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MEASUREMENT OF THE ARTICULATION OCCURRING IN THE UPPER EXTREMITY NEEDED TO REACH THE LIMITS OF GARMENT CLOSURES

by

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CHAPTER I

INTRODUCTION

The study of body movement has been a subject of inquiry since ancient times. Greek philosophers and scientists, as well as the researchers of the Renaissance and later centuries can be credited with many discoveries and accomplishments made in this area. The knowledge and interest of these people in the human mechanism, its structure, and its physiological and mechanical functioning influenced the performance of the tasks of everyday life (10). Bratton and Steidl (4) have stated that the human body constitutes the most important item of equipment utilized in work. Therefore, it is well worth the effort it takes to acquire understanding of how the body functions in work and to develop skill in using the body effectively.

Research has been done dealing with work simplification in the home which emphasized reduction of motions and time in developing energy saving techniques in performing specific tasks. Also attempts have been made to measure or describe the extent of postural changes or body movements due to methods of work, equipment used or space alloted for the performance of a task. Limited research has been carried out relating body articulation and clothing and less pertaining specifically to required range of motion and the physical aspects of garments. The research that has been done has concentrated on what people with particular handicaps are able to accomplish. No work has been found on predicting the amount of movement needed to accomplish certain dressing tasks, specifically the manipulation of garment fasteners, in order to eliminate trial and error analysis of each individual limitation. The present study was focused on body angles related to the ability to dress and undress and particularly those necessary in performing reaches to the extreme limits of certain garment closures.

The multiplicity of activities involved in dressing and undressing require certain adeptness even for the person without any physical limitation. Frequently the type of garment closure is not compatable with the capabilities of the individual. The majority of persons can and will adapt themselves to procedures required for standard garment closures. The physically disadvantaged may require that adaptations be made in their garment closures and/or new and more suitable ones selected if they are to maintain independent status in the activities necessary in personal care. It should also be stated that any technique that could be devised for assisting the physically disadvantaged in simplifying methods of dress and adjusting the physical aspects of garments to individual needs should also serve the woman with no disadvantage toward an understanding of her capabilities within the normal range of motion for the performance of a task.

Therefore, research with the angles of body articulation involved in the performance of reaches to the extreme limits of garment closures was an exploratory study. It would be of four fold value; first, a technique for measuring angles of body articulation would be of value to researchers in more accurate recording of body articulation. Second, this type of research would be important to clothing manufacturers in terms of general design and construction in meeting the ease necessary for the normal amount of movement while performing garment closures. Thirdly, an understanding of the angles of articulation and the amount of movement necessary for performing certain dressing activities could be applied to those with a limited range of motion when selecting clothing suited to their individual situation. And, finally it would be of value to such specialty garment manufacturers who design items of apparel for those not having their full range of motion.

Objectives of the Study

This study was an attempt to develop techniques for the analysis of certain postural changes and body movements that would be used in the study of functional clothing selection. Due to the variety of possible posture positions and movements of which the body is capable and which are required in dressing and undressing, those positions regarded to be associated with the movements at the joints of the upper extremity were selected for study. However, the intricate movements of the fingers were not analyzed.

This research was planned in terms of the following objectives:

1) to develop a technique for the measurement of body angles occurring at the joints of the upper extremity which would be applicable in the study of many dressing procedures

2) to measure the body angles formed in the upper extremity of a normal mature young woman while performing certain dressing activities

3) to analyze the amount of articulation occurring at the joints in the upper extremity while performing reaches to the extreme limits of certain garment closures in terms of the following experimental factors: height, weight, back waist length, front waist length, the lengths of the right and left arms, the slopes of the right and left shoulders and the extreme limits of the garment closures defined.

Definitions of Terms Used

Center Front. The center of the front view of the body. The abbreviation CF describes this location.

Center Back. The center of the back view of the body. The abbreviation CB describes this location.

Back Waist Length. The length of the back of the body measured according to Brockman (5) from the high point on the top of the shoulder down the back to the waistline. This measurement can be obtained with the use of the Brockman Shoulder Slope Finder. The abbreviation BWL describes this location.

Front Waist Length. The length of the front of the body measured according to Brockman (5) from the high point on the top of the shoulder down the front across the bust to the waistline. This measurement can be obtained with the use of the Brockman Shoulder Slope Finder. The abbreviation FWL describes this location.

CHAPTER II

REVIEW OF LITERATURE

In the absence of literature specifically related to the range of motion in dressing and undressing, motion studies in other fields have been cited as background. Studies and literature in anatomy and kinesiology were also looked to for their information on the articulations of the limbs in the upper extremity. These aided in defining body movement, but the particular relation of task performance and clothing was found in rehabilitation literature. They dealt mainly with specific disabilities and attractive and suitable apparel. The importance of the ability to remain independent has many connections with the ability to perform dressing activities on the morale of an individual who has less than free mobility.

Self Image and Human Needs Related to Clothing

Clothing is designed for the person with normal mobility. This requires the individual to learn to conform to the physical aspects imposed by garments. Fashion designers give little attention to any possible restrictions in movement of their customers; therefore, with a physical handicap in the range of motion this ability to conform may be limited or impossible.

The handicapped person has the same needs and desires as any other individual, even though he is often unable to participate in these activities because of his limitations. Special considerations in order to simplify dressing procedures may put this task into the category of self-help activities. According to rehabilitation research (24) the most important objective in rehabilitation therapy is for the handicapped to be able to care for their daily needs and dressing is a basic activity of daily living.

Rehabilitation research is concentrated on the disability or the ways of adapting to the disability (24). Both the disability and the methods of adaptation must be understood to help the handicapped help themselves. An understanding of the internal and external barriers the handicapped face as human beings must also be understood in order to aid them.

Thompson (28) studied personal appearance as a clue to mental health, as well as a technique useful in rehabilitation therapy. She stressed the establishment of personality through clothes and a feeling of self-worth. Clothes may be useful in giving a boost to morale and helping find personal identity. Trotter (29) also believed clothing should enhance one's self-esteem and be psychologically satisfying. MacDonald (19) stated that people base their expectations of the conduct of handicapped from the clothing they wear, as much as they do the physically impaired mobility. Clothing may help to improve their self-image and aid in their psychological well being. Hallenbeck (15) feels human needs fit into two classifications: physical and psychological. Self-help in dressing, comfort and the elimination of strain in motion while performing activities should be characteristics exhibited by clothing. Dallas (7) investigated the features that were worn and preferred by two groups of teen agers: one group with cerebral palsy and one non-handicapped. She found, "given an appearance that varies from the normal, attractive becoming clothes give a needed boost to the morale." Authorities believe if we can improve poor images to ones of acceptance of self through clothing, this will improve their entire development by stimulating them to attempt other challenges.

Clothing as Related to Physical Limitations

Zaccagnini (33) stated in her study of adapting fasteners of ready-to-wear knit pullover shirts for a child with cerebral palsy that fastenings on garments often hinder the handicapped child from dressing himself. She hypothesized that simplified fastenings adapted to ready-to-wear knit pullover shirts could enable the handicapped child to learn self-help in the dressing process. Velcro, Number 4 snap, wooden toggle with elastic loop, skirt hook and bar, large zipper, and gold clasp with oval ring were the fasteners inserted in center front positions of knit pullover shirts. The child attempted to operate these fasteners. Evaluations were based on the ease of dressing and undressing and the child's like and dislike of the fastener. Three fasteners, Velcro, large zipper, and gold clasp with oval ring, were evaluated as being best for the particular child studied.

A small part of Dallas' study (7) was focused on the use of fasteners and the placement of closures by designers of clothing for handicapped children. Dallas found that her sample of teenage girls preferred garments using zippers but that Velcro had the greatest possibilities for use.

Several authors have discussed the design and service of clothing for handicapped. The lack of strong fibers, reinforcements and easy-to-manipulate closures are a few things that make ready-to-wear garments unsatisfactory for use. Mass production of clothing for the handicapped has not achieved wide spread acceptance. Hallenbeck (15) advocated mass produced garments for the handicapped; however, Dallas (7), Frescura (13), Cookman (6) and Zaccagnini (33) have all found limited applicability for any one design and feel a need to adapt especially for the particular situation and limitation. Special publications are available describing the adaptations of garment styles and fasteners, as well as enumerating where these aids may be obtained (9 and 24).

The Range of Motion in Selected Joints

The ultimate range of movement in a normal joint is determined by several factors. Duvall (10:32) stated that the arrangement of the inelastic ligamentous tissues which form part of all synovial joint articulations will limit the extent of motion. The arrangement of ligaments and tendons, and tension of surrounding muscles will check movement before the extreme limit allowed by bony structure is reached. In some normal individuals, and in those with certain abnormal conditions of muscles and ligaments, this may not necessarily be true, and bony prominences and the shape of articulating surfaces would be considered as the possible restriction to the range of motion.

Movement at the Shoulder. Studies of anatomy (11 and 21) and kinesiology (26) described the arthrodial (ball and socket) joint of the shoulder as exhibiting a range of motion which is greater than in any other joint. This is due to the looseness of the ligaments and to the large size of the head of the humerus in comparison to the depth of the glenoid cavity (Appendix A, page 55). The great range of movement of the humerus is increased by the mobility of the shoulder girdle. The two articulating bones of the shoulder joint are the humerus and the scapula.

The following movements of the humerus are permitted at this joint: swinging forward (flexion), swinging backward (extension), elevation from the side (abduction), depression to the side (adduction), and a combination of these movements (circumduction) in which the humerus describes a cone, the apex of which is at the shoulder joint and the base at the distal extremity of the bone. The scapula rotates inward (medially) and outward (laterally).

Flexion of the humerus is freer than extension, the extent of movement being about 60 degrees forward and about 45 degrees backward. Abduction of the humerus at the shoulder joint is restricted to about 90 degrees by the contact of the greater tubercle with the arch formed by the acromion, the coracoid process, and the coracoacromial ligament (Appendix A, page 55). Adduction is checked by the arm coming in contact with the side of the body. Starting from the position with the arm pendant, extreme abduction or flexion can take place through 180 degrees, terminating in a vertical position with the arm raised above the head. Movement is possible by elevating the arm not only in a plane directed forward (flexion) or sideward (abduction) but also in any plane between these two. The circle of circumduction moves across in front of the body and is flattened out somewhat at the back. Articulation at the shoulder is limited in the front by the contact of the arm with the body and posteriorly it is checked largely by muscular tension.

Movement at the Elbow. The elbow is a ginglymus or hinge joint (2, 11 and 21). The elbow consists of the articulation of the lower end of the humerus with the upper ends of the radius and ulna (10). The mobility, strength and security of the joint are dependent on the shape of the articular surfaces, rather than on the ligaments and muscles which cross it. The trochlear notch of the ulna articulates with the trochlea of the humerus, and the head of the capitulum of the humerus (Appendix A, page 55). It is surrounded by an articular capsule which is reinforced medially and laterally by collateral ligaments. The movements which take place at this joint are flexion and extension. During these movements the head of the radius glides upon the capitulum and the trochlear notch of the ulna upon the trochlea. Flexion is the movement of the forearm upward and is limited by contact of the cononoid process and the head of the radius with the corresponding fossae on the front of the humerus, by passive stretching of the extensor muscles of the forearm, by tension of the radial and ulnar collateral ligaments, and by contact of the soft parts of the upper arm and the forearm. Extension is the downward movement of the forearm and is checked by contact of the olecranon process with the olecranon fossa of the humerus, and by tension of the radial and ulnar collateral ligaments (Appendix A, page 55).

Movement of the Forearm. The radio-ulnar joints are pivot, or trochoid joints (2, 10 and 11) permitting only medial and lateral rotation of the forearm. Medial rotation of this segment of the upper limb is called specifically pronation, as in turning the palm of the hand posteromedially and lateral rotation is known specifically as supination, as in turning the palm anterolaterally. In both these movements the ulna remains relatively stationary, the radius rotating around its longitudinal axis. In full pronation the radius crosses the ulna on its anterior surface, thus forming an X-shaped arrangement, its head rotating medially around the head of the ulna so as to carry it across the anterior aspect of the ulna. In full supination, the two bones lie parallel to each other.

Movement at the Wrist. The wrist joint is classified as a condyloid variety (2, 11 and 21). Authorities in anatomy (11) and kinesiology (10, 23 and 26) describe the movements at the wrist as flexion, extension, abduction, adduction, and circumduction of the hand. Flexion is movement of the palm toward the anterior surface of the forearm, extension is movement of the dorsum (back) of the hand toward the posterior surface of the forearm, abduction is movement of the hand 180 degrees toward its lateral border, or thumb side, adduction is movement of the hand 180 degrees toward its medial border, or little finger side, and circumduction is the movement of the hand at the wrist whereby the finger tips describe a circle, and the hand as a whole describes a cone. Flexion is most pronounced in its range and it provides most of the leeway for abduction.

According to a physical therapist (22) the absence of free supination and pronation of the lower arm restricts those with limited movement more so than does the absence of free movement at the wrist. People with little ability to articulate the wrist are able to perform many intricate tasks by utilizing their ability to supinate and pronate the forearm and hand. Where free supination and pronation are absent there is much difficulty in attempting to perform even the simplest tasks of everyday living.

<u>Methods of Measuring Shoulder Movement</u>

Wells (30) measured the movements of flexion, outward rotation, inward rotation, and horizontal extension of the arm at the shoulder joint. In each of the arm movements the subject was required to perform the movement with both arms although the measurement was taken on only the left arm. The purpose of this was to prevent the tendency to rotate the body toward the side being measured in an attempt to get an apparent increase of motion. Twenty-four young women were used as subjects.

To measure the flexion at the shoulder joint the subject sat on a bench with the head and back braced against the edge of an open door and raised both arms forward-upward as far as possible, keeping them shoulder distance apart, with palms facing each other and the elbows fully extended. The angle between the upper arm and the vertical was measured with a plumb line protractor. The range varied from 161 degrees to 186 degrees; the median was 172.5 degrees (30:46).

Wells (30:46) used the same position as described above, except that the upper arms were raised sideward to shoulder level, with elbows bent at right angles and the forearms pointing forward with palms down for measuring outward rotation. The upper arms were then rotated outward so that the forearms moved in an arc, upward and backward as far as possible, with the upper arm remaining at the horizontal. The angle between the forearm in its final position and the horizontal was measured with a plumb line protractor. There was a 48 degree range (90 degrees to 138 degrees) from the smallest angle to the largest. The median was a 99 degree angle.

Wells (30:46) measured the inward rotation at the shoulder joint by using the same starting position for this measurement as that for outward rotation. The upper arms were rotated inward so that the forearms moved forward-downward as far as possible, with the upper arms remaining at the horizontal. The angle between the final position of the forearm and the horizontal was measured with a plumb line protractor. The range was from 75 degrees to 148 degrees, with the median at 108 degrees.

Horizontal extension at the shoulder joint was also measured by Wells (30:47) with the subject lying on her back on a narrow bench with her knees drawn up and feet resting on the bench. Care was taken to see that the bench was narrow enough so as not to interfere with free movement of the shoulder joints. The arms were extended sideward at shoulder level, then lowered toward the floor as far as possible. The angle between the upper arm and the horizontal was measured with a plumb line protractor. The range was between 20 degrees and 57 degrees, with a median angle of 44 degrees.

Van Horn, as found in Wells (30:49), measured forward elevation of the arm. He used 165 women between the ages of sixteen and eighteen. The subjects were instructed to lie on a board with their knees drawn up and their back kept in contact with the board. The angle between the horizontal surface of the board and the subject's arm was measured with a protractor. The measurements recorded were a right hand range of 159 degrees to 196 degrees.

The forward elevation of the arm or flexion was measured by Glanville and Kreezer also as cited in Wells (30:49). They used ten male subjects between the ages of twenty and forty. The subjects were instructed to lie on their back on a table with their shoulders over the edge of the table. The measurement was made with an arthrometer having a circular scale and a weighted metal pendulum type of indicator. This instrument was strapped to the lateral surface of the subject's arm, just proximal to the elbow. They recorded a range of 164 degrees to 191 degrees on the right arm, with a mean of 179 degrees; and a range of 165 degrees to 187 degrees on the left arm, with a mean of 180 degrees.

The techniques of the four investigators for measuring forward elevation of the arm were different, but all used either the vertical or the horizontal as a point of reference rather than the long axis of the trunk. And dispite the small number of subjects and the differences in techniques, the results were fairly consistant. The later technique requires the use of subjective judgement in aligning the protractor with the subject's trunk, but Wells (30:50) considered it to be the more valid measure of the range of joint motion.

Photographic Methods of Recording Articulations for Analysis

In a research effort, suitable methods for recording data are imperative to accurate interpretation. Methods of recording data for descriptions and measures of work are mainly found in research dealing with household management studies.

Micromotion and memomotion study techniques provide a means for detailed and accurate analysis of work using the motion picture camera (1 and 18). Bratton and Steidl (4) summarize the techniques. Micromotion records an activity by means of a motion picture. The results of the activity are therefore subject to analysis by more than one person and to detail researching. Both the filming of the activity and the analysis of the film are time consuming and expensive. Memomotion involves the use of a drive for the motion picture camera which can be adjusted to expose the film at 60 or 100 frames per minute instead of 960. This permits a coarser analysis of the activity being recorded than can be made by micromotion, with a saving on film used and on time for analysis.

Keiser (16) in determining techniques for the measurement of posture and body movements during bed making used motion pictures to provide a permanent record of the activity and allowed for more detailed and accurate analysis. She used two cameras for simultaneous recording. This made it possible to record the maximum change in posture as the bed was being made, as well as have a profile, front or back view of the worker at any given time and continuous analysis could be made. One camera was placed at the foot of the bed at a distance allowing for a full height view of the worker, and the second camera was similarly placed at the side of the bed.

To analyze the postural angles Keiser (16) projected the image on plain white paper which had been graduated in degrees. When the picture was projected, the zero mark of the paper was placed at the axis of the angle. She recorded measurements on angle of body bend, angle of knee bend, angle of stability and angle of reach.

Booth (3) studied the design of a kitchen for either use with a motorized chair or standing in terms of efficient work centers and efficient arrangement among the centers. She used the memomotion film technique with a 16-mm camera with a variable shutter. Two flood lights were used for illumination as well as additional lighting from a ceiling light and the light from the windows of the research laboratory. A chart on the side of the refrigerator identified the sequences being filmed by the film reel number, and the code number assigned to the foods being prepared. There were management reasons for using this filming method as she studied total distance traveled in preparation of a menu and preparation time, as well as recording all manipulations and reaches of the subject.

For recording body positions Booth (3) exposed frames of the motion picture film, first, as the subject stood erect placing the palms of both hands on the front edge of the counter or shelf at about elbow height, and then with two hands to the back of the counter and to each shelf above the storage wall. Each time the subject indicated if the position was comfortable, slightly uncomfortable or very uncomfortable. The pictures were snapped at the furthest extension of the reach. A record was made of each position filmed and the frame number and the subject's reaction. The procedure was repeated with the subject in the motorized chair.

For analyzing the angles of movement, Booth (3) used a time and motion projector, projecting the film on a white screen. She also used a custom-made device, consisting of a base, frame and mirror to project the film image onto a flat table surface for analysis of the body angles. The projector rested on the base of the device with the pipe frame extending to to the front of the projector. The mirror was attached to the front of the projector frame at a 45 degree angle, received the projected image and reflected it on a sheet of white poster board on the table surface. In order to study the angles of body positions, the film images and body landmarks were traced onto white paper. A line was drawn between the points and a protractor measured the angles formed.

Wright (32) in her research on body bend in loading dishwashers considered still pictures more satisfactory than moving pictures since her research pertained primarily to the deepest part of each bend. She found the deepest part could be accurately determined and photographed by the still method and it also involved fewer pictures to be analyzed with more precise analysis of the angles of bend.

Wright (32) used a 36-mm camera; supplementary lighting was provided by three 200-watt lamps. Two lights were placed halfway between the camera and the dishwasher area and at 45 degree angles to the subject. A third light was placed nine feet above and seven and one-half feet to the left of the center of the work area. By using constant supplementary lighting rather than flash lighting, the subject was not distracted by periodic flashes of light nor was added emphasis placed on the deepest part of each bend.

Wright (32) measured the normal relaxed angle of bend as each subject stood in a normal relaxed standing position before using each dishwasher. These angles were subtracted from the angles of bend for each task, and the differences were the extent of neck bend, slump, and back bend required for loading an article into each of the eight positions in the dishwasher. The photographs used for analysis were 5 x 7 inches in size. Transparent paper was placed over each photograph to transfer landmarks on the subject's body to tracing paper. Each angle was measured to the nearest 0.5 degree with a transparent plastic protractor.

Micromotion and memomotion pictures are useful when detailed information on body movement is desired, while still pictures offer useful information when specific postural positions are desired for analysis. Bratton and Steidl (4) stated most of the data for measuring could be taken directly from the screen in the case of the projected image. A projection table permitting analysis of the projected image at the analyst's writing level is more desirable. However, the transferal of the body landmarks from the motion pictures, as well as from the still pictures, to paper has been used more frequently for accurate analysis.

CHAPTER III

PROCEDURE

The objective of this study was the development of a technique for measurement of angles of articulation in joints of the upper extremity applicable in the study on many dressing activities. This exploratory study examined the movements of twenty young women between the ages of eighteen and twenty-five as an effort to study the articulations of the mature person still exhibiting complete freedom of movement.

Several methods of procuring data for movement analysis were considered. With the use of a goniometer and other measurement techniques taken directly from the body an approximate measurement of the angles of articulation can be made but for an analysis of the normal reach to the extremt limits of garment closures, a more precise and defined analysis is required. Therefore, the following photographic procedure was used to provide a uniform and accurate method for measurement of articulations involved in the upper extremity. Also the procedure was proposed to facilitate the recording of angles of articulation necessary for data analysis.

Closure Limits

To identify the most common garment closure locations a survey was made of garment construction manuals, commercial pattern books and ready-to-wear garments. Seven different closure limits were noted as those most commonly encountered by young women in the normal dressing and undressing processes. These limits were:

1) a center front closure as a zipper or buttoned placket with the upper limit at the interclavicular notch

2) a center front closure as described above with the lower limit at nine inches below the center front waistline

3) a center back closure as a zipper and a hook and eye or a buttoned placket with the upper limit at the seventh cervical vertebra

4) a center back closure as described in number 3 with the lower limit at nine inches below the center back waistline

5) a left side closure as a zipper placket with a hook and bar or button fastening with the upper limit on the waistline at the sideseam position

6) a left side closure as described in number 5 with the lower limit at nine inches below the waistline on the left sideseam

7) a mid-back closure for a swim suit or bra or the lower limit of a short center back zipper with the limit defined at the ninth thoracic vertebra

Selection of Subjects

Twenty subjects were selected for this exploratory study. Subjects chosen were free from health mobility problems so that a normal range of motion could be analyzed. Subjects were selected from volunteer students at Kansas State University who were between the ages of eighteen and twenty-five. In order to reduce the number of variables only right handed persons were asked to participate.

Placement of Landmarks

To maintain uniform points of reference in measuring the angles of articulation, landmarks were attached to all the subjects in predetermined anatomical and distance locations. To facilitate accurate location and preservation of the landmarks on the body, each subject wore a two-piece swim suit. Attaching landmarks to the body prevented change in their location due to shifting of clothing in postural changes and allowed a more precise and consistant analysis of the angles of articulation.

A one-inch square of dark colored tape was placed on the subject to designate the various body landmarks. The corners of the square of tape served as a basis for more precise determination of the center of the mark. The positions identified and marked as landmarks were the acromion process, the olecranon process, the styloid process of the ulna, the lateral and dorsal metacarpophalangeal joints of both arms; the interclavicle notch; the seventh cervical vertebra; the ninth thoracic vertebra; the greater trochanter of the femer of both thighs; the natural waistline distinctly marked; the center front, the center back and the sideseam location at the waistline; and the points nine inches below the waistline at the center front, center back and the sideseam. A four-inch wire was attached by transparent tape to the center of the landmarks on the acromion process and the olecranon process of both arms in order to identify these positions accurately in the photographs (Figures 1 and 2, page 27 and Appendix A, page 55).

Location of Waistline

A tape was placed around the midsection of the subject's body and allowed to settle; the place where the tape rested determined the natural waistline location (12). The center front and the center back were located for landmarks; the center front over the navel and the center back on the spinal column. The location of the sideseam at the waistline was identified according to Brockman (5) by dividing the distance between the center front and the center back in half and adding one-half inch to the back measurement. The waistline tape remained on the subjects for use in further measurements, as well as becoming a guide for the location of the closure limits below the waistline and in the analysis of body articulation.

Body Measurements

Body measurements were taken and recorded on individual data sheets (Appendix B, page 56) for each of the twenty subjects. These measurements were made after the identification of the landmarks and prior to the actual research procedure.

Height. Height measurements were made against a scale graded in centimeters. Measurement was taken from the front as the subject stood shoeless with heels together against the scale which was mounted on a wall; buttocks and shoulders touched the scale without having the subject strain her head back. With the subject standing erect and looking straight ahead a right angle leveler was lowered to the subject's head so that the resistance of the skull was felt but not enough to make the subject shrink. A pencil line marked the height on the scale. Height measurement was read from this point on the scale to the floor (14). Three measurements were taken and the average recorded.

Weight. Each subject was weighed on a scale. The reading in pounds was recorded on the subject's individual data sheet.

Back Waist Length. Measurement for the back waist length was taken by using a device invented by Brockman (5) for use with her theory of pattern development rather than the conventional method (12). Measurement for the back waist length was taken with the subject standing in a relaxed position. The Brockman Shoulder Slope Finder was placed around the subject's neck and fastened into place. The sections over the shoulders were overlapped when they were found to lie directly on the top surface of the shoulder. The top of the shoulder at the neck was marked on the shoulder slope finder. A measuring tape was attached to the shoulder slope finder beginning at this point. Back waist length measured the distance between the top of the shoulder at the neck on the shoulder slope finder down the back to the base of the waistline tape. This distance was measured in centimeters. The mean of three measurements was recorded.

Front Waist Length. Measurement for the front waist length was taken as specified by Brockman (5) with the subject is the same position as for the previous measurement. Beginning at the top of the shoulder mark on the shoulder slope finder the front waist length measurement continued down over the point of the bust to the base of the waistline tape. The mean of three measurements was recorded in centimeters.

Arm Length. The subject maintained the standing position for the measurement of the body height with the arms hanging at the sides of the body with the elbows slightly bent. The lengths of the right and left arms were measured from the protrusion of the acromion process down across the olecranon process to the styloid process of the ulna. The measurement was made in centimeters. Again the average of three measurements was recorded as the arm length.

Method of Photographing Body Articulation

A light colored flat panel eight feet by seven feet was mounted against a wall with the base resting on the floor. The surface of the panel was partitioned by dark lines into four-inch square spaces. The subject was positioned in front of this panel with heels resting against a one inch raised mark on the floor which was one and one-half feet from the panel for photographs taken of the front and back, and positioned with the raised marking in between the feet for photographs of the right and left sides. The camera was mounted on a tripod and placed perpendicular to the wall and eight feet from the raised guide on the floor; it was leveled at a height three and a quarter feet above the floor.

Black and white prints were made with a Polaroid camera. Supplementary lighting was provided by two 500-watt lamps. One lamp was placed to the left and halfway between the camera and the subject. It was positioned at a height of four feet at a 45 degree angle to the subject. The other lamp was placed to the right of the camera and also four feet from the subject. It was raised to a height of seven feet and turned at a 45 degree angle to the subject. The positioning of the lamps in such a manner eliminated many shadows behind the subject (20). By using constant supplementary lighting rather than flash lighting the subject was not distracted by periodic flashes of light.

Each photograph was permanently coded in terms of the closure limit by mounting numerals behind the subject before each set of photographs was taken. The closure limits were designated with numerals one to seven and the natural relaxed body posture was given the numeral zero. To aid in the sorting and the analysis of each series of photographs the subject's number and the photograph number were written on each photograph.

Each subject posed for twenty-three still pictures. Three of the photographs were taken as the subject stood in a natural relaxed position exhibiting a view of the back, the right and the left side. For the remaining photographs the subject was instructed to move to the deepest point of the articulation for each one of the seven closure limits. While maintaining the reach to the extreme limits defined for each closure the photographs were taken of a front or back view and the side view of the arm performing the articulation. Each closure limit demanded particular views be photographed as shown on the articulation analysis data sheet (Appendix B, page 57). To assure a more uniform and accurate description of the angle of movement for each closure procedure the subjects were asked to clasp the tip of the thumb to the tip of the mid-phalange in opposition and place them over the designated landmark with the thumb nail resting flat on the body.

Method for Analysis of the Angles Formed by Articulation

The photographs used in the analysis of the amount of body articulation in performing reaches to the extreme limits of the identified garment closure limits were 2 3/4 x 3 3/4 inches in size. Angles produced by the articulations of the limbs of the upper extremity were measured directly from the photographs with a protractor. The angles of articulation measured were arm flexion and extension at the shoulder, abduction and adduction of the arm at the shoulder, elbow flexion and extension, and either wrist flexion and extension or wrist abduction and adduction. An example of the measurements can be found in Figures 1 and 2, page 27. The angles measured were recorded on the individual data sheets (Appendix B, page 57). Every tenth angle was checked by transferring the body landmarks to tracing paper and remeasuring the body angles to test accuracy.

Arm flexion is the movement of the humerus forward and extension is the movement of the humerus downward and backward. For purposes of analysis in this study flexion measured the movement from the perpendicular between the floor and the acromion process forward and extension measured the movement of the humerus backward and beyond the perpendicular. The center of the acromion process landmark was used as the vertex of the angles and the arms of the angles were formed by a line perpendicular to the floor and a line to the center of the olecranon process landmark. The angles of shoulder flexion and extension were measured on the photographs of the side views of the subjects for the natural relaxed standing posture and for each reach to a garment closure limit. The degrees of forward flexion were recorded as positive degrees and the degrees of backward extension were recorded as minus flexion for data analysis.

Abduction is the side elevation of the arm and adduction is the depression of the arm across the body. For purposes of recording these articulations in this study abduction was measured away from a perpendicular line between the floor and the acromion process, and adduction was measured from the perpendicular as the arm moved across the front or back of the body. The angles were again obtained by drawing a base line perpendicular to the floor through the acromion process landmark, with the center of the acromion process landmark as the vertex, and the other arm produced by joining the vertex to the center of the olecranon process landmark. In order in indicate the direction of movement in a single term for ease in summarizing the data, the degrees of outward abduction were recorded as positive numbers while the degrees of adduction were given negative values or minus abduction.

Flexion at the elbow is the forward movement of the lower part of the limb and extension is the downward movement. The angle of elbow flexion was measured by joining the center of the acromion process landmark and the center of the styloid process landmark to the center of the olecranon process landmark, the vertex.

Wrist flexion and extension describe the up and down movements of the palm while wrist abduction and adduction describe the side to side movements of the hand. Because of the flat two dimensional photographs only wrist flexion and extension or wrist abduction and adduction could be measured. The angles of wrist abduction were measured on the natural standing posture and all positions except the reach to the mid-back closure limit which made the hand turn so the measurement observed and recorded was flexion. Both articulations could be described by angles formed by lines from the center of the olecranon process landmark and the lateral metacarpophalangeal joint landmark joining at the center of the styloid process landmark.

The photographs of the natural relaxed standing position of the subject before moving into the reaches to the extreme limits of the closures gave the natural angles of body posture at the shoulder, elbow and wrist. These were measured and recorded on each subject's individual data sheet (Appendix B, page 57). The angles measured for the articulations of the reaches to each closure limit were subtracted from the natural body angles for arm flexion, arm abduction, elbow flexion, wrist flexion or wrist abduction. This determined the number of degrees of movement necessary to reach each closure limit. These differences were recorded for each subject.

The slope of the shoulder for the natural posture and during each

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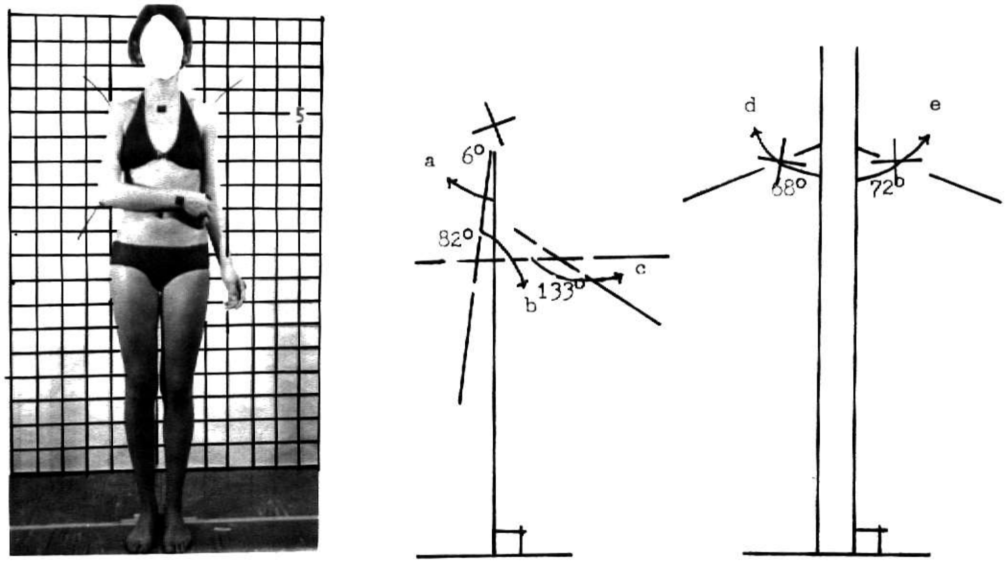
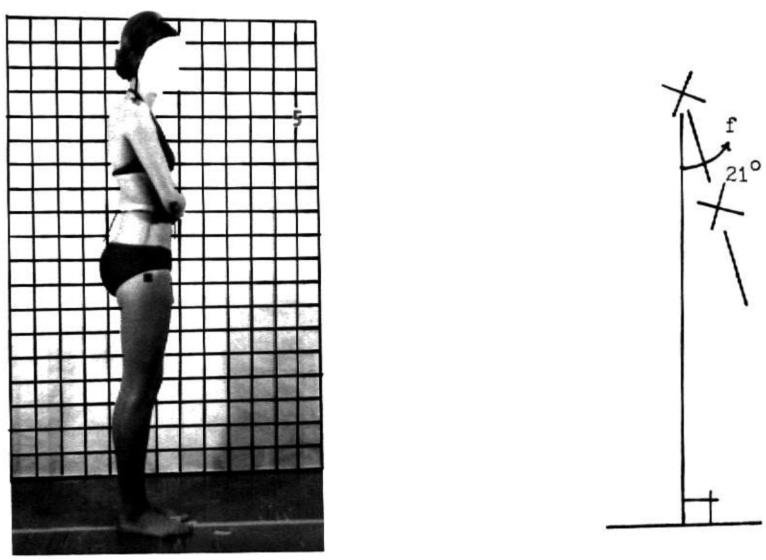


A B C

Figure 1-A. Front view of subject reaching to the left sideseam at waistline closure limit and placement of landmarks on the body. 1-B. Angles of articulation measured for the left sideseam at the waistline closure limit, a) shoulder abduction, b) elbow flexion and c) wrist abduction. 1-C. Angles of shoulder slope measured for the left sideseam at waistline closure limit, d) right shoulder slope and e) left shoulder slope.



A B

Figure 2-A. Right side view of subject reaching to the left sideseam at waistline closure limit and placement of landmarks on the body. 2-B. The angle of articulation measured on the right side view of the reach to the left sideseam at waistline closure limit, f) shoulder flexion.

articulation was also measured. It was determined by tracing the slope of the shoulder from the front or back views of each set of photographs onto tracing paper. The shoulder slope was determined by resting a line on the top surface of the shoulder and connecting the acromion process landmark to the neck. A perpendicular was drawn between the point at the shoulder-neck and the floor to form an angle. The right and left shoulder slopes for all closure limits were recorded (Appendix B, page 57), as well as the difference between the natural angle of shoulder slope and the angle formed during each reach to the defined closure limits.

CHAPTER IV

DISCUSSION AND RESULTS

The articulations at the joints of the upper extremity to reach the seven defined closure limits are discussed individually. The angles formed by the slope of the right and left shoulders; the angles of flexion, extension, abduction and adduction of the upper arm at the shoulder; of elbow flexion and extension; and the flexion and extension or the abduction and adduction at the wrist are included, as well as the amount of movement or articulation expressed in degrees required to reach these limits. Means, standard deviations and the standard errors were calculated on each measurement and tests of simple correlation were made between all the variables. For each closure limit any significant correlations between the variables are incorporated.

Body Measurements of the Twenty Subjects

The individual measurements for height, weight, back waist length, front waist length, arm length and the angles of shoulder slope for the twenty subjects are recorded in Table 1, page 30. The means, standard deviations and the standard errors are recorded at the base of the table for each variable listed. The length measurements were recorded in centimeters; the measurements in inches are as follows: height - Range = 60.2 inches to 69.35 inches, mean = 64.7 inches; back waist length - Range = 14.88 inches to 18.75 inches, mean = 16.72 inches; front waist length - Range = 15.25 inches to 17.75 inches, mean = 16.73 inches; right arm length - Range = 21.25 inches

TABLE 1

BODY MEASUREMENTS OF 20 SUBJECTS
AND THEIR MEANS AND VARIANCES

No.	Height in cms.	Weight in lbs.	BWL[1] in cms.	FWL[2] in cms.	Right Arm Length in cms.	Left Arm Length in cms.	Angle of Right Shoulder Slope	Angle of Left Shoulder Slope
1	168.4	125	41.6	41.0	60.3	57.8	62°	68°
2	160.6	118	44.4	43.8	55.9	57.2	68°	68°
3	165.4	136	44.4	43.5	59.7	57.2	70°	64°
4	157.7	135	43.8	45.1	56.5	56.2	63°	66°
5	174.6	140	43.8	43.2	62.2	62.2	60°	65°
6	160.8	130	43.8	43.2	59.4	57.5	64°	64°
7	175.3	128	44.8	44.4	60.3	57.7	64°	67°
8	161.5	115	41.9	41.3	56.8	59.4	62°	70°
9	168.6	126	44.4	43.5	55.0	55.9	58°	64°
10	156.5	119	40.3	42.9	55.0	54.6	65°	66°
11	163.1	113	41.9	43.9	58.4	58.4	60°	63°
12	166.6	134	42.2	44.8	55.9	56.2	58°	60°
13	166.6	136	42.9	42.2	58.7	58.1	67°	63°
14	171.4	126	41.6	43.8	60.3	61.0	60°	64°
15	152.9	97	37.8	38.7	53.6	54.0	65°	62°
16	160.0	120	38.7	40.6	56.2	57.2	65°	65°
17	154.7	106	38.7	40.0	54.6	53.6	69°	66°
18	167.1	136	43.5	40.6	57.2	57.5	65°	69°
19	162.6	107	42.2	39.7	56.5	57.8	70°	70°
20	176.1	134	47.6	43.7	59.1	59.7	71°	69°
$\bar{X}=$	164.5	124	42.5	42.48	57.6	57.5	64.2°	65.6°
$\sigma^2=$	44.9	141.6	5.6	3.4	5.5	4.5	15.9	7.6

[1] Back Waist Length

[2] Front Waist Length

$\sigma=$	6.70	11.90	2.35	1.84	2.34	2.13	3.99°	2.75°
$\sigma_{\bar{X}}=$	1.49	2.66	0.53	0.41	0.53	0.48	0.89°	0.62°

to 24.5 inches, mean - 22.7 inches; and left arm length - Range = 21.10 inches to 24.50 inches, mean = 22.60 inches. Weight was recorded in pounds and the shoulder slope was figured in degrees.

<u>Natural Body Angles of the Twenty Subjects</u>

The angle formed by the upper arm forward from the perpendicular between the acromion process and the floor was called flexion, and the angle formed back and away from the perpendicular was recorded as extension. Both the right and left arms in the relaxed natural standing position hung back and away from the perpendicular forming an angle of extension (Table 2, page 32).

The angles of abduction and adduction of the upper arm at the shoulder were also measured from a perpendicular between the acromion process and the floor. If the arm hung out from the perpendicular it was coded as abduction and if the arm hung in toward the body from the perpendicular it was termed adduction. The mean angle formed was an angle of abduction (Table 2, page 32).

The angles formed at the elbow were due to the bend or flexion of the elbow. There was a natural bend recorded on the entire sample. The angle most nearly approaching a straight angle was that of 152 degrees (Table 2, page 32).

Due to the inability to measure natural wrist flexion from the photographs used in this study the natural wrist positions were not given a natural angle of flexion or extension. Further relations to wrist flexion in the reaches to closure limits which turned the hand in view of the flexion articulation were in terms of deviation from a straight angle of 180 degrees. The angle of abduction, movement toward the lateral border of the hand, was measured on the natural position of the wrist (Table 2, page 32).

TABLE 2

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH NATURAL ANGLE FORMED BY THE UPPER LIMBS; n=20*

Articulation	Right Arm	Left Arm
Angle of Extension at Shoulder		
Range	5 to 16	3 to 11
Mean	8.05	8.15
Standard Deviation	2.68	2.60
Standard Error	0.60	0.58
Angle of Abduction at Shoulder		
Range	-1 to 8**	-3 to 8**
Mean	2.40	3.40
Standard Deviation	2.93	3.14
Standard Error	0.65	0.70
Angle of Flexion at Elbow		
Range	132 to 152	135 to 152
Mean	143.85	143.30
Standard Deviation	4.46	5.01
Standard Error	1.00	1.12
Angle of Abduction at Wrist		
Range	139 to 174	142 to 170
Mean	151.65	151.00
Standard Deviation	9.14	8.74
Standard Error	2.04	1.93

* The unit used to describe all articulations and body angles is degrees

** Minus numbers refer to the articulation opposite the recorded term: abduction at the shoulder - adduction at the shoulder

The relaxed natural posture of the body provided the basis for determining the amount of movement described in degrees of articulation. The following discussion and results are concerning the angles formed by the reaches to the defined extreme limits of garment closures and the amount of articulation required to reach these limits.

Reach to Closure Limit at Interclavicle Notch

When the right arm moved to fasten a closure which had its limit at the interclavicle notch both shoulders rose forming a larger angle of shoulder slope. The articulations occurring at the shoulder were those of flexion and abduction. The reach required a gross amount of flexion at the elbow. Abduction was the articulation measured at the wrist (Table 3, page 34).

Reach to Closure Limit Nine Inches below Center Front Waistline

For the right hand to reach the extreme low limit of a center front closure there was a mean elevation of both the right and left shoulders in this sample. The mean angle formed by the upper right arm was back and away from the perpendicular between the acromion process and the floor in extension. The degrees of articulation for the shortest and the tallest in the sample were in extension while ten subjects had amounts of articulation between 2 and 14 degrees of flexion recorded. The other angles and amounts of articulation recorded for the right arm were those of abduction at the shoulder, flexion at the elbow, and abduction at the wrist (Table 4, page 35).

Reach to Closure Limit at Center Back on Seventh Cervical Vertebra

In performing the reach to the closure limit on the seventh cervical vertebra both shoulder slopes showed an elevation; however, the right shoulder had a greater mean amount of rise. The right upper arm moved upward in a

TABLE 3

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO CENTER FRONT AT THE INTERCLAVICLE NOTCH; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	62 to 77	68.65	4.04	0.90
Difference**	-2 to 15***	4.35	4.50	1.01
Left Shoulder Slope	60 to 72	67.10	3.21	0.72
Difference**	-4 to 8***	1.45	2.33	0.52
Angle of Flexion at Shoulder	3 to 38	26.90	8.12	1.82
Flexion Articulation**	27 to 42	34.95	6.41	1.43
Angle of Abduction at Shoulder	-7 to 43***	14.95	11.71	2.62
Abduction Articulation**	2 to 41	12.85	11.69	2.61
Angle of Flexion at Elbow	15 to 30	22.40	5.40	1.21
Flexion Articulation**	107 to 134	121.20	6.68	1.50
Angle of Abduction at Wrist	150 to 189	171.10	12.20	2.73
Abduction Articulation**	-9 to 37***	19.85	12.89	2.88

* The unit used to describe all articulations and body angles is degrees

** The difference between the natural body angles and the angles formed by the right-hand reach to the interclavicle notch

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, abduction at the shoulder - adduction at the shoulder, and abduction at the wrist - adduction at the wrist

TABLE 4

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO NINE INCHES BELOW THE CENTER FRONT WAISTLINE; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	62 to 74	66.60	3.91	0.87
Difference**	-3 to 8***	2.30	3.63	0.81
Left Shoulder Slope	61 to 73	67.90	3.34	0.75
Difference**	-2 to 6***	2.25	2.15	0.48
Angle of Extension at Shoulder	-6 to 10***	-1.05***	4.51	1.01
Extension Articulation**	-14 to 11***	1.80	8.25	1.84
Angle of Abduction at Shoulder	10 to 22	15.65	3.51	0.78
Abduction Articulation**	5 to 20	13.30	4.17	0.93
Angle of Flexion at Elbow	111 to 141	127.50	9.62	2.15
Flexion Articulation**	-12 to 30***	16.55	10.64	2.38
Angle of Abduction at Wrist	163 to 204	172.95	24.95	5.58
Abduction Articulation**	1 to 41	26.60	11.04	2.47

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to nine inches below the center front waistline

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, extension at the shoulder - flexion at the shoulder, and flexion at the elbow - extension at the elbow flexion articulation and away from the side of the body in an abduction articulation. Both movements involved a great amount of upward motion. Another gross articulation was observed in the elbow flexion. Table 5, page 37 gives the sample range, mean, standard deviation, and standard error for each of the articulations of the right arm.

Reach to Closure Limit at Nine Inches below Center Back Waistline

The right shoulder had a mean rise while the left shoulder exhibited a mean depression while performing a right hand reach to the extreme low limit of a center back closure. The upper right arm moved backward in extension and also articulated to form an angle of abduction. The lower arm recorded varied in either moving up from the natural posture or moving downward from the natural posture in order to reach this closure limit. The longest arm recorded in the sample formed the largest angle of extension articulation at the elbow, while the shortest arm perfomed a flexion articulation at the elbow although not the largest amount of articulation. Abduction was the movement analyzed at the right wrist (Table 6, page 38).

Reach to Closure Limit on Left Sideseam at Waist

The right hand reach to the left sideseam on the waist did not require a large amount of articulation at the shoulder or in the articulations at the joints of the upper extremity (Table 7, page 39). Elbow flexion was the most extensive movement.

Reach to Closure Limit at Nine Inches below the Waist on Sideseam

The upper right arm performed a flexion articulation in the right hand reach to nine inches below the waist on the left sideseam, as well as adducting across in front of the body. Table 8, page 40 records the entire

TABLE 5

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO CENTER BACK AT THE SEVENTH CERVICAL VERTEBRA; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	77 to 87	78.20	5.42	1.21
Difference**	7 to 23	13.90	4.52	1.01
Left Shoulder Slope	65 to 75	68.05	3.49	0.78
Difference**	-3 to 7***	2.40	2.72	0.61
Angle of Flexion at Shoulder	100 to 150	123.90	13.12	2.93
Flexion Articulation**	113 to 158	131.95	12.92	2.89
Angle of Abduction at Shoulder	90 to 133	121.70	11.80	2.64
Abduction Articulation**	91 to 140	119.30	11.71	2.62
Angle of Flexion at Elbow	10 to 19	15.05	3.12	0.70
Flexion Articulation**	122 to 136	128.80	4.26	0.95
Angle of Abduction at Shoulder	150 to 180	166.55	9.90	2.21
Abduction Articulation**	-17 to 38***	15.20	14.39	3.22

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to center back at the seventh cervical vertebra

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, wrist abduction - wrist adduction

TABLE 6

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO NINE INCHES BELOW THE CENTER BACK WAISTLINE; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	58 to 72	62.95	4.35	0.97
Difference**	-8 to 6***	-1.35***	3.84	0.86
Left Shoulder Slope	56 to 74	66.85	4.77	1.07
Difference**	-8 to 6***	1.20	3.44	0.77
Angle of Extension at Shoulder	28 to 46	38.25	5.25	1.17
Extension Articulation**	21 to 44	30.05	5.28	1.18
Angle of Abduction at Shoulder	-7 to 25***	14.55	8.88	1.99
Abduction Articulation**	0 to 28	12.15	9.46	2.12
Angle of Flexion at Elbow	87 to 155	130.40	18.15	4.06
Flexion Articulation**	-25 to 32***	13.45	19.10	4.27
Angle of Abduction at Wrist	128 to 180	151.80	14.47	3.24
Abduction Articulation**	-30 to 43***	1.40	16.38	3.66

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to nine inches below the center back waistline

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, abduction at the shoulder - adduction at the shoulder, flexion at the elbow - extension at the elbow, and abduction at the wrist - adduction at the wrist

TABLE 7

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO THE LEFT SIDESEAM AT WAIST; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	66 to 80	71.80	5.63	1.26
Difference**	0 to 16	7.45	4.88	1.09
Left Shoulder Slope	64 to 74	69.70	2.79	0.62
Difference**	1 to 8	4.05	2.24	0.50
Angle of Flexion at Shoulder	10 to 31	19.80	5.96	1.33
Flexion Articulation**	19 to 41	27.85	6.81	1.52
Angle of Abduction at Shoulder	-4 to 14***	5.10	5.06	1.13
Abduction Articulation**	-1 to 15***	2.80	4.81	1.08
Angle of Flexion at Elbow	72 to 90	81.45	4.86	1.09
Flexion Articulation**	53 to 69	62.25	5.75	1.29
Angle of Abduction at Wrist	122 to 177	147.15	14.87	3.33
Abduction Articulation**	-17 to 42***	-4.15	17.53	3.92

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to the left sideseam at the waist

*** Minus numbers refer to the articulation opposite the recorded term: abduction at the shoulder - adduction at the shoulder and abduction at the wrist - adduction at the wrist

TABLE 8

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO NINE INCHES BELOW THE WAIST ON LEFT SIDESEAM; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	60 to 84	68.35	6.48	1.45
Difference**	-8 to 19***	4.05	6.83	1.53
Left Shoulder Slope	60 to 76	69.10	4.52	1.01
Difference**	-2 to 9***	3.40	2.74	0.61
Angle of Flexion at Shoulder	1 to 15	9.75	5.08	1.34
Flexion Articulation**	-9 to 31***	16.90	8.39	1.88
Angle of Adduction at Shoulder	2 to 20	9.50	4.47	1.00
Adduction Articulation**	1 to 21	11.60	4.84	1.08
Angle of Flexion at Elbow	113 to 140	127.60	6.81	1.52
Flexion Articulation**	6 to 30	16.25	7.69	1.72
Angle of Abduction at Wrist	134 to 170	151.15	10.12	2.26
Abduction Articulation**	-27 to 22***	6.45	14.58	3.26

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to nine inches below the waist on the left sideseam

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, flexion at the shoulder - extension at the shoulder, and abduction at the wrist - adduction at the wrist articulation analysis.

Reach to Closure Limit at the Ninth Thoracic Vertebra

The right hand reach to the closure limit at the ninth thoracic vertebra produced a mean depression of the right shoulder while the slope of the left shoulder showed a mean elevation in the sample studied. The right upper arm abducted from the side of the body while it extended toward the back. The angles of flexion were observed on the elbow, and in this reach, on the wrist (Table 9, page 42).

Two-Hand Reach to Mid-Back at the Ninth Thoracic Vertebra

There was a significant correlation at the 0.01 level between the mean depression recorded on the right shoulder and the mean depression on the left shoulder. In the two hand reach to the mid-back at the ninth thoracic vertebra both the right and the left arms are performing the same articulation. Again the angles formed by the upper arms at the shoulders were those of extension and abduction. Flexion articulations were recorded on the elbows and the wrists (Table 10, page 43).

Two-Hand Extreme Reach in Opposition to Mid-Back

The right arm reached down over the right shoulder to as far down the center back as possible while the left arm came back and around the trunk of the subject and reached upward as far as possible. In this reach the upper right arm abducted from the side of the body and moved forward from the perpendicular between the acromion process at the shoulder and the floor, while the upper left also abducted from the side of the body it moved backward to form a mean angle of extension. The angle of elbow flexion was acute for both arm movements. The angle of articulation recorded on the right wrist for this

TABLE 9

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A RIGHT-HAND REACH TO THE MID-BACK AT THE NINTH THORACIC VERTEBRA; n=20*

Right Arm Articulation	Range	Mean	Standard Deviation	Standard Error
Right Shoulder Slope	53 to 77	60.75	4.69	1.05
Difference**	-8 to 1***	-3.55***	3.27	0.73
Left Shoulder Slope	61 to 73	66.50	3.42	0.77
Difference**	-3 to 9***	0.95	2.72	0.61
Angle of Extension at Shoulder	10 to 57	30.30	14.86	3.32
Extension Articulation**	2 to 48	22.25	15.33	3.43
Angle of Abduction at Shoulder	2 to 50	21.80	10.18	2.28
Abduction Articulation**	4 to 48	19.90	10.84	2.42
Angle of Flexion at Elbow	54 to 70	62.10	5.21	1.16
Flexion Articulation**	70 to 93	81.75	6.96	1.56
Angle of Flexion at Wrist	108 to 152	132.20	14.83	3.32
Flexion Articulation**	9 to 72	47.80	14.83	3.32

* The unit used to describe all articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the right-hand reach to the mid-back at the ninth thoracic vertebra

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression

TABLE 10

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY A TWO-HAND REACH TO THE MID-BACK AT THE NINTH THORACIC VERTEBRA; n=20*

	Right Arm				Left Arm			
	Range	Mean	Standard Deviation	Standard Error	Range	Mean	Standard Deviation	Standard Error
Shoulder Slope	58 to 71	64.10	4.32	0.96	56 to 72	64.95	4.45	1.00
Difference**	-5 to 9***	-0.20	3.50	0.78	-11 to 8***	-0.70	4.70	1.05
Angle of Extension at Shoulder	14 to 50	40.25	14.45	3.23	14 to 56	33.15	12.57	2.81
Extension Articulation**	5 to 53	32.00	14.85	3.32	1 to 46	24.80	13.35	2.98
Angle of Abduction at Shoulder	26 to 66	43.15	8.94	2.00	26 to 58	44.10	7.70	1.72
Abduction Articulation**	29 to 64	40.90	8.88	1.99	23 to 51	40.60	7.69	1.72
Angle of Flexion at Elbow	46 to 80	57.35	8.70	1.95	40 to 58	51.60	4.90	1.10
Flexion Articulation**	66 to 103	86.35	9.66	2.16	73 to 104	91.45	8.04	1.80
Angle of Flexion at Wrist	100 to 173	138.00	16.70	3.73	120 to 163	145.00	14.58	3.26
Flexion Articulation**	7 to 80	43.00	18.12	4.05	15 to 55	34.00	14.58	3.26

* The unit used to describe the articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by a two-hand reach to the mid-back at the ninth thoracic vertebra

*** The minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression extreme reach was abduction while the angle recorded on the left wrist was flexion (Table 11, page 45).

Significant Correlations Observed in this Sample

In this sample an articulation at a joint in the upper extremity did not consistantly correlate with another variable at a level of high significance. Correlations were made between variables to assertain how the articulation at one joint would relate to another. Table 12, pages 46 and 47 lists the significant correlations on the means for each variable analyzed at the identified closure limits.

Height and back waist length have high correlations as do the lengths of the right and left arms. Tall people naturally have longer waist lengths and similarly longer arms. The length of the right arm correlates very highly (at the 0.01 level of significance) with the angles of shoulder flexion, shoulder abduction and elbow flexion on the reaches to the three closure limits nine inches below the waistline at the center front, center back and on the left sideseam. The sample showed that the longer the arm the less amount of articulation was needed to reach these extreme limits below the waistline (Table 12, pages 46 and 47).

The right shoulder slope does not consistantly correlate with any variable. The correlations between the right and the left shoulder slope at each closure limit indicated no significant correlation at any of the closure limits except on the two-hand reach to the ninth thoracic vertebra. In this reach both arms are performing the same movement; therefore, the depression of the angles of shoulder slope are similar in direction (Table 12, pages 46 and 47).

Upper arm extension and shoulder abduction have highly significant

TABLE 11

SAMPLE RANGE, MEAN, STANDARD DEVIATION, AND STANDARD ERROR FOR EACH ARTICULATION AND BODY ANGLE FORMED BY AN EXTREME TWO-HAND REACH IN OPPOSITION TO THE MID-BACK; n=20*

	Right Arm				Left Arm			
	Range	Mean	Standard Deviation	Standard Error	Range	Mean	Standard Deviation	Standard Error
Shoulder Slope	71 to 99	88.25	6.45	1.44	60 to 77	68.10	5.50	1.23
Difference**	9 to 31	23.35	7.23	1.62	-7 to 10***	2.45	4.72	1.06
Angle of Flexion at Shoulder	120 to 154	139.90	11.34	2.54	1 to -39	-17.15***	13.59	3.04
Flexion Articulation**	140 to 175	147.95	10.98	2.45	1 to -47	-10.00***	12.10	2.70
Angle of Abduction at Shoulder	136 to 180	156.00	10.36	2.31	6 to 46	21.80	9.70	2.17
Abduction Articulation**	128 to 177	153.60	11.64	2.60	-2 to 46***	18.40	10.78	2.41
Angle of Flexion at Elbow	22 to 44	31.55	8.80	1.97	18 to 58	43.75	10.63	2.38
Flexion Articulation**	85 to 130	112.05	9.52	3.13	70 to 135	98.20	16.04	3.59
Angle at Wrist	abduction 165 to 192	178.00	9.43	2.11	flexion 114 to 160	126.95	33.71	7.54
Articulation**	6 to 41	26.90	11.69	2.61	20 to 84	43.55	18.47	4.13

* The unit used to describe the articulations and body angles is degrees

** The differences between the natural body angles and the angles formed by the extreme two hand reach in opposition to the mid-back

*** Minus numbers refer to the articulation opposite the recorded term: shoulder slope rise - shoulder slope depression, flexion at the shoulder - extension at the shoulder and abduction at the shoulder - adduction at the shoulder

TABLE 12

SIGNIFICANT CORRELATIONS OBSERVED BETWEEN BODY MEASUREMENTS, BODY ANGLES AND THE REACHES TO THE EXTREME LIMITS OF GARMENT CLOSURES; n=20

Variable	Closure Limit	Correlation and Level
Height	natural posture	back waist length**
	" "	rt. arm length**
	" "	lt. arm length**
	9" below CF waist	rt. shoulder flexion*
	" " " "	rt. elbow flexion*
	9" below CB waist	rt. shoulder flexion*
	" " " "	rt. shoulder abduction*
	9" below side waist	rt. elbow flexion**
	2-hand at mid-back	lt. elbow flexion*
Weight	natural posture	back waist length**
	" "	front waist length**
	" "	rt. arm length**
	" "	lt. arm length*
	9" below CB waist	rt. shoulder abduction*
Back Waist Length	natural posture	front waist length**
	" "	rt. arm length*
	" "	lt. arm length*
	interclavicle notch	rt. elbow flexion*
	9" below CF waist	rt. wrist abduction*
	2-hand at mid-back	rt. elbow flexion*
	" " "	lt. elbow flexion*
	" " "	lt. wrist flexion*
Front Waist Length	natural posture	lt. shoulder slope*
	9" below CB waist	rt. shoulder abduction*
	2-hand at mid-back	rt. elbow flexion*
Right Arm Length	natural posture	height**
	" "	back waist length*
	" "	lt. arm length**
	9" below CF waist	rt. shoulder abduction*
	" " " "	rt. elbow flexion*
	9" below CB waist	rt. shoulder abduction**
	" " " "	rt. elbow flexion**
	9" below side waist	rt. shoulder flexion**
	" " " "	rt. elbow flexion**
Left Arm Length	natural posture	height**
	" "	back waist length*
	" "	rt. arm length**

TABLE 12 (Con't)

Variable	Closure Limit	Correlation and Level
Rt. Shoulder Slope	natural posture	rt. elbow flexion*
	interclavicle notch	rt. shoulder abduction**
	sideseam at waist	rt. shoulder flexion**
	2-hand at mid-back	lt. wrist flexion*
	2-hand in opposition	lt. elbow flexion*
Lt. Shoulder Slope	interclavicle notch	lt. wrist abduction*
Shoulder Flexion	7th cervical vertebra	rt. shoulder abduction**
	9" below side waist	rt. shoulder adduction**
	9th thoracic vertebra	rt. shoulder abduction**
Shoulder Extension	natural posture	rt. elbow flexion**
	2-hand at mid-back	lt. shoulder abduction**
	2-hand in opposition	lt. shoulder abduction**
Shoulder Abduction	9" below CF waist	rt. elbow flexion*
	7th cervical vertebra	rt. shoulder flexion**
	9" below CB waist	rt. elbow flexion**
	sideseam at waist	rt. elbow flexion**
	9th thoracic vertebra	rt. shoulder flexion**
	2-hand at mid-back	lt. shoulder flexion**
	2-hand in opposition	lt. shoulder flexion**
Shoulder Adduction	9" below side waist	rt. elbow flexion**
	" " " "	rt. shoulder flexion**
Elbow Flexion	9" below CF waist	rt. shoulder abduction*
	9" below CB waist	rt. shoulder abduction**
	sideseam at waist	rt. shoulder abduction**
	9" below side waist	rt. shoulder flexion**
	" " " "	rt. shoulder adduction**
	2-hand at mid-back	lt. wrist flexion**
	2-hand in opposition	rt. wrist flexion**
Wrist Flexion	2-hand at mid-back	rt. elbow flexion**
	2-hand in opposition	rt. elbow flexion**
Wrist Abduction		

* Correlation significant at the 0.05 level

** Correlation significant at the 0.01 level correlations (0.01 level of significance) at the mid-back closure limit and at the reach to the seventh cervical vertebra. Elbow flexion also correlated very highly with flexion at the shoulder in several instances. Elbow flexion had a high significant correlation to abduction and adduction at the shoulder in four out of the seven articulations (Table 12, pages 46 and 47).

In both the two-hand reaches to the mid-back the angle of wrist flexion correlated very highly (significant at the 0.01 level of significance) with the angle of elbow bend or flexion. Abduction at the wrist made no significant correlation with any of the variables (Table 12, pages 46 and 47).

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This exploratory study set out to develop a method for measuring the amount of articulation occurring in the joints of the upper extremity which could apply to the analysis of body angles formed by reaches to the extreme limits of certain garment closures.

The still photographic method of recording the reaches provided a description of the natural posture and the extreme position of the reaches to the closure limits for analysis. To insure a uniformity for measurement, landmarks were placed on the body in predetermined anatomical and distance locations. To clearly identify these places, a square piece of dark colored tape was adhered to the landmark locations; the landmarks that could be partially obscured during the articulations were further marked by attaching a four-inch wire to the center of the landmark tape. In this study the acromion processes and the olecranon processes received the added attention.

The body angles formed by the articulations were measured from Polaroid pictures with a protractor. Shoulder slope was recorded by a line lying directly on the top surface of the shoulder connecting the acromion process landmark to a perpendicular between the floor and the shoulder line. The angles formed by the upper arm at the shoulder also used a perpendicular line as the basis for describing the movement at the shoulder joint; this line was between the acromion process and the floor. The acromion process, the olecranon process, the styloid process of the ulna and the lateral metacarpophalangeal joint were the body landmarks used with the perpendicular lines to form the arms of the body angles on the shoulder slope, at the shoulder joint, elbow joint and the wrist joint.

To determine the amount of movement or articulation at the joints of the upper extremity for each movement from the natural posture to the limits of the garment closures, the angles produced by the reaches were subtracted from the angle provided by the natural posture for each angle on the shoulder slope and at each joint. The differences described the range of motion in degrees needed or required at joints to reach the closure limits. Also the type of movement necessary to perform these reaches could be determined.

The body angles measured on the shoulder and elbow joints were descriptive of the articulations taking place. The analysis of total movement at the wrist was only partially accomplished. Therefore, an additional procedure needs to be developed in order to describe total wrist movement. Further studies of the articulations of supination and pronation of the forearm and finger manipulation would lead to greater understanding of the articulations needed to perform many dressing procedures.

An analysis of the accuracy of this method versus direct body measurement would be desireable. Also a second study of the sample would check the consistancy of individual articulations.

The human body is extremely flexible and capable of a multiplicity of movements which make precise measurement of stature and articulation improbable. Postural changes can not be defined to require an exact amount of movement to perform specific tasks; however, a range of expected articulation could be established.

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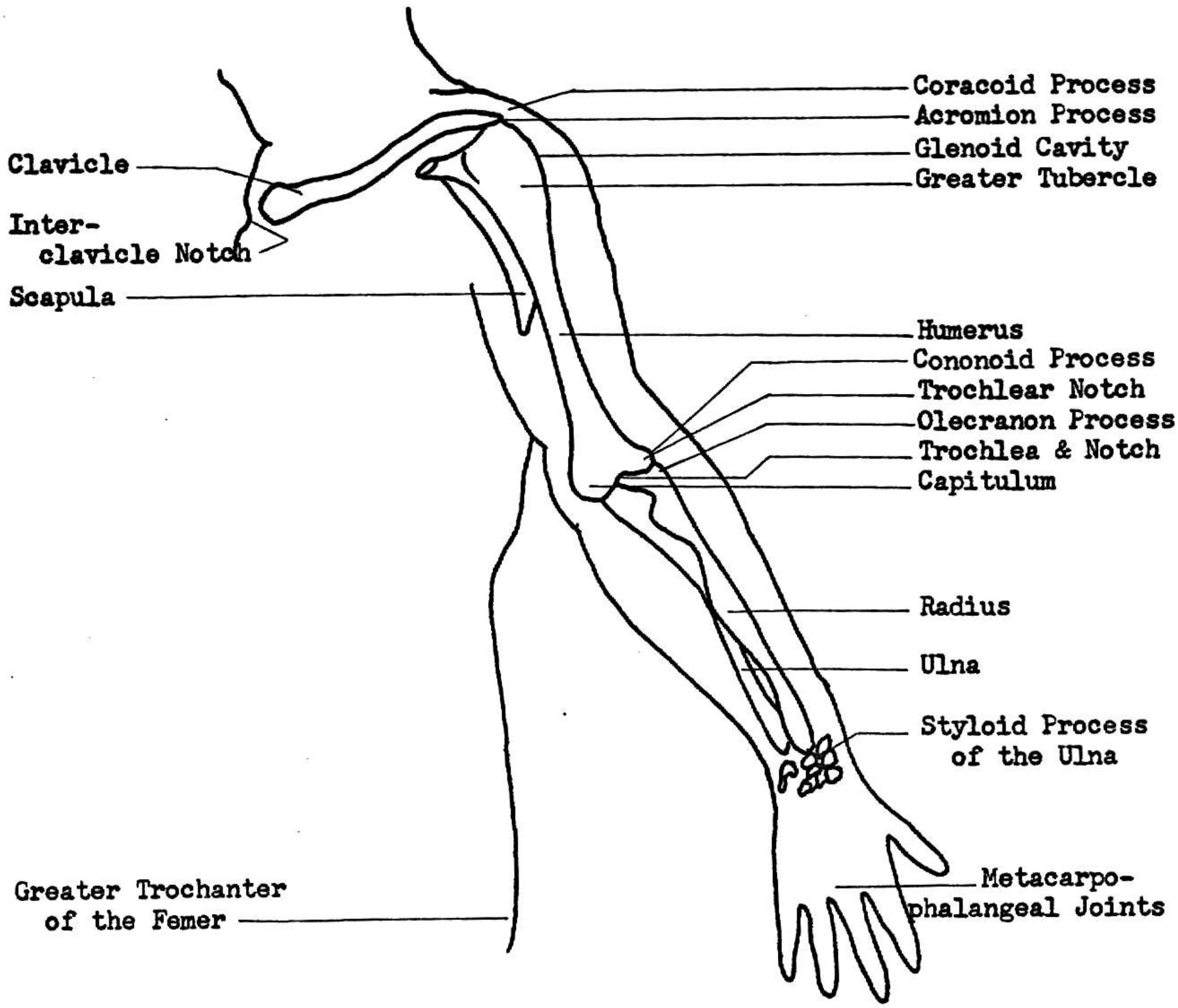
APPENDIXES

APPENDIX A

ANATOMY OF THE UPPER LIMB



APPENDIX B

INDIVIDUAL DATA SHEET

NAME____________________________________NUMBER__________

ADDRESS____

AGE____________________DATE OF BIRTH______________________

BODY MEASUREMENTS:

HEIGHT . . . . ____________cms.

WEIGHT . . . . ____________lbs.

BACK WAIST LENGTH . . . . ____________cms.

FRONT WAIST LENGTH . . . . ____________cms.

RIGHT ARM LENGTH . . . . ____________cms.

LEFT ARM LENGTH . . . . ____________cms.

COMMENTS:

ANALYSIS OF THE ANGLES OF ARTICULATION IN PERFORMING GARMENT CLOSURES

Subject____________________________

Closure Number	Position	Photo. No.	Closure Location	Shoulder												Elbow				Wrist									
				Rt. Shoulder Slope	Difference	L. Shoulder Slope	Difference	Flexion	Difference	Extension	Difference	Abduction	Difference	Adduction	Difference	Flexion	Difference	Extension	Difference	Supination	Pronation	Flexion	Difference	Extension	Difference	Abduction	Difference	Adduction	Difference
0	Back	1	Natural Relaxed Standing Position																										
	Rt. Side	2																											
	Left Side	3																											
1	Front	4	Center Front to Interclavicular Notch																										
	Rt Side	5																											
2	Front	6	Center Front to 9" below Center Front Waistline																										
	Rt. Side	7																											
3	Back	8	Center Back to 7th Cervical Vertebra																										
	Rt. Side	9																											
4	Back	10	Center Back to 9" below Center Back Waistline																										
	Rt. Side	11																											
5	Front	12	Left Side at Waistline																										
	Rt. Side	13																											
6	Front	14	Left Side at 9" below the Side Waistline																										
	Rt. Side	15																											
a 7	Back	16	Mid-back to 9th Thoracic Vertebra																										
	Rt. Side	17																											
b	Back	18	2-hand reach to Mid-back at 9th Thoracic Vertebra																										
	Rt Side	19																											
	Left Side	20																											
c	Back	21	2-hand Extreme Reach in Opposition to Mid-back																										
	Rt. Side	22																											
	Left Side	23																											

MEASUREMENT OF THE ARTICULATION OCCURRING IN THE UPPER EXTREMITY NEEDED TO REACH THE LIMITS OF GARMENT CLOSURES

by

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B. S., North Dakota State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

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KANSAS STATE UNIVERSITY

Manhattan, Kansas

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The measurement of the body angles in the upper extremity formed by reaches to the extreme limits of garment closures was explored. The seven limits identified as those most commonly encountered by young women in normal dressing processes were: a center front closure as a zipper or buttoned placket with the upper limit at the interclavicle notch and the lower limit at nine inches below the center front waistline, a center back closure as a zipper, hook and eye or a buttoned placket with the upper limit at the seventh cervical vertebra and the lower limit at nine inches below the center back waistline, a left side closure as a zipper placket with a hook and bar or button fastening with the upper limit on the waistline at the sideseam position and the lower limit at nine inches below the waistline on the sideseam, and a mid-back closure for a swim suit or bra or the lower limit of a short center back zipper with the limit at the ninth thoracic vertebra.

An objective of the study was the description of the articulation of a normal mature young woman. Reaches to the garment closure limits were performed by twenty Kansas State University students who volunteered for the study. The subjects were between eighteen and tweny-five years of age and chosen with no health mobility problems.

A still photographic method provided the means from which the angles of shoulder slope, upper arm flexion and extension, upper arm abduction and adduction, elbow flexion and extension, and wrist flexion and extension or wrist abduction and adduction were analyzed. Means, standard deviations, standard errors, and simple correlations were calculated involving all variables. Correlations between the articulations at the shoulder, elbow and wrist were not shown to have consistant significant relationships in the amount of articulation performed to reach the extreme limits of garment closures.