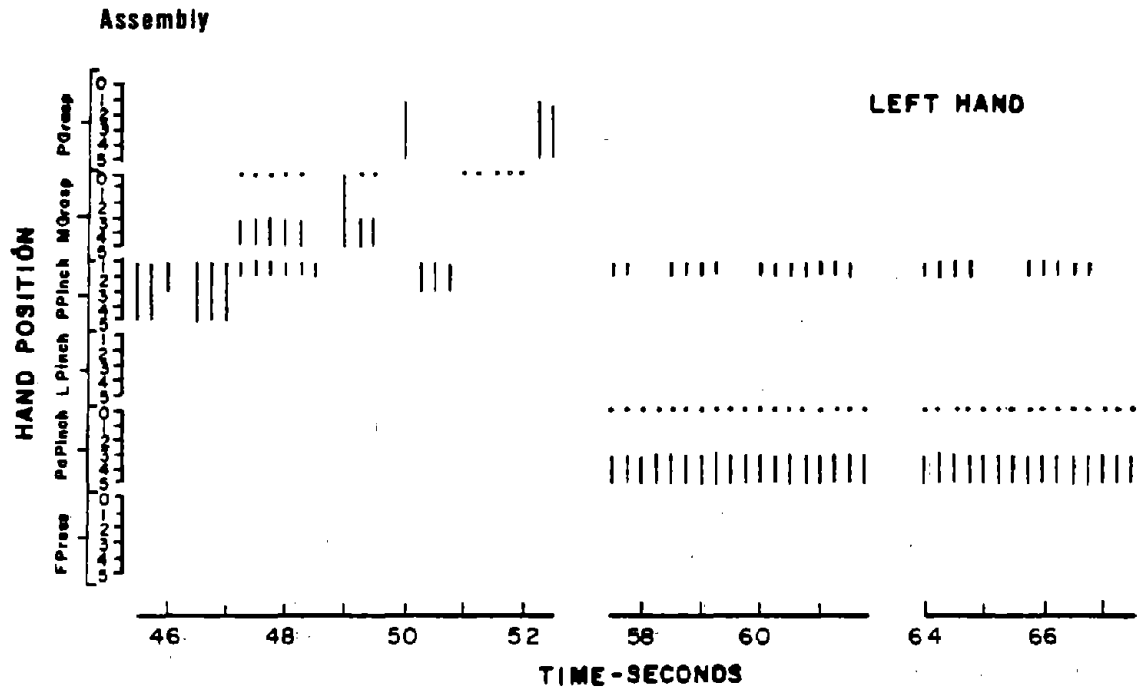


Figure C2.7 cont.



