# THE EFFECTS OF SHOULDER POSITION ON FOUR SLEEVE/BODICE STRUCTURES

by

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(ABSTRACT)

Investigated in this research was the effect of different shoulder positions on different sleeve/bodice structures. Since a sleeve/bodice may have numerous variations and design details incorporated into the structure, this research concentrated on the set-in sleeve, kimono sleeve, raglan sleeve, and kimono sleeve with gusset. The variables used to determine the reaction of the different structures to different shoulder positions were garment slippage away from the wrist, the waist, the center back/waistline positions, and the angle formed by the center back/waistline intersection.

A Factorial ANOVA was used to test for significant differences between the sleeve/bodice structures and shoulder positions. A Tukey's pairwise comparison was used to determined the difference between the slippage at each shoulder position and each sleeve/bodice structure compared with each of the others. Regression equations were fit as linear, quadratic and their interactions with each sleeve/bodice structure.

Based on the theoretical framework, the amount and location of the slippage found in the statistical analyses was not necessarily those predicted. From the analyses, it was determined that when comparing the slippage at the wrist, waist, center back/waistline location and the center/back angle as a whole, general trends which occurred in the data were that the set-in sleeve consistently exhibited the greatest amount of slippage and the kimono sleeve exhibited the least. From the plots of the regression coefficients, the amount of slippage illustrated for the raglan sleeve was of similar slope to that of the set-in sleeve, whereas the kimono sleeve with gusset was more closely related to the slippage of the kimono sleeve.

The results of this study provide information that other clothing designers may find useful when developing sleeve/bodice structures based on specific shoulder positions. From known shoulder positions, a designer may determine which sleeve/bodice structure would exhibit the least or most garment slippage, or be able to predict the amount of garment slippage for a specific structure.

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# CHAPTER I

# INTRODUCTION

Normally the design of clothing has been concerned with covering the human body for aesthetic reasons. Historically, people have been more concerned with the appearance of a garment than with its functionality. With the increase in sports and concern for safety in the workplace, the functional aspects of a garment have also become important.

In the development of functional apparel, the physical components of garments can be studied as individual parts. There is an abundance of information on the durability and thermal properties of fibers, fabrications, closures, and notions used in garments. The structural component of a garment has not been thoroughly investigated. The design or structure of a garment will impact its functionality.

Design is a process by which apparel designers develop garments to meet specific needs of the wearer. A design process should guide the designer, in a series of steps, from the user's apparel needs through the evaluation of a final garment. At each step various methods and tests, such as physical testing of fabrics or identification of the physical movements of the wearer, can be used to advance the designer to the next step. Thus an operational framework can be developed for apparel design.

In previous design research, Mullet (1984) followed a process in which the perceived and physical needs of kayakers formed a basis for various paddling jacket designs. The movements of the kayakers were easily recorded. The translation of the movements into appropriate paddling jacket designs was based on the aesthetics of the designs, and on what the researcher thought would be the best garment structure for the movement. The only way that the jacket designs could be evaluated was to wear-test each jacket.

Mullet (1984) identified a major problem in translating the data from the body movements into garment designs. She had to rely on her intuitive design capability since no procedures or data were available to determine the best garment design for the movements performed by the kayakers. The less a designer must rely on intuitive responses the more objective the design will become. To eliminate or reduce the need for intuitive solutions to a clothing problem, information or data should be available for others to use. Since freedom of body movement is necessary in many clothing designs, data which contribute to selecting apparel components based on body movements are useful.

In this research, the shoulder complex of the body was selected for study for two reasons. First, the shoulder complex has the greatest range of movement of any joint area of the body and can be positioned in various planes of motion. The second reason for studying the shoulder complex was the variety of garment structural designs which can be developed to cover this area.

When the body moves, the bones, muscles, joints, and skin reconfigure. A garment which covers the body can not duplicate the same actions as the body. The garment's reaction to body movement is to slip, wrinkle, stretch, or restrict the wearer. Information which can explain a garment's reaction to body movement would be useful. Therefore, the purpose of this study was to investigate the effects which various shoulder positions have on four different sleeve/bodice structures.

Data from this study are expected to provide criteria by which designers could select sleeve designs based on known relationships of garment structures with body positions. Costly wear-testing or implementation of a number of possible design prototypes could then be reduced.

# CHAPTER II

# REVIEW OF RELATED LITERATURE

Background information about the apparel design process as it relates to body movements was necessary in order to establish a basis for this study. The review of literature includes the following topic areas: 1) apparel design processes; 2) apparel design related to body movements; 3) shoulder complex; and 4) designing sleeve/bodice structures.

## Apparel Design Processes

Design is a term used in many different disciplines. Each discipline defines design in its own manner to communicate its purpose and concepts to others. For the artist, design may refer to the use of particular colors and lines in a painting. For the computer engineer, design may be the interfacing of various computer functions. For the apparel designer, the word may mean the use of specific techniques in the construction of a garment. Whatever the discipline, the word design denotes a certain action or outcome.

Design is used either as a noun or a verb. As a noun, it refers to the object or final plan aimed at a specific purpose (Webster, 1990). Design used as a verb, is the process or steps to be followed to achieve a purpose

(Webster, 1990). When persons design an object or plan, the process used may be difficult for the designer to describe and therefore unclear to others. "Design is difficult to describe because it includes so many intangible elements such as intuition, imagination and creativity" (Zeisel, 1981, p. 3). Though a person can observe the tangible process of developing a design, the design process which goes on within the mind of the designer is not as easily observed. "Describing the design process may help designers and teachers of design understand their own behavior and therefore improve their design ability" (Zeisel,1981, p. 5).

Apparel design is usually divided into two categories, aesthetic and functional design. Aesthetic design is for appearance only. The purpose of an aesthetically designed garment is that it be visually pleasing. Aesthetic design is more difficult to define because of the difficultly in defining the term "aesthetic". Functional design is more easily defined since it deals with a garment's physical attributes in meeting specified criteria for particular use situations.

There are certain advantages in describing a methodical design process. The first advantage is being able to break down a design process into various steps so that the designer can see and study each step. This enables others to understand and follow the development of the design. A second advantage is that data can be collected at various steps and then guide the designer to the next step.

This study reviewed the apparel design processes which have been used in functional clothing design research. Designers of functional clothing have lent themselves to the use of apparel design processes in that the initial problem or need can be defined more objectively, and data collected more easily. The data collected at various steps are then used to design the final product. Though numerous researchers have developed or evaluated the effectiveness of specific apparel designs, their studies did not begin by identifying the original need or problem of the user (Brandt & Cory, 1989; Fourt & Hollies, 1970; Hoffman, 1979; Huck, 1988; Kernaleguen, 1978; Laine, 1987; Lawson, 1985, Lopez, 1985; Murray, 1982; Niehm, 1985; Sontag, 1985). Therefore, the apparel design process was not easily and systematically completed from beginning to end.

For functional apparel design, Mullet (1984), Orlando (1979),and Watkins (1988) developed basic apparel design processes which evolved or were adapted from other disciplines. Their processes begin with a user need or problem, not with a preconceived garment design. Their processes provide an operational framework which takes the designer step-by-step from the initial clothing problem or need through the evaluation of the final design. Orlando and Watkins adapted theirs from design processes used in architecture. Orlando adapted her process from methods described by Jones (1970) in his book Design Methods. Watkins (1988) explained the use of the design process from the Universal Traveler (Koberg & Bagnall, 1981) as a basis for teaching students to become better clothing designers. Mullet (1984) adapted her apparel design process from education, using the needs assessment process of Kaufman and English (1979) as the basis for designing clothing for kayakers. In each of these processes similar steps were followed. Table 1 shows the similarities between these three design processes.

In all three design processes the first step is to identify the apparel goal or need of the user. Aesthetic clothing design may ignore this step because the user's need is often subjective. Researchers in functional clothing design have studied various user groups. These include athletes (Garner, 1982; Laine, 1987; McCormick, 1986; Mullet, 1984; Watkins, 1977), the physically handicapped (Atkins, 1980; Niehm, 1985; Sontag, 1985) or workers in specific occupations (Ashdown, 1989; Vass, 1989; Watkins, 1978; Workman, 1986). It is important in the first step to concentrate on defining the real need or problem of the user, and not necessarily on correcting an existing design. Data are collected through interviews with the users or

Table 1

Apparel Design Processes

| | Orlando(1979) | Watkins(1988) | Mullet(1984) |
|---|---|---|---|
| Step 1 | Request Made | Accept | |
| Step 2 | Design Solution Explored | Analyze | Identify Problem Based on Needs |
| Step 3 | Problem Structure Perceived | Define | Determine Solution Requirements |
| Step 4 | Specifications Described | Ideate | Select Solution Strategies |
| Step 5 | Design Criteria Established | Select | Implement |
| Step 6 | Prototype | Implement | Determine Effectiveness |
| Step 7 | Evaluation | Evaluate | Evaluate/Revise |

through a literature search. Biomechanical analysis, observations, or actual user participation are other methods. Data from this step are then used in the next step of the process.

From the identified needs or problems, solutions are sought. A hierarchy is established to determine the most important need or solution. Orlando (1979) prioritized the solutions; Watkins (1988) and Mullet (1984) prioritized the needs or problems, then selected the solutions to solve the most important problems. This division of the needs or solutions enables others to identify more easily the mental design process which the designer performs. Watkins (1988) described the process by which solutions are developed and selected as ideation and idea selections. She described ideation as "the work designers do", and idea selection as the "creative part of the design process" ( p. 13). This step takes place within the mind of the designer. By describing and dividing the problem into smaller components, solutions can be selected or thought of more easily.

The solutions to the problems are then combined to be used to form garment designs. This may be called implementation (Mullet, 1984; Watkins, 1988) or prototype development (Orlando,1979). Researchers have relied on intuitive or creative integration of the collected data. In the process used by Orlando (1979) this is the step where she creatively integrated the solutions. Mullet (1984) also integrated possible solutions to the identified problems and then eliminated possible garment designs based on intuitive reasoning as to which designs were acceptable. Watkins said that the "facts must be put together in a creative way that involves feeling the right choices and combinations" (p. 13). Effective idea selection involves the successful integration of cognitive ideas based on facts, data and logic, and intuitive responses which are those that are subjective and sensory. Ashdown (1989), Laine (1987), McCormick (1986), Mullet (1984), and Vass (1989) studied garment designs developed from identified problems. Solutions to the clothing problems were developed through creative integration of what the researcher believed would satisfy the user's need. The only testing which is provided for in the implementation step is for the materials or fabrics used.

The final step in the design processes used by Mullet (1984), Orlando (1979) and Watkins (1988) was evaluation. Though numerous researchers have evaluated the effectiveness of specific apparel designs, these designs were not developed by them (Fourt & Hollies, 1969; Huck, 1988; Lawson, 1985; Lopez, 1985; Murray, 1982). Their evaluations were based on the assumption that the apparel designs satisfied the needs of the users; the original user need was not identified for the research. Orlando, Mullet and Watkins each emphasized that the evaluation should be done against the original identified needs or problems of the user. To do this, the methods used in step one to collect data concerning the needs or problem would then be used to evaluate the design. The ultimate goal was to reduce or eliminate the original problem (Mullet, 1984).

The purpose of describing an apparel design process is so others may use the procedure. Detailed design processes are available for apparel designers to follow. In the steps used, they have not eliminated the need for intuitive reasoning of solutions to particular apparel needs or problems.

The less a designer must rely on the intuitive responses of an individual the more objective the design will become. To eliminate or reduce the need for intuitive solutions to a clothing problem, is to provide information or data for others to use. Since freedom of body movement is necessary in many clothing designs, data which contribute to selecting apparel components based on body movements are useful.

## Apparel Designs Based on Body Movement

In an apparel design process, it is often necessary to develop a design which allows for freedom of motion. Factors which must be considered are the fit, the type of fabric to be used, and the activities for which the garment will be used.

### Garment Fit As Affected By Movement

Fit is a term used in apparel design to describe how a garment sets on the body. Correct fit is evaluated by giving attention to line (an art element), balance (an art principle) and fabric ease (a fitting principle) (Liechty, Pottberg & Rasband, 1986).

Ease is the garment fitting principle that allows for body movement. Ease is provided by incorporating additional length and width measurements in a garment that are beyond the basic body dimensions. Two types of ease that may be introduced into a basic pattern are designer ease and wearing ease. Designer ease is fullness added to a garment to change the style or silhouette. It is added for aesthetic purposes and may or may not enhance body movements. Designer ease is added to the basic sleeve and bodice patterns to form different structures such as the kimono or the raglan sleeves. The amount of designer ease needed in any pattern is not standardized, and is left to the discretion of the pattern designer (Farmer & Gotwals, 1982).

Wearing ease is the fullness needed for comfort and freedom of movement, permitting the garment to accommodate such natural body movements as breathing and swinging the arms (Liechty et al., 1986). It often involves minimal dimensional additions, since a garment that is too large will be annoying and limit comfort (The New Vogue Sewing Book, 1984). The precise amount of wearing ease in a garment is not standardized; authors may recommend varying amounts. Regardless of the design, one should be able to move without strain or restriction, and the garment should resume its natural position after movement without the need for adjustment (The Vogue Sewing Book of Fitting, 1972).

Heisey, Brown and Johnson (1988) attempted to provide a theoretical framework for modelling the fitting process of a garment to the body. They were interested in using quantitative three dimensional data to develop a properly shaped pattern. From their theoretical framework, mathematical models were developed using the physical process of draping with the use of mapping and projection procedures. The model was used to produce three dimensional data needed to make the garment's pattern. They stated that the "functional relationship between the body and patterns has been almost entirely ignored" (p. 2).

Heisey et al.(1988) made a distinction between what they refer to as " structural fit" and "functional fit". Structural fit was their primary concern. To achieve structural fit a pattern must be developed to accommodate the dimensions and contours of the stationary body. Functional fit data, classified as a fourth dimension, would be collected over a period of time while the body is in motion or in different positions. The researchers identified functional fit data as important, but addressed only structural fit in their study.

The anatomical position has been the standard body position for which clothing is normally fitted. Since the body does not remain in this position, several researchers have experimented with fitting the garment while the body is in a static active position. Ashdown (1989) fitted garments to simulated body positions of asbestos abatement workers, and Garner (1982) fitted a jacket design to a man while he sat in a bicycling position. Because these garments were fitted to a static active position, the fit of the garment while in the anatomical position may not have been correct. Watkins (1984) states that when performance of the garment is critical to the livelihood or safety of the person, the appearance in the anatomical position may simply have to be accepted. By knowing the exact amount of ease needed for a specific activity, a designer has a greater chance of planning successful design features.

## Fabric Stretch As Affected By Movement

Fabrics which stretch or expand with the body are used in apparel to allow for freedom of movement. " A fabric's ability to stretch is determined by its fiber content, yarn texturing and fabrication structure" (Ziegert & Keil, 1988, p. 54). In a woven fabric there is generally less stretch than in a knitted fabric. A plain weave fabric is the simplest construction form of woven fabric and is considered the most stable.

A woven fabric is not thought to extend in either the warp or weft direction unless a stretch fiber or yarn is used. However, when force is applied along the direction of the yarn the fabric can extend as much as a single yarn will allow. In most woven fabrics, the yarn structure ensures that a piece of fabric cut to the shape of a garment will "give" enough to be comfortable (Miller, 1984).

The greatest amount of stretch in a woven fabric is along the true bias. True bias is a direction of 45 degrees to the warp or weft yarns. If tension is applied along this angle, the force is no longer along one yarn but a shearing action can take place between the yarns. Whenever there is tension along any diagonal in relation to the warp and weft yarns, there is a slipping action which can take place, but the greatest stretch is when the force is along the true bias.

Research has been conducted to determine the structural mechanics of fibers and yarns in fabric, but only in one or two dimensions. Heisey and Halley (1988) said that obstacles in developing a method of fitting fabric to a three dimensional object have been the inability to specify unambiguously the three dimensional objects, and the computational intensity of modeling the physical mechanism of fabric conformation.

One approach to providing for body movement has been to use a stretch fabric. To determine the amount of fabric stretch needed in a garment, Kirk and Ibrahim (1966) measured the elongation and contraction of the skin at specific body areas. They maintained that comfort is achieved by reducing garment constraint on the body through increased fabric stretch. By measuring how much the skin stretched in certain areas of the body, such as over the knee cap and the elbows, these data could be used in identifying how much stretch was needed in a garment's fabric. Following the conceptual equation: Body Skin Strain

= Garment Fit + Garment Slip + Fabric Stretch, stretch garments were made based on the body skin strain. The researchers found that, given the same garment style, subjects preferred garments made with a high stretch fabric.

The purpose of Kirk and Ibrahim's (1966) study was to identify fabric stretch properties which are necessary for body movement. The other variables of the Body Skin Strain equation, Garment Fit and Garment Slip, were held constant. They stated: "Garment Fit and Slip are affected by the ratio of garment size to body size, and by the nature of the garment design" (p. 40).

The garment design affects the fit of the garment and therefore the movement which can be performed. Kirk and Ibrahim (1966) were interested in determining the amount of fabric stretch in a garment that was the most comfortable to the wearer. However, not all garments can be made from stretch fabric. Other fabric properties, such as being waterproof or bullet-proof, may be needed or be more desirable for the garment design.

Ziegert and Keil (1988) also investigated the relationship between garment fit and fabric stretch. These researchers were interested in a system that adjusted a flat pattern for woven fabrics into a modified pattern for use with any stretch fabric. A process of fabric testing was developed and the results were used to modify a flat pattern. As in the Kirk and Ibrahim study, the variable of interest was the fabric used in the garment, not the garment's structure.

When a major function of a garment is to allow for freedom of movement, both ease and fabric stretch are important. However, the garment's structure is an important factor in determining the comfort and fit of the final design.

## Movement As A Basis For Garment Design

The study of body movement related to garment design has focused on three areas. One area has been the impedance of body movement based on the type of clothing worn. A premise of much of the research has been that clothing should be studied as a whole system, with the body in motion (Brown, 1954; "Effects of Layers", 1977; Huck, 1988; Teitlebaum & Goldman, 1972). The research has dealt with mechanical impedance of the body based on the clothing a subject wore.

Brown (1954) was concerned with the effects of clothing on the use of the arm and shoulder. She assumed that garments placed undue strain on the body in motion, and concluded from her study that the range of motion and the push endurance of the arm and shoulder were affected by clothing. The garment used was a wool fleece-lined jacket and no consideration was given to the fit of the jacket on the individual subjects.

Huck (1988) illustrated the application of the Leighton Flexometer for the measurement of restriction to body movement caused by wearing protective clothing and equipment. The Leighton Flexometer is a gravity goniometer and was used because of its ease in application and reliability in determining the range of motion. From this study it was determined that there were significant differences in restriction to body movement between protective clothing designs. The differences were explained as a function of the type and layers of materials used since the structures of the garments were very similar.

In a study on the effects of clothing on motor performance, researchers found that,

> The flexibility tasks involving movement of the arms and shoulder in either the frontal or sagittal plane of the body... resulted in a worsening of the performance as layers were added to the torso. [The upper arm abduction task] involves an upward pull on the upper and lower torso clothing. Performance levels would seem to be affected by the ease with which the clothing moves upward as the arms are abducted. Upper arm forward extension was affected by the number of clothing layers. Restrictions imposed by the clothing in the arm-shoulder area would be more critical during upper arm abduction than during upper arm forward extension. ("Effects of Layers", 1977, pp. 57-58)

Teitlebaum and Goldman (1972) compared the metabolic "costs" of two groups of subjects walking on a treadmill.

One group wore multiple layers of clothing while the other group wore a weighted belt which provided the same additional weight as the clothing. The conclusion was that the group wearing the layers of clothing expended more energy because of the frictional drag between the multiple clothing layers and/or an interference with body joint movements caused by bulky clothing.

These studies showed that clothing as a whole could impede body movement (Brown, 1954; "Effects of Layers", 1977; Huck, 1988; Teitlebaum & Goldman, 1972). Recommendations given in these studies were based on the number of clothing layers or types of fabrics used. No recommendations were given as to how a garment's structure could be changed or evaluated.

A second area of study has been to investigate changes which occur in a garment when various movements are performed by the subject. Studies have been done that started with a garment structure, and then modified the structure as the body assumed various body positions.

Atkins (1980) used a human-scale articulating plastic mannequin dressed in a close fitting basic garment with the armscye seam attached only at the shoulder to act as a pivot point. Gaps around the armscye were measured as shoulder flexion, hyperextension and abduction were performed. In this study,

> The underarm gap which occurred with shoulder abduction was relatively symmetrical. The underarm gaps which occurred with shoulder flexion and hyperextension were much more asymmetrical, with the posterior portion of the gap being wider for shoulder flexion and the anterior portion being wider for hyperextension. Linear measurements were made of the gap shapes which occurred. Those for shoulder flexion, hyperextension and abduction were made at the underarm seam of the sleeve/side seam of the bodice. (Atkins, 1980, p. 142)

She noted that a problem with her research was that inaccurate results were obtained from the mannequin when compared to tests made with humans. Additional studies were recommended, using human subjects to determine the effects of changes in body position on garments.

In a similar procedure, Ashdown (1989) tried to develop protective coveralls for asbestos abatement crews. She slashed the coveralls and recorded the gaps that occurred when the workers moved. The gaps then provided information as to where additional ease was needed in the garment. However,the additional ease was added to various garment structures because no data were found which could eliminate a garment structure based on its possible limited range of motion.

Researchers in a third area of study have dealt with analyzing the body movement and then recommending a garment design based on those movements. Researchers in this area have tended to base their design recommendations on the preconceived notion of which garment structures would be suitable for the movement performed (Hoffman, 1979; Kernaleguen, 1980; Mullet, 1984; McCormick, 1986; Renbourn, 1972; Slocum & Shern, 1986).

Texts that address the clothing needs of the physically handicapped make reference to the types of garment structures that do not restrict shoulder motion (Hoffman, 1979; Kernaleguen, 1980; Renbourn, 1972). No evidence has been found to support these texts. The raglan and kimono sleeves and sleeves with inserted gussets or action pleats are mentioned as structures that allow for ease of movement (Hoffman, 1979; Kernaleguen, 1980; Renbourn, 1972). These authors do not explain how or what movements can be performed in the structures. No explanation is given as to why other sleeve/bodice structures are not as well suited for ease in movement.

Researchers often make assumptions concerning the body mobility in sleeve/bodice structures based on personal experience. Research conducted by Mullet (1984) involved analyzing the body movements of kayakers for the design of paddling jackets. Movements were analyzed without garments being worn, and recommendations for the sleeve/bodice structures were based on the researcher's design knowledge. Action pleats, gussets and raglan sleeve structures were recommended for freedom of movement. It was stated that the evaluation of the structures would require a wear-test to determine the effectiveness of each garment.

McCormick (1986) analyzed the body movements of cheerleaders to determine which garment designs would be appropriate for the selected activity. The range of motion was the determinant of the garment designs selected. No explanation other than to accommodate movement was given for why the action sleeve (drop shoulder), as opposed to other sleeve designs, was selected for the warm-up jacket design.

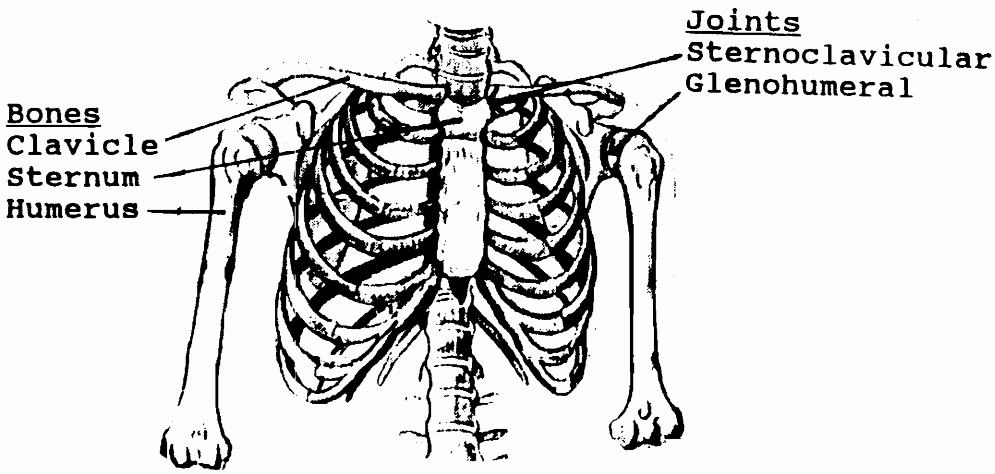
In the development of protective clothing for lawn specialists, Slocum and Shern (1986) were primarily concerned with prevention of dermal absorption of chemicals. They analyzed the movement performed by lawn specialists to determine where and how chemicals were deposited on the body. Specific sleeve types and action pleats were selected to be used in prototype designs. It was not clear how these design features were determined to be the most suitable for the movements analyzed. Evaluation of the designs could not be done until a final wear-test was conducted.

Clothing design researchers have used body movement or position to investigate the fit of the garment, to recommend the type of fabric to be used in the garment, and to make recommendations as to overall garment design. Further understanding of how body movement could be a basis for garment designs, and how the body performs various movements are of importance. The area of the body with the greatest range of movement, for which a wide variety of garment structures can be produced to cover the area is the shoulder complex.

## The Shoulder Complex

The shoulder complex is composed of four joints and the related bones, muscles and ligaments that form this area of the human body. The four joints of the shoulder complex are the glenohumeral, the acromioclavicular, the sternoclavicular and the scapulothoracic (Figure 1). At these joints one finds the articular surfaces of the humerus, the clavicle, the scapula and the sternum (Figure 1). Within this complex, the shapes of the articulating surfaces, the ligaments, and the joint capsules are critical anatomical structures which determine the freedom of movement that can occur between the various surfaces (Schenkman & Rugo De Cartaya, 1987). The movements within the shoulder complex may be described as taking place in one of the three planes of motion: the sagittal plane, the frontal plane and the transverse plane (Figure 2). Flexion/extension are the movements which take place in the sagittal plane; abduction/adduction in the frontal plane;

Anterior View




Posterior View

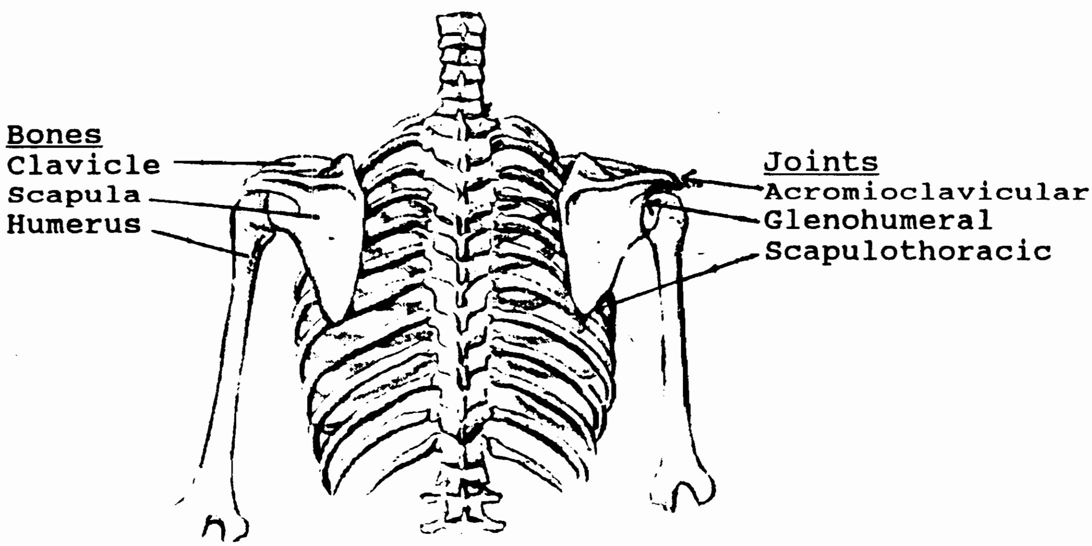



Figure 1

Bones and Joints of the Shoulder Complex

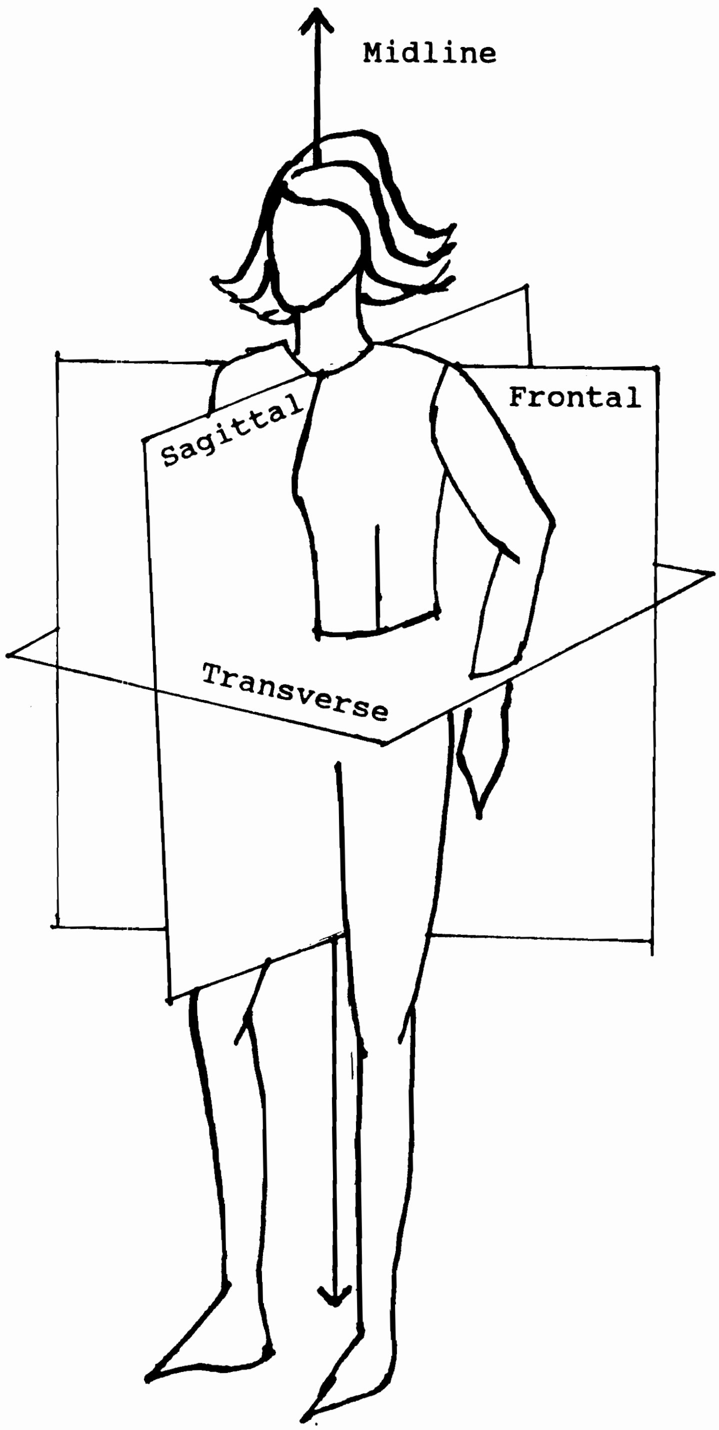



Figure 2

Planes of Motion

and horizontal abduction/adduction in the transverse plane. For this study, each joint and the movements performed by each joint will be discussed, then the movements in each plane of motion.

The glenohumeral joint is the articulation of the humerus and the scapula. This joint allows for movements of flexion/extension, abduction/adduction, and medial/lateral rotation of the humerus. For flexion, the humerus is moved forward through the sagittal plane from 0 degrees in the anatomical position to 180 degrees in the overhead position. Extension occurs when the humerus is moved in the sagittal plane, from the side of the body backward to approximately 45 degrees. Abduction/adduction are movements similar to flexion/extension, but occur in the frontal plane of motion (Figure 2). Abduction is the movement of the humerus away from the midline of the body, increasing the angle between the humerus and the body. Lifting the arm directly to the side of the body in the frontal plane of motion is abduction. Adduction is the lowering the arm toward the body. Lateral and medial rotations are the rolling of the humerus due to its positioning in the glenoid fossa of the scapula. The humerus rolls toward the body in medial rotation and away from the body in lateral rotation. The extent of humeral rotation varies with the degree of elevation in abduction or flexion (Kendall, Kendall & Wadsworth, 1971).

At the lateral end of the clavicle is the acromioclavicular joint which is a gliding joint, similar to the sternoclavicular. At the acromioclavicular joint, the acromion of the scapula is connected to the clavicle. This joint has limited motion and its primary function is to maintain the relationship between the clavicle and scapula (Norkin & Levangie, 1983). The movements are a gliding motion of the clavicle on the acromion and the rotation of the scapula forward and backward upon the clavicle (Gray 1948). When the arm is elevated, this joint allows the scapula to rotate or slide side to side. Movements through this joint are done with movements of other joints of the shoulder complex.

The sternoclavicular joint is the linkage between the sternal end of the clavicle and the manubrium of the sternum (Figure 1). This joint is the only point of articulation of the shoulder with the trunk, and therefore is the center from which all movements of the shoulder complex originate (Gray, 1948). The sternoclavicular joint contributes to the elevation/depression, protraction/retraction and rotation of the shoulder complex. These movements are defined as the up or down movement of the clavicle in elevation/depression; the forward and backward movement in protraction/retraction and the circular movement in rotation. In each of these movements, the clavicle rolls or revolves on the articular surface of the sternum. The range of motion of the clavicle averages 45 degrees of elevation and 15 degrees depression, about 15 degrees in both protraction and retraction, and 30 degrees of rotation (Norkin & Levangie, 1983).

The scapulothoracic joint is not a true anatomical joint, but rather the connection of the scapula over the ribs. Because of the connection of the scapula to the clavicle through the acromioclavicle or sternoclavicular joints, any movement of these joints results in movement of the scapula (Norkin & Levangie, 1983). Movements of the scapulothoracic joint are elevation/depression, abduction/adduction and upward/downward rotation. The elevation/depression is the movement up or down of the scapula. The abduction/adduction is the sliding of the scapula toward or away from the spine. Rotation of the scapula results in movement of the inferior angle of the scapula toward or away from the spine in an arc. The ultimate function of the scapulothoracic joint is to maintain scapular stability when the other joints move and to provide greater range of motion at each joint (Norkin & Levangie, 1983).

The joints of the shoulder complex work together in a coordinated manner so the arm may be moved smoothly through the planes of motion. There is conflicting information as to the exact angle at which each joint of the shoulder complex contributes to the movement of the arm. Table 2 summarizes the contributions of the various shoulder complex joints when the arm assumes different positions, as reported by Norkin and Levangie (1983).

In the sagittal plane of motion, the first 30 degrees of flexion take place at the glenohumeral joint (Sarrafian, 1983). No other area of the shoulder moves. After the initial 30 degrees, the acromioclavicular and the sternoclavicular joints enable the scapula to elevate and slide about the scapulothoracic joint. The scapulothoracic joint is not a true joint, but is the riding of the anterior surface of the scapula on the rib cage (Peat, 1986). This joint allows the scapula to slide and rotate. After 60 degrees of flexion, the ratio between the scapula upward rotation and the humerus extension is relatively constant; for every ten degrees of glenohumeral joint motion there are five degrees of scapula upward rotation (Hart & Carmichael, 1985).

When the humerus is positioned backward from the midline of the body to -30 degrees, the arm is said to be hyperextended. Due to the anatomical features of the glenohumeral joint, the humerus is prevented from traveling further toward the back than approximately -50 degrees. In

Table 2

Shoulder Complex Joints Used for Arm Movement

| Plane of Motion | Range of Motion | Joints |
|---|---|---|
| Sagittal | | |
| | 180° to 90° | G-H, A-C, S-C, S-T |
| | 90° to 60° | G-H, A-C, S-T |
| | 60° to 30° | G-H, A-C |
| | 30° to 0° | G-H |
| | 0° to -30° | G-H, S-T |
| Frontal | | |
| | 180° to 90° | G-H, A-C, S-C, S-T |
| | 90° to 60° | G-H, A-C, S-T |
| | 60° to 30° | G-H, A-C |
| | 30° to 0° | G-H |
| Transverse | | |
| | 130° to 90° | G-H, A-C, S-T |
| | 90° to 45° | G-H, A-C, S-T |
| | 45° to 0° | G-H, A-C, S-T |
| | 0° to -45° | G-H, A-C, S-T |

G-H Glenohumeral joint: movement of humerus and scapula
A-C Acromioclavicular joint: movement of scapula and clavicle
S-C Sternoclavicular joint: movement of clavicle
S-T Scapulothoracic joint: movement of the scapula

Norkin, C.C. & Levangie, P.K. (1983). Joint structure and function: A comprehensive analysis. Philadelphia: F.A. Davis Co.

this movement, the scapula is rotated toward the spine through the scapulothoracic joint.

Different joints are involved when the arm assumes the different angles of abduction in the frontal plane (Table 2). The first 30 degrees are the result of the glenohumeral joint (Peat, 1986). From this position to full arm abduction, movement occurs at the scapulothoracic and glenohumeral joints (Peat, 1986). The scapula movements are due to the movement about the sternoclavicular and acromioclavicular joints. These movements of the joints are the same as those for flexion/extension (Sarrafian, 1983).

Movements in the transverse plane of motion occur at a uniform level perpendicular to the body's midline. Shoulder horizonal abduction and adduction are movements in opposite directions from the body's midline. For horizontal abduction/adduction, the neutral or zero degree position is when the arm is flexed to 90 degrees in the sagittal plane. The limits in the range of motion performed are determined by the body. The arm is not able to traverse beyond the trunk of the body in adduction, and the limits of the muscles' stretch prevent the arm from traveling further than 130 degrees in abduction. The majority of the movements are performed by the glenohumeral joint. Hart and Carmichael (1985) reported that, at 90 degrees of humeral elevation, scapular rotation and clavicular elevation occur, but are variable depending on the forces acting on the arm.

Though information is available to describe the movement of the joints when the arm assumes various positions, form fitting clothing must take into account the body's dimensional changes that occur due to the joints, muscles and skin movements. Emanuel and Barter (1957) studied the linear distance changes that occurred between two points marked on either side of a joint when the joint assumed various positions. They determined that there were definite and significant changes in the body dimensions with the joint movement, and that the amount of change is fairly constant regardless of stature or weight of the person. No explanation was given as to which shoulder component, the joint, muscles or skin, contributed to the dimensional changes.

The results of the study by Emanuel and Barter (1957) are reported in Table 3. The linear distance changes are the differences between the measurements taken in the neutral or anatomical position and the series of joint movements performed. The movements were listed as protrusion, retraction, horizontal abduction and overhead abduction. Protrusion was the flexion of the arm to 90 degrees in the sagittal plane of motion. Retraction was hyperextension backward of the arm in the sagittal plane to

Table 3

Linear Distance Changes Over the Shoulder Area
(Means Reported in Inches).

| | Horizontal Abduction | Hyperextension | Flexion | Abduction Overhead |
|---|---|---|---|---|
| Anterior Surface | | | | |
| Suprasternale to Acromion | — | -.87 | — | -.48 |
| Sternum to Armscye | -1.13 | 1.09 | .97 | |
| Armscye to Mid-Arm line | — | -.33 | .72 | .58 |
| Lateral Surface | | | | |
| Acromion to Mid-Arm line | -1.25 | -.96 | -1.46 | -2.25 |
| Posterior Surface | | | | |
| Cervicale to Acromion | -.21 | -1.01 | -1.94 | -3.44 |
| Vertebra to Armscye | 3.66 | — | .79 | 2.27 |
| Armscye to Mid-Arm line | 1.88 | — | .61 | 1.81 |

Emanuel, I. & Barter, J. T. (1957). Linear distance changes over body joints. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, WADC-TR-56-364.

the maximum position. Horizontal abduction was the abduction of the arm to 90 degrees in the frontal plane of motion. Overhead abduction was abduction of the arm in the frontal plane of motion such that the arm was held as close to the head as possible. From their study, it was determined that the greatest change in linear distance occurred across the back when the arm was horizontally abducted.

Though researchers have studied the shoulder area and the movements which are possible by the arm, the body has been studied without clothing. The design of clothing has traditionally been with the body in the anatomical position with the legs and arms straight, palms of the hand facing the body. To date, there are no standard methods or dimensions for relating body movement or position data to the design of clothing.

## Sleeve/Bodice Structures

Sleeve/bodice structures are defined as the patterns or garments which are made for the upper torso and arms of the body. Four basic sleeve/bodice structures which are described and used in apparel are the set-in, kimono, kimono with gusset, and raglan sleeves. The basic style of each of these sleeve/bodice structures are illustrated in Figure 3.

## Pattern Development

Of the three methods of pattern making, drafting, draping and flat pattern, the most widely taught are draping and flat pattern. Each method relies on the skill of the pattern maker for the success of the design. Flat pattern techniques may be the desired method of design when speed and accuracy are needed (McDonald and Weibel, 1988).

Many flat pattern textbooks explain the development of various sleeve/bodice structures. Armstrong (1987), Hollen and Kundel (1987), Kopp, Rolfo, and Zelin (1978), and MacDonald and Weibel (1988) are among the most current pattern making texts, and they represent a variety of flat pattern techniques.

For flat pattern techniques a basic pattern, called a sloper, is used to develop other sleeve/bodice structures. The sloper for the upper torso of the body consists of three pieces, the set-in sleeve and the front and back bodice patterns. These pattern pieces have no seam allowances. With a designated shape and ease allowance, the sloper can be developed by draping or drafting techniques. These techniques require additional pattern making skills and

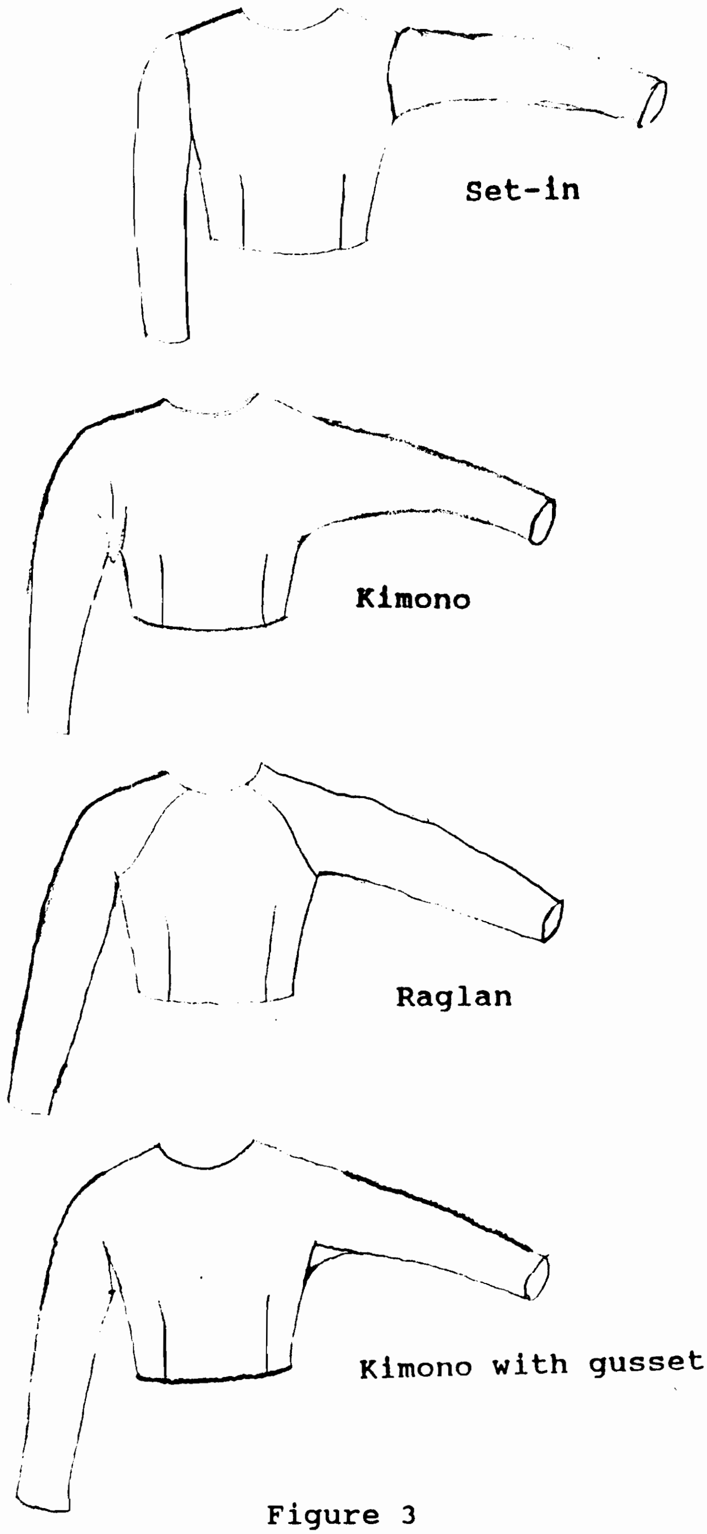



Figure 3

Four Basic Sleeve/Bodice Structures

manipulations. In flat pattern texts, the sloper is often supplied to the reader in half-scale form and the full-scale development is not explained. To save time, commercial pattern companies provide patterns for the basic sloper.

## Set-in Sleeve

From the sloper a set-in sleeve/bodice structure can be easily developed by the addition of seam allowances. The bodice front has one bust fitting dart originating from the waistline. The bodice back has one shoulder area dart which radiates to the shoulder blade from either the neckline or shoulder seam, and another dart which originates from the waist. Two darts are found in the back bodice since there is no defined point for which fullness is needed. Seamlines and openings are located at anatomical junctions of the body; the neckline is at the base of the neck, the shoulder seam is on the ridge of the shoulder, and the armhole seamline is at the junction between the torso and arm. The sleeve is a cylinder that covers the arm and sets into the armhole or armscye seam. In order for both the center front and center back of the basic bodice to be cut on the lengthwise grain of the fabric, a side seam is positioned under the arm.

Kimono sleeve

The kimono sleeve differs from the set-in sleeve in that the armscye seam is eliminated. The bodice and sleeve for both the front and back are cut as one piece. These pieces are connected with a seam which extends from the neckline across the shoulder to the wrist and with a side seam which curves from the waist under the arm to the wrist. Armscye wrinkles are inherent in this design due to the extra fabric incorporated into the garment during pattern development.

Different techniques are found for developing the kimono sleeve. Hollen and Kundel (1987) start by cutting the sleeve pattern in half from the shoulder to the wrist. Each sleeve half is then laid on the bodice, overlapping the shoulder points 1/2 inch and forming a straight line from the neckline to the wrist. The underarm seamline is made by rounding off the bodice side seam to meet the seamline of the sleeve. The authors state that the largest underarm angle gives the most reaching room. Problems encountered with this text are that when the directions are followed the underarm seams are usually not the same length and must be adjusted, and the curves drawn at the underarm and shoulder area are left to the designer's interpretation.

Kopp, Rolfo and Zelin (1978) develop the kimono sleeve by the abutment the front and back shoulder seams on a guideline. Then the entire sleeve pattern is placed such that the underarm points of the sleeve touch the side seam/armscye points of the bodices. The problem with this procedure is that the front and back bodices are not the same shape, and the sleeve may or may not touch the bodice patterns. To avoid twists and pulls across the back and to balance the overall lengths of the two sides of the underarm seam, the side seam of the back may be adjusted by increasing the pickup of the back dart. Other corrections which may or may not have to be done to this pattern are: adjustments to the overarm seamline, if it is not on grain; adjustment of the center back when the back dart is changed; blending of the neckline if the back shoulder seam is longer than the front; and adjusting the amount of curvature drawn at the underarm-side seam intersection.

The kimono sleeve patterns developed by MacDonald and Weibel (1987) and by Armstrong (1987) can be produced consistently because adjustments are made to the bodice pattern before the sleeve pattern is attached. Care is taken to describe how the sleeve is attached and how the underarm curve is drawn. MacDonald and Weibel (1987) recommend an overlap at the shoulder point of the sleeve and bodice; and Armstrong (1987) has a 1/4-inch gap at the shoulder point. It would seem that if the sleeve is to fit the arm while it is in an anatomical position, the additional length is needed for the sleeve to curve over the glenohumeral joint.

Raglan Sleeve

The raglan sleeve is characterized by the close fit of the underarm and the diagonal seamline which is sewn from the underarm to the neckline. Kopp et al. (1978) state that the raglan sleeve has the fit characteristics of the set-in sleeve. The shoulder area of the bodice is attached to the sleeve pattern. A shoulder dart is inserted to provide fit at the neck and fullness for the shoulder. The dart remains as a triangular wedge if the sleeve is one pattern piece, or the dart is incorporated into an overarm seamline if the sleeve is made with separate front and back sleeve patterns.

The pattern making methods for the raglan sleeve vary. Hollen and Kundel (1987) use their kimono sleeve pattern and an "armscye device", a wedge shaped piece, which is illustrated in the authors' instructions. The kimono sleeve is pivoted downward toward the bodice side seam to reduce the underarm angle, and the "device" is placed at the underarm intersection. The "device" has three sizes: small, medium and large. No instructions are given as to which size should be used.

MacDonald and Weibel(1988) develop the raglan sleeve from their kimono sleeve with gusset pattern. The raglan seamline is drawn from the underarm to neckline, and that the sleeve is then removed. From the bodice pattern the underarm is extended upward two inches and a new raglan underarm is formed. This procedure converts the bodice underarm to the same position as the set-in sleeve's basic bodice.

The raglan sleeve patterns developed by Kopp et al. (1978) and Armstrong (1987) begin with the basic bodices and sleeve patterns. The procedure is to attach the bodices' shoulder areas to the sleeve at the armscye break points. Armstrong (1987) prepares the bodices by moving the back shoulder dart to the armscye, and adjusts the front and back armscyes so they are the same length. The sleeve is adjusted so an inch of additional ease is added to the underarm seam to provide for arm lift. One-fourth inch is added at the shoulder point of the sleeve so it will fall smoothly over the shoulder. Kopp et al. (1978) add no additional ease to their pattern.

Kimono Sleeve with Gusset

The wrinkles caused by the excess armscye fabric in a basic kimono sleeve can be reduced by making the angle of the underarm smaller and inserting a gusset (MacDonald &

Weibel, 1988). This is a diamond shaped piece of fabric inserted into slits at the underarm area of the sleeve. The gusset allows for closer fit to the body without loss of movement (MacDonald & Weibel, 1988).

In the methods for developing the kimono sleeve with gusset pattern the kimono sleeve pattern may be used (Hollen & Kundel, 1987; Kopp et al., 1978; MacDonald & Weibel, 1988). The problems encountered with the kimono sleeve instructions may then be repeated in the development of the kimono sleeve with gusset. To obtain the kimono sleeve with gusset pattern, the kimono sleeve pattern is slashed from the underarm/side seam intersection to the shoulder point. The sleeve is rotated downward so that the overlap at the underarm is at least one inch. The gusset placement lines are then drawn from the new underarm point 3 1/2-inches toward the neckline/shoulder intersection. Problems with the gusset occur when the stitching lines of the slit are drawn on the pattern. The stitching lines in the bodice must be of the same length, since the gusset pattern has four sides which are equal in length. In each of the texts listed, the stitching lines are not equal length when the directions are followed.

Armstrong (1987) develops the kimono sleeve with gusset from the basic bodices and sleeve patterns. By starting with the basic patterns, additional ease is incorporated in the overarm seam because the sleeve is not overlapped as much as the directions in other texts suggest. The slit for the gusset is drawn on the underarm seam so that the stitching lines are of equal length.

## Structural Differences

No information was found which recommends a particular pattern text for the development of sleeve/bodice structures. The structural differences which occur between different sleeve/bodice structures are due to the instructions given for the development of the patterns. From the instructions given in Armstrong's (1987) text the structural differences between the basic sloper and the specific sleeve/bodice structure can be reviewed from the text. The measurements recorded for the four different sleeve/bodice structures are presented in Table 4. Each sleeve/bodice pattern was developed from the basic sloper.

The set-in sleeve is the basic sloper pattern with seam allowances added so construction of the garment is possible. The basic pattern pieces used are illustrated in Figure 4.

The development of the kimono sleeve from the basic bodice involves the movement of the back shoulder dart to the back bodice armhole, and part of the bust dart to the

Table 4

Seamline Measurements of Sleeve/Bodice Structures

(Inches)

| Sleeve/Bodice Structures | Underarm Seam | Side Seam | Total |
|---|---|---|---|
| Set In | 15.63 | 7.87 | 23.50 |
| Kimono | 17.00 | 6.12 | 23.12 |
| Raglan | 17.12 | 7.87 | 24.99 |
| Gusset | 17.38 | 8.25 | 25.63 |

Measurements from Misses Size 12

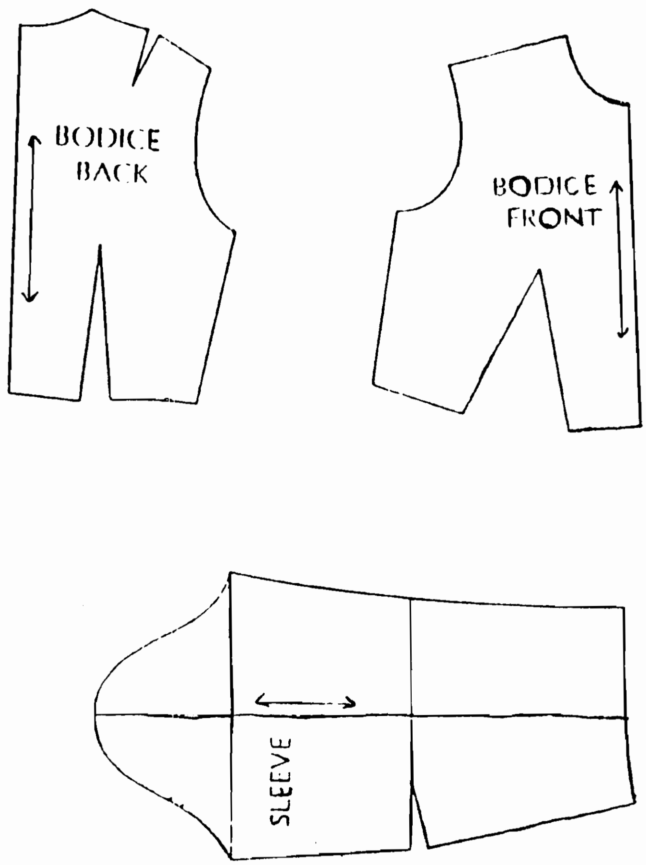



Figure 4

Set-In Sleeve Pattern

Armstrong, H.J. (1987). Patternmaking for fashion design. New York: Harper and Row.

front bodice armhole (Armstrong, 1987). This pattern change provides extra fullness to the shoulder/armscye area of the kimono sleeve, as compared to the set-in sleeve. When the sleeve is combined with the front and back bodices, the armscye seam of the set-in sleeve is eliminated in the kimono sleeve pattern. This combination adds additional ease in the armscye area, and requires the sleeve to have the same grainline position as the bodices. Figure 5 illustrates the position of the bodices and sleeve pattern for the kimono sleeve pattern.

The seamlines in the kimono sleeve change due to the development of the pattern. When the sleeve is set with the bodices, 1/4-inch is added to the top of the set-in sleeve, thus adding the same amount to the total overarm length of the kimono sleeve (Armstrong, 1987). To form the underarm seam of the kimono sleeve, the basic bodice's side seams are shortened by one inch (Armstrong, 1987). The sleeve underarm seam is changed to meet the new lowered side seam position and curved to form the traditional underarm seam of the kimono sleeve (Figure 5). The length of the side seam of the kimono sleeve is therefore shorter than the set-in sleeve, and the underarm seam is longer. The kimono sleeve measurements described in comparison to the set-in sleeve are indicated in Table 4.

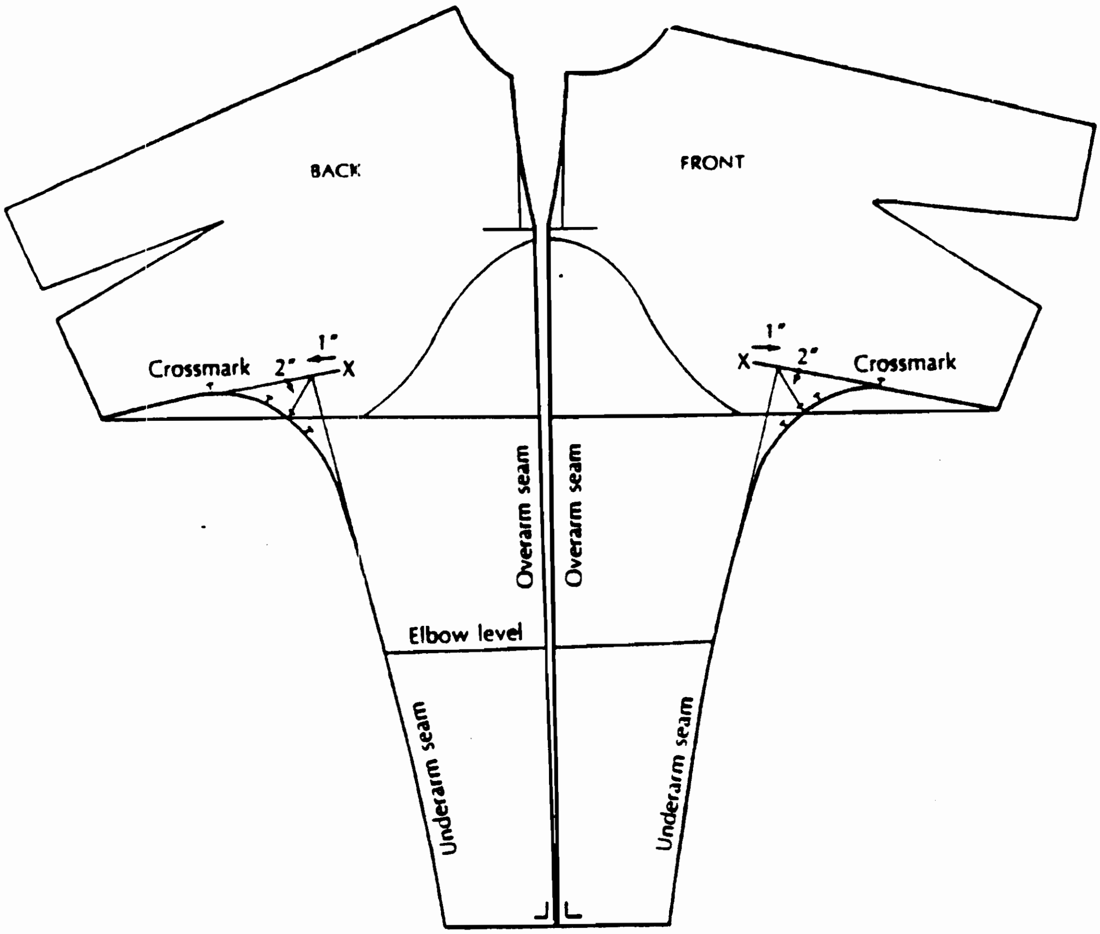



Figure 5

Kimono Sleeve Pattern

Armstrong, H.J. (1987). Patternmaking for fashion design. New York: Harper and Row.

In the kimono sleeve with gusset, Armstrong (1987) begins the pattern development by adding 1/4-inch to the cap of the sleeve and subtracting 1 1/2-inches from the underarm seam of the sleeve. The sleeve is divided into front and back sections. The bodices are then altered by subtracting 2 1/2-inches from the side seams (Armstrong, 1987). The front bodice is manipulated to allow 1/2-inch of the bust dart to become fullness in the armhole area (Armstrong, 1987). The placement of the sleeve patterns to the bodice is illustrated in Figure 6.

When the sleeve and bodices are combined, the grainline positions for the finished pattern pieces are placed parallel to the center front or center back of the bodice. In Figure 6, the sleeve has been placed so that the angle formed by the sleeve and side seam is less than the angle of the kimono sleeve. In order for the arm to be moved to different positions, a gusset is made to fit the slit made at the underarm/side seam intersection. The gusset is made to replace the length removed from the underarm seam and side seam. Based on mathematical calculation the dimensions of the gusset are 3 1/2-inches on each side with a center length of 5.74 inches (Armstrong, 1987). When the gusset is sewn into the slit of the underarm, the underarm seam length becomes 17 inches and the side seam length 8.25 inches (Armstrong, 1987).

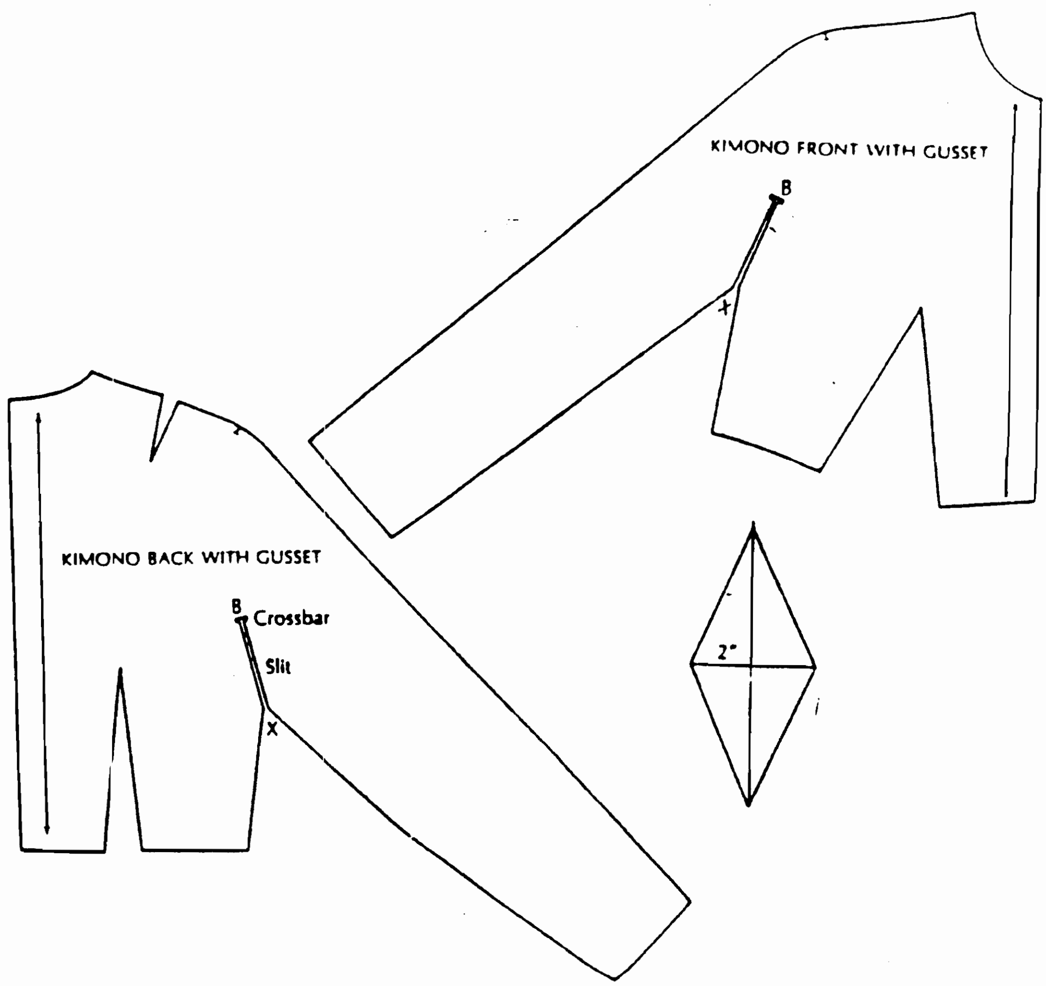



Figure 6

Kimono Sleeve with Gusset Pattern

Armstrong, H.J. (1987). Patternmaking for fashion design. New York: Harper and Row.

For the raglan sleeve, the development of the pattern is similar to that of the kimono sleeve, in that the shoulder dart is moved to the back armhole and 1/2-inch of the bust dart is added to the front armhole (Armstrong, 1987). To develop the raglan sleeve, part of the bodice is removed and added to the sleeve, thus establishing the traditional neckline-to-underarm seamline. Since part of the bodice is attached to the sleeve, the bodice patterns are reduced in size. The bodice area which is attached to the sleeve changes its grainline position. The grainline is changed from parallel to the center front or back to parallel to the shoulder seam at the bicep (Figure 7).

To develop the raglan sleeve pattern, additional fullness is added to the underarm seam and cap area by slashing the pattern and pivoting the underarm/armscye position up one inch (Armstrong, 1987). The shoulder area of each bodice is then attached to the sleeve (Figure 7). In the development of the raglan sleeve the side seams of the bodices are not changed and are therefore the same length as the basic bodice of the set-in sleeve. The underarm seam is increased by at least one inch, and the overarm seam by 1/4 inch (Armstrong, 1987). The final lengths of the seams are reported in Table 4.

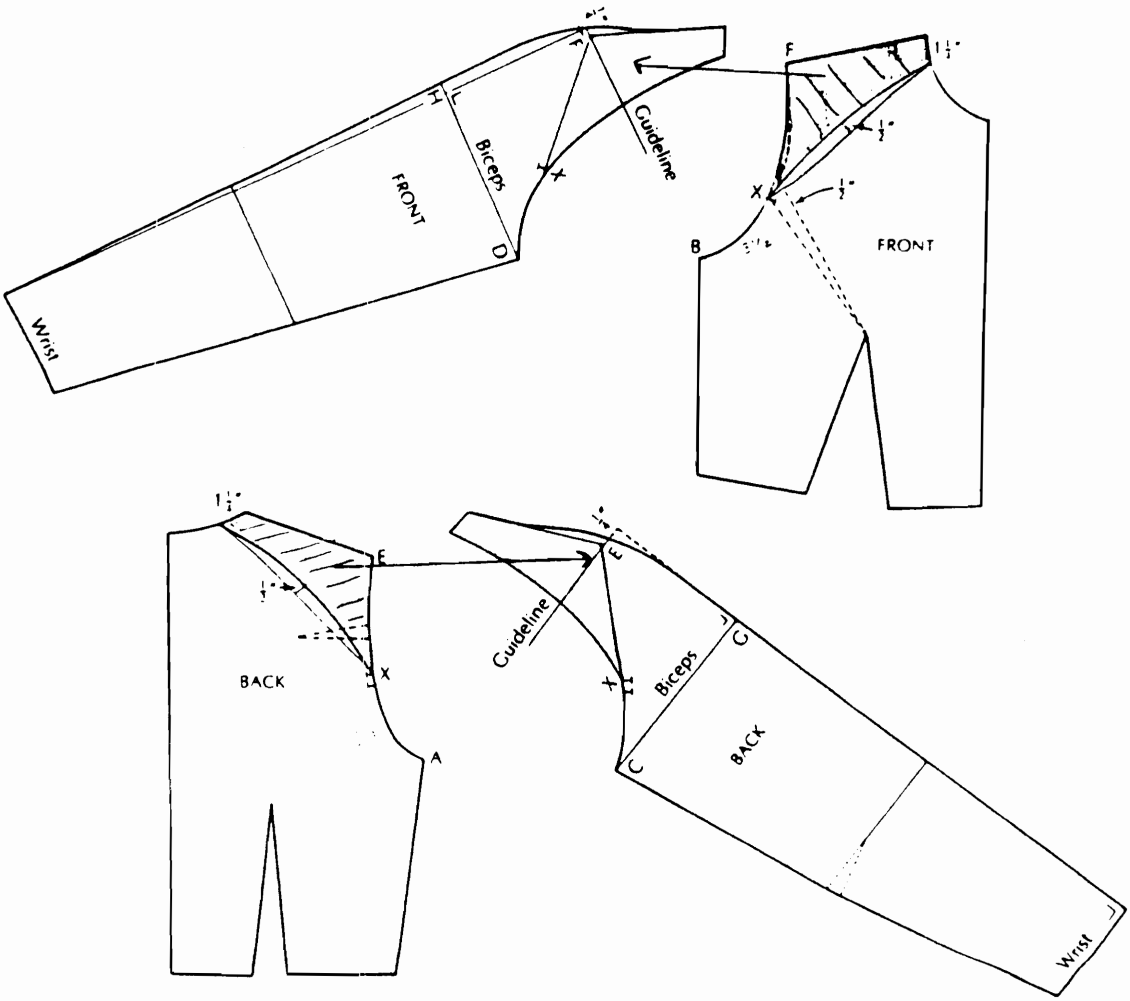



**Figure 7**

Raglan Sleeve Pattern

Armstrong, H.J. (1987). Patternmaking for fashion design. New York: Harper and Row.

## Summary

This review of literature established the fact that researchers have attempted to provide apparel design processes from which clothing can be developed for specific user needs. Through a series of steps, a designer may begin by identifying a user's clothing needs and progress to a final garment design. In the steps that are followed in the process, there are gaps which the designer must bridge by "creative integration". This is what the designer intuitively believes will satisfy the need. The less a designer must rely on the intuitive responses of an individual the more objective the design will become.

When designing functional clothing, freedom of body movement is often an identified need which the designer must satisfy. Data which contribute to selecting apparel components based on body movements are useful. Research which has been conducted to correlate body movements or positions to garment structures has concentrated on one body position, the fabric used, or the change in the structure of the garment. No literature was found that described or supported the use of one type of garment structure over another for particular body positions.

To develop garment structures, flat pattern methods are the most commonly used. Though various texts have been published which describe how basic sleeve/bodice structures are developed, Armstrong's (1987) text was the most precise. From this text, the structural differences between sleeve/bodice structures could be reviewed from the literature.

Information is available about the range of motion and the biomechanical structure of the shoulder area of the body. Information concerning the development of garment structures or patterns is also available. Information relating the two was not found in the literature.

Therefore this research was developed to determine possible relationships between different sleeve/bodice structures and the structures' behavior when the shoulder complex assumes different positions.

# CHAPTER III

# STATEMENT OF PROBLEM

In an apparel design process, a researcher may systematically follow steps which lead to a final design. In this process, data or information are provided to eliminate or reduce the need for intuitive solutions to a clothing problem. Since freedom of body movement may be a need which clothing must address, data which contribute to selecting apparel components based on body movements are useful.

A review of the literature indicated that the emphasis has been to change the garment structure to solve specific movement problems. These changes have been based on such data as garment fit (Ashdown, 1990) and fabric stretch (Kirk & Ibrahim, 1966), or on the researcher's "creative integration" of garment structures or components (McCormick, 1986; Mullet, 1984). A thorough understanding of a garment's structure and its relationship to body movements is lacking.

Though clothing covers the body, the fabric and garment structure can not duplicate the elastic quality of the body articulations. For clothing design, researchers either select the anatomical or a different body position on which to base structural garment dimensions. Changes in body position are often thought to be of lesser importance and thus not considered for a garment's design. When the body moves, the bones, muscles, joints and skin reconfigure. A garment which covers the body can not duplicate the same actions as the body. The garment's reaction to body movement is to slip, wrinkle, stretch, or restrict the wearer.

When different garment structures have different physical dimensions, each may be affected differently when the body changes position. In different garment designs the structural dimensions may not be the same even when the garment is made to fit the same body position. There needs to be some means to predict the effect on the structure of different body positions. This information will enable researchers to select or eliminate possible garment structures based on body movements before a prototype is made and a wear-test conducted.

## Purpose

The purpose of this research was to investigate the effect of different shoulder positions on different sleeve/bodice structures. Since sleeves may have numerous variations and design details incorporated into the structure, only four basic structures were investigated. These were the set-in sleeve, the kimono sleeve, the raglan sleeve, and the kimono sleeve with gusset. The measurement used to determine the reaction of the structures to different shoulder positions was garment slippage. Garment slippage is defined as the movement, or displacement of a garment away from a set anatomical body position. For this study, slippage was measured by the linear distance displacement at the wrist, waist and center back/waistline location measured in inches. To study the relationship between the garment slippage of the center back of the garment and its waistline the change in the angle at the center back/waistline was studied.

## Theoretical Framework

The shoulder complex of the body is composed of specific anatomical components, such as bones and muscles. In the shoulder complex, the scapula, clavicle and humerus bones are interdependently linked by the sternoclavicular, the acromioclavicular, the glenohumeral, and the scapulothoracic joints. The muscle tissue surrounding these linkages makes movements of the arm possible.

A sleeve/bodice structure is made of different components, the fabric and the structural dimensions of the garment's style, which react to body movements. The reaction of the sleeve/bodice structure is not the same as the body's when the arm is moved.

When the arm assumes various positions, the shoulder area of the body reconfigures. This reconfiguration is due to the movement at or around a joint. As the joint moves, the bones change position, the skin stretches or is compressed, and the muscles stretch or contract. During extreme arm movements the skin is capable of extending or compressing as much as three inches across the shoulder area (Emanuel & Barter, 1957). Unless made of a stretch fabric, a garment itself is not capable of stretching or compressing to such an extent. A garment's reaction to body changes is to slip, wrinkle or change position.

For small movements of the arm, the skin stretch has not been measured, but information concerning the movement of the joints is available. Movements of the arm less than or equal to 30 degrees of flexion/extension or adduction/abduction take place exclusively at the glenohumeral joint (Norkin & Levangie, 1983). Such movements are a rotation of the humerus in the glenoid fossa of the scapula. No other joints of the shoulder move.

A garment which is fitted to the anatomical position should allow for some movement of the arm. Any garment slippage with arm movements of 30 degrees or less would occur at the wrist only. Due to the movement of the glenohumeral joint, the small angular changes of the shoulder complex would result in small amounts of garment slippage. Based on the measurements of the sleeve/bodice structure in Table 4, the set-in sleeve would show the greatest amount of slippage during these movements, because it has the shortest underarm length. The other sleeve/bodice structures have underarm lengths similar to each other ($\pm$ .38 inch), and significant differences may not be discernable.

For arm movements greater than 30 degrees, different joints contribute to the movements. From 30 degrees to 90 degrees of extension or abduction, the acromioclavicular joint joins the glenohumeral joint to allow the arm to be raised (Norkin & Levangie, 1983). For these movements a garment would be expected to slip at the wrist because the sleeve can not rotate in the shoulder area of the garment. The sleeve has a set length which has been fitted for the arm hanging straight at the side of the body. Slippage at the waist area of the garment would also be expected because the acromioclavicular and scapulothoracic joints allow the shoulder area to elevate. The elevation of the shoulder coupled with the sleeve's insufficient length and inability to rotate to accommodate the elevation, would cause varying amounts of garment slippage at the waist. In different sleeve/bodice structures the underarm lengths vary and the position of the fabric grain differs. these differences were discussed in the review of literature with respect to Table 4 and Figures 4, 5, 6 and 7.

When the arm is flexed or abducted more than 90 degrees, all four shoulder complex joints contribute to the movements. The glenohumeral, sternoclavicular, acromioclavicular and scapulothoracic joints make these movements possible (Norkin & Levangie, 1983). The movement of the garment should exhibit slippage at the waist and wrist. Because of the structural differences the sleeves should show varying amounts of slippage. The differences in slippage would be due to the total side seam and underarm sleeve lengths and to the additional ease in the shoulder area of the garment. The sleeve/bodice structure with the greatest total underarm length was the kimono sleeve with gusset, the shortest was the set-in sleeve. Therefore, when the arm is extended to its full overhead position the gusset sleeve should show the least garment slippage and the set-in sleeve the most.

Based on the movements performed by the shoulder area and the known pattern measurements of the sleeve/bodice structures, the amount of slippage for each sleeve/bodice structure should be predictable. The sleeve/bodice structures which have the longest structural lengths would exhibit the least slippage when the arm is moved. In the development of the kimono sleeve and kimono sleeve with gusset patterns additional ease is added to the shoulder area (Armstrong, 1987). Due to this additional ease, movements such as horizontal abduction would result in less slippage in the kimono sleeve and kimono sleeve with gusset when compared to the more fitted bodices of the raglan or set-in sleeves.

From the review of the literature it was determined that for different arm movements the shoulder area uses different joints and muscles. For the same body position the reconfiguration of the shoulder area is consistent. The four sleeve/bodice structures studied have been developed from the same set-in sleeve pattern (Armstrong, 1987). Differences between the patterns are due to pattern development. Therefore when the body moves, the garments made from the developed patterns should reconfigure differently due to the structural differences between the sleeve/bodice structures.

## Research Hypotheses

The purpose of this study was to determine the effects of shoulder position on different sleeve/bodice structures, the set-in sleeve, kimono sleeve, raglan sleeve and kimono sleeve with gusset. The variable used to determine the effects of shoulder position was garment slippage, measured by the garment displacement at the wrist, waist, and center back/waistline location, and the angle at the center back of the garment.

The research hypotheses were stated to test if there were significant differences in the garment slippage or change in center back angle for all sleeve/bodice structures and all shoulder positions. If the null hypotheses were rejected additional post hoc analyses were performed to determine the specific differences which occurred.

## Garment Slippage at Wrist and Waist

Research Hypothesis I: There will be a difference in the amount of garment slippage at the wrist among all shoulder positions due to differences between the four sleeve/bodice structures.

Research Hypothesis II: There will be a difference in the amount of garment slippage at the waist among all shoulder positions due to differences between the four sleeve/bodice structures.

Rationale: The movement of the arm results in the use of the different shoulder joints as different arm angles are assumed (Table 2). The amount of wrist and waist slippage for each of the four sleeve/bodice structures should vary because of the physical structural differences between these structures. There should be significant differences between the amount of slippage at the various shoulder positions. The smaller the arm position angle, the smaller the amount of slippage which should occur.

## Garment Slippage at Center Back

Research Hypothesis III: There will be a difference in the amount of garment slippage at the center back/waistline location among selected shoulder positions due to differences between the four sleeve/bodice structures.

Research Hypothesis IV: There will be a difference in the angle at the center back/waistline location among selected shoulder positions due to differences between the four sleeve/bodice structures.

Rationale: The angle and center back/waistline location should provide additional information as to the structural differences may have between the sleeves. For the four different sleeve/bodice structures the amount of ease and position of the fabric grain line are different. Therefore, significant differences in garment slippage should occur for the sleeve/bodice structures at the various shoulder positions.

## Limitations

The theoretical framework developed for this study suggests that different sleeve/bodice structures slip differently on the body, and data which help explain these slippage differences may enable designers to make more appropriate clothing design choices. As exploratory research, this study has limitations.

Some limitations of this study involve the development of the sleeve/bodice structures from Armstrong's (1987) Patternmaking for Fashion Design text . The structures developed were limited to those for which instructions were given, and the style variations used in the text were assumed to be the most appropriate.

The method used to record the data provided other limitations to this study. Since this was an exploratory study, a test procedure with established validity was not available. The use of a digitizer for the collection of the data was assumed to provide accurate readings.

## Assumptions

The following assumptions are the foundation on which this research was based.

1. Each sleeve/bodice structure examined allowed for normal freedom of movement by a subject when standard guidelines for evaluating fit were me

2. Garment slippage is a measurable variable which varies among sleeve/bodice structures.

# CHAPTER IV

# PROCEDURE

The procedure section is divided into topic areas based on the variables used in this research. The areas discussed are the development of the four sleeve/bodice structures, the selection of the subjects, and the shoulder positions assumed by the subjects while wearing the structures, and measurement of the garment slippage and center back angle. The procedure for analyzing the collected data concludes this chapter.

## Sleeve/Bodice Structures

Sleeves and bodices can be constructed in many different styles and silhouettes. Fashion dictates the popular sleeve structure at any given time. A sleeve can be classified as either a set-in sleeve, where the sleeve is cut separately and stitched into an armhole of the bodice; or as a sleeve/bodice combination where the sleeve is combined with all or part of the bodice. Several basic sleeve structures are explained or developed in almost all patternmaking texts. This study used the text written by Armstrong (1987).

Garments can be developed through various methods of design, with flat pattern techniques, where patterns are developed from a basic sloper, being the most precise (MacDonald and Weibel, 1988). This method was used to make the patterns for the sleeves investigated in this study.

The basic bodice and sleeve slopers can be developed by the following three methods: draping, drafting or from previously made patterns. A pilot test was conducted to determine the best method of sloper development for this study. The criterion used was the fit of the basic bodice and sleeve sloper. Draping was not considered as a viable method due to the time and difficulty factors. Drafting measurements were taken of one subject's body, and patterns for a basic front bodice, back bodice and sleeve slopers were drafted. From the drafted slopers a bodice with set-in sleeves was made. A commercial pattern of the basic bodice and sleeve was altered for the body measurements of the same subject and another garment constructed. When the two garments were evaluated using the guidelines described in most fitting texts. A more accurate fit was obtained from alterations of the commercial pattern than from the pattern made by drafting techniques. This discrepancy may be due to the researcher's lack of drafting practice as opposed to fitting and alteration skills.

The basic sloper used to produce the sleeve structures used in this study was made from the commercial sewing pattern, Butterick 3415. The size of the commercial pattern purchased was based on the comparison of a subject's personal body measurements with the pattern's measurements. The wearing ease provided in the sloper was: 1/4-inch to center front length, 1/4-inch to shoulder tip width, 2 inches to bust circumference, 3/4-inch to waist circumference, 1 1/2-inches to biceps circumference and 1-inch to wrist circumference. For consistency and repeatability, one reference book was used in developing four sleeve/bodice structures from the sloper. The researcher has found through personal experience and review of the literature that the techniques described by Armstrong (1987), in Patternmaking for Fashion Design, are more precise than other texts which allow for designer's freedom of interpretation.

The four basic sleeve/bodice structures used in this study were:

1. Set-in
2. Kimono
3. Raglan
4. Kimono with gusset.

These sleeve/bodice structures and pattern pieces are pictured in Figures 3, 4, 5, 6 and 7 in Chapter II.

Since the purpose of this research was to understand the sleeve/bodice structures, fabric variables which may contribute to a sleeve's function were controlled by using one plain weave fabric. A one-inch gingham check fabric was used because the grain was easily recognized and the stretch of the fabric was minimal. A total bodice with the right and left sleeves was produced to provide balance and ease in wearing for the subject. To reduce bulk and to facilitate dressing, a 22-inch dress zipper was applied to the center front seam, with the excess zipper length extending below the waist. Construction characteristics for each structure were seam allowances of 5/8-inch, and plain seam construction with a stitch length of 12 stitches per inch.

One garment of each of the four sleeve/bodice structures was developed for each of the four subjects, for a total of 16 garments. The fit of each garment was evaluated using the guidelines described in most fitting texts: the lengthwise grain is straight and perpendicular to the floor at the center front, center back and sleeve; the crosswise grain is straight and parallel to the floor at bustline, back and bicep; the bodice and sleeve are free from diagonal or horizontal distortion; and ease is adequate to permit breathing and prevent gaps and strain in the fabric. If a garment did not satisfy a guideline, then the garment and pattern were corrected until a fit meeting all the guidelines was achieved. The assumption was made that a properly fitted garment allows for freedom of movement.

## Subjects

Since most patternmaking texts deal with design for women's clothing, female subjects with misses proportions were selected for this study. The body dimensions of the four subjects are listed in Table 5. The female subjects selected could have been of any misses size, since the range of movement of a person does not differ as the body dimensions change (Laubach, 1970). Each subject was measured with a goniometer to ensure that she was capable of assuming the desired shoulder positions.

## Shoulder Complex Positions

The shoulder complex positions selected for study are performed by most individuals in daily activities. The shoulder positions performed by the subjects in this study allowed the examination of the effect of the position on the sleeve/bodice structures; measurement of an individual's flexibility was not the issue. Therefore, the shoulder positions used in this study are considered to be within the

Table 5

Body Measurements of Female Subjects

(inches)

| | Subjects I | II | III | IV |
|---|---|---|---|---|
| Circumference | | | | |
| Bustline | 33 | 34 | 34.5 | 35 |
| Waistline | 25.5 | 27.5 | 25.5 | 25.5 |
| Length | | | | |
| Center Back | 16.2 | 15.7 | 15.2 | 17.5 |
| Arm[1] | 21.2 | 21 | 21.7 | 20.5 |

[1] acromion process to styloid process

standard ranges of movement for the shoulder complex (Daniels, Williams & Worthingham, 1946). The positions used were divided into three planes of motion and are illustrated in Figure 8.

## Data Collection

A pilot test was conducted to determine if more than one of the four sleeve/bodice structures per subject were needed, and what data could be obtained from photographs of a subject. For the first pretest, a raglan sleeve pattern was developed. Two garments were made using the same pattern and the gingham check fabric. One subject wore both garments and assumed selected shoulder positions. No difference was found between the measurements and observations taken for each garment. Therefore, one garment of each sleeve/bodice structure was constructed for each subject. Data based on the shoulder positions were taken for the right side of the body.

To facilitate the collection of data, 35mm slides were taken of each subject wearing each of the sleeve/bodice structures at each shoulder position. Three cameras, with 50mm lens, were positioned 12 feet from the subject at the front, the right side and the back of the body, which enabled simultaneous photographing of three views.

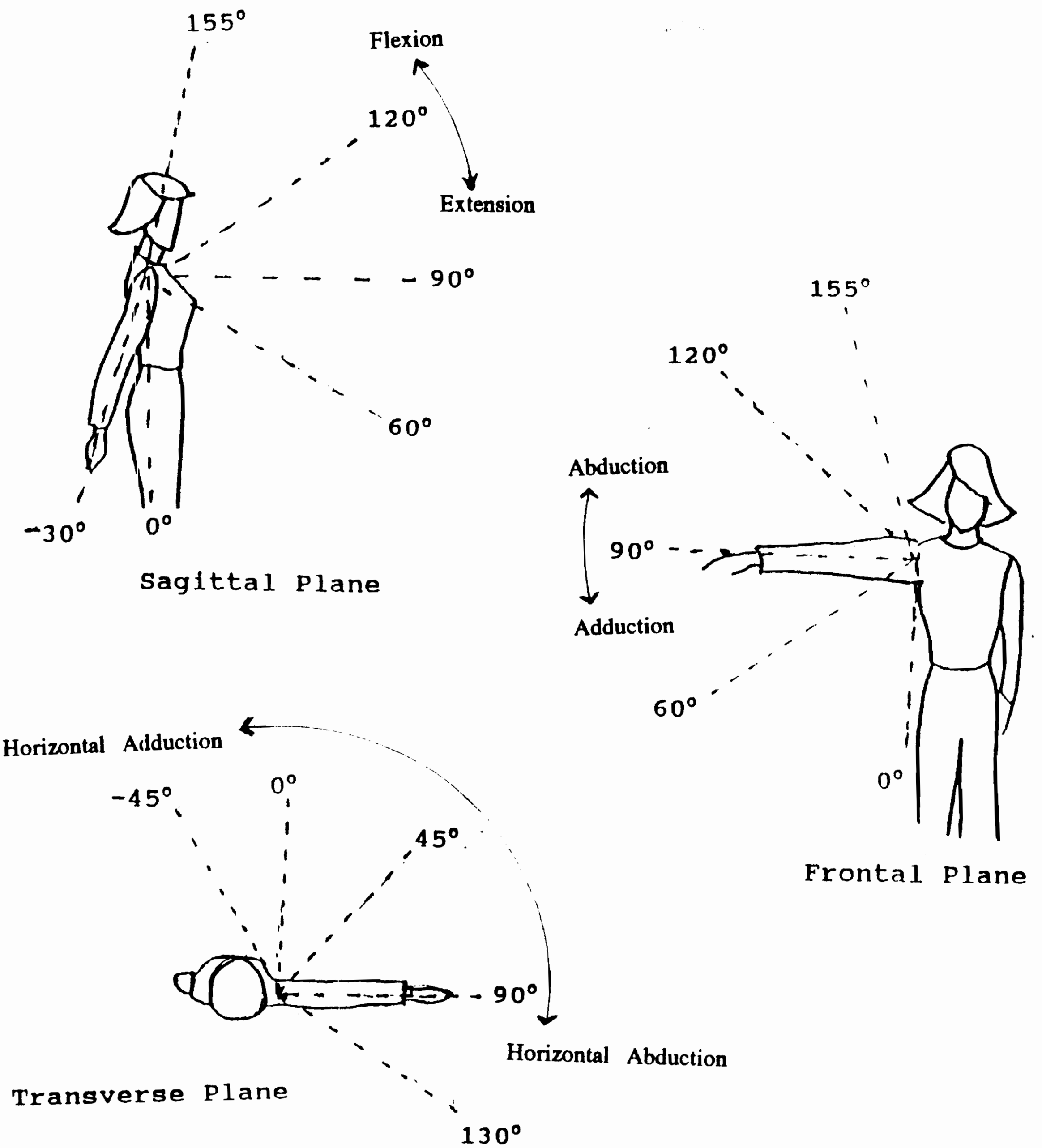



Figure 8

Arm Positions in Three Planes of Motion

A total of 144 pictures per subject was taken.

All slides were reviewed. It was impossible to measure the slippage at the waist and wrist in all three views of each position, because of the blockage by the body in various positions. One view for each subject, sleeve type and arm position was selected for measurement of wrist and waist slippage. The front view was selected for the shoulder positions in the frontal plane of motion and horizontal abduction in the range of -45 degrees and 45 degrees. The side view was selected for positions in the sagittal plane of motion and horizontal abduction to 130 degrees. The back view was selected for measurement of the center back/waistline location and angle.

The slippage data were collected using the Numonic Model 1224 electronic digitizer with connection to an IBM PC. The data from each slide were coded on the PC file before input from the digitizer. The code included slide identification number, sleeve type, subject identification, body view and shoulder position number. With the features of the digitizer, the scale was established so the reading for the slippage would be life-size. This was possible since it was known that the gingham check in the bodices was one inch square and the digitizer could be programmed to adjust the scale.

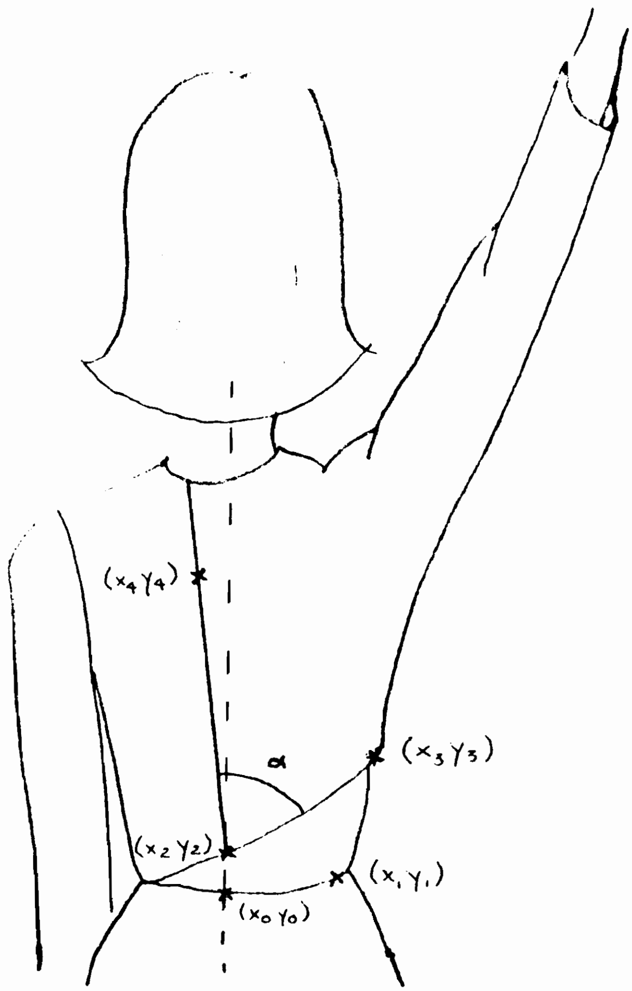
Garment slippage refers to the amount the garment moves from its original anatomical position. In this study, the slippage at wrist and waist of the garment was measured to the nearest tenth of an inch.

Each subject's right wrist was marked with a 1/4-inch wide line. This line circled the wrist on the hand side of the styloid process of the radius. The wrist edge of the sleeve was positioned parallel to this line when the arm was in the anatomical position. The subject's waist was identified with a 1/4-inch wide elastic band. The elastic band naturally fell to the waist and the band was traced with a 1/4-inch wide line. The garment's waistline was aligned with the drawn waistline while the body was in the anatomical position.

The Numonic digitizer has the capability to measure point to point lengths. To conduct point to point length measurements, the point of the waistline/side intersection on the body and the waistline/side seam intersection on the garment were selected and the length inputed into the data file in the PC. At the wrist, the slippage measurement was taken from the underarm/wrist point on the garment and the point closest to the garment on the wrist marking.

Two types of garment slippage were recorded at the center back of the garment. One type was recorded as a linear distance movement and the other as an angular change of the center back/waistline location. A computer program was written to calculate the linear movement and the angular garment slippage. The program was based on the x,y coordinates inputed into the program from the digitizer. Figure 8 illustrates the coordinates taken from a slide. Coordinates $x_0, y_0$ are the center back/waistline location; $x_1$, $y_1$ are the coordinates of the waistline/side location when the body is in the anatomical position. When the shoulder assumes a new position and the garment moves, $x_2$, $y_2$ is the new location of the center back/waistline point, $x_3$, $y_3$ the new waistline/side seam location, and $x_4$, $y_4$ a point on the center back line of the garment.

The equations used to compute the garment slippage at center back are given in Figure 9. The letter R shows a possible linear distanced measured for garment slippage at the center back, and $\alpha$ illustrates an angle which could be calculated from the coordinates. From the coordinates inputed from the digitizer the computer program calculated the slippage of the center back/waistline location in inches. The equation to calculate this movement was R= $(x_2 - x_0)^2 + (y_2 - y_0)^2$. The angle formed by the center back/waistline was first calculated with the garment in the anatomical position to obtain a reference angle. The anatomical position was not necessarily 90 degrees since the




Variables calculated from coordinates

$L_1 = (x_3 - x_2)$ $L_2 = (y_3 - y_2)$

$M_1 = (x_4 - x_2)$ $M_2 = (y_4 - y_2)$

Equation use to calculate angle at center back/waistline location:

$$\alpha = \text{Arctan} \left[ \frac{(L_1^2 + L_2^2) * (M_1^2 + M_2^2)}{(L_1 * M_1) + (L_2 * M_2)} + 1 \right]$$

Figure 9
Coordinates and Calculations for Slippage at Center Back

back of the body is not flat and the waistline curves as it goes toward the side of the body. When the arm position is changed the garment slips at the waist and the center back line may also shift, therefore the angle formed at the center back/waistline illustrates garment slippage as the movement of two legs of an angle. The equation used to calculate the center back/waistline angle is shown in Figure 8. An example of the data from the digitizer would be: $x_1,y_1$ = (2.10, .12); $x_2,y_2$ = (-.32, .40); $x_3,y_3$ = (2.24, 1.47); $x_4,y_4$ =(-1.11, 4.82). The variables calculated from these coordinates would be: $L_1$ = (2.56); $L_2$ = (1.07); $M_1$ = (-.79); $M_2$ = (4.42). Therefore, the equation used to calculate angle at center back/waistline location would be:

$$\text{Arctan}\left(\frac{(2.56^2 + 1.07^2) * (-.79^2 + 4.42^2)}{(2.56 * -.79) + (1.07 * 4.42)} + 1\right) = 77.45^0$$

## Null Hypotheses

Based on the research hypotheses which are stated in the previous chapter, the following null hypotheses were used for statistical analysis. The level of significance for all statistical analyses used was set at the .05 level.

Null Hypothesis I: There will be no differences in the amount of garment slippage at the wrist among shoulder positions due to the differences between the four sleeve/bodice structures.

Null Hypothesis II: There will be no differences in the amount of garment slippage at the waist among shoulder positions due to the differences between the four sleeve/bodice structures.

Null Hypothesis III: There will be no differences in the amount garment slippage at the center back/waistline location among selected shoulder positions due to the differences between the four sleeve/bodice structures.

Null Hypothesis IV: There will be no differences in the angle at the center back/waistline location among selected shoulder positions due to the differences between the four sleeve/bodice structures.

## Analysis of Data

Null hypotheses I and II were tested using the analysis of variance statistical procedure with a 4 X 4 X 12 factorial using a split plot design (Table 6). The factors contained in the analysis were the four subjects, the four sleeve/bodice structures, and twelve body positions. Body positions which occur in more than one plane of motion were not duplicated in the overall analysis. The statistical model used for the ANOVA was

Table 6

Analysis of Variance for Garment Slippage

| Source | df | Expected Mean Square |
|---|---|---|
| Subject | 3 | $\sigma_e^2 + 48\sigma_p^2$ |
| Position | 11 | $\sigma_e^2 + 4\sigma_{pm}^2 + 16\sum M_j^2/11$ |
| Subject*Position | 33 | $\sigma_e^2 + 4\sigma_{pm}^2$ |
| Sleeve | 3 | $\sigma_e^2 + 12\sigma_{ps}^2 + 48\sum S_k^2/3$ |
| Subject*Sleeve | 9 | $\sigma_e^2 + 12\sigma_{ps}^2$ |
| Position*Sleeve | 33 | $\sigma_e^2 + 4\sum\sum (SM)_{jk}^2/33$ |
| Residual | 99 | $\sigma_e^2$ |
| Total | 191 | |

$$y_{ijkl} = \mu + P_i + M_j + (PM)_{ij} + S_k + (PS)_{ik} + (MS)_{jk} + e_{ijkl}$$

where $y_{ijkl}$ is garment slippage

$\mu$ is population mean

$P_i$ is the random effect of ith subject, i=1...4

$M_j$ is the effect of jth shoulder position, j=1...12

$(PM)_{ij}$ is the interaction of ith subject and jth shoulder position

$S_k$ is the fixed effect of kth sleeve/bodice structure k= 1...4

$(PS)_{ik}$ is the interaction of ith subject and kth sleeve/bodice structure

$(MS)_{jk}$ is the interaction of jth shoulder position and kth sleeve/bodice structure

$e_{ijkl}$ is the residual.

The amounts of garment slippage recorded at the wrist and waist were the dependent variables. The subjects in this study were used to provide repeated measures. This variable was controlled in the analysis so more than one measurement per sleeve and position could be used in the analysis. Variation due to individual subjects was removed from the other treatment effects, such as position and sleeve interaction. The analysis was consequently a split plot design, with the interactions with subjects used to test the main effects of position, sleeve and the interaction of position and sleeve.

The same statistical analyses were used to test null hypotheses III and IV. The dependent variables were the amount of garment slippage at the center back/waistline location and the change in the center back/ waistline angle. Because not every body position could be measured at the center back there were only eight body positions used. The ANOVA was then a 4 X 4 X 8 factorial analysis. The dependent variables were garment slippage from the center back/waistline location and the change in the center back/waistline angle.

If the null hypotheses were rejected, post hoc statistical analyses were used to determine the relationship between the sleeve/bodice structures and the shoulder positions. A Tukey pairwise test of least square means was used to determine differences between the sleeve/bodice structures for specific shoulder positions.

A regression analysis was used to estimate the effect of changes in shoulder position on each of the dependent variables. The regression analyses were fit as linear, quadratic and their interactions with the sleeve/bodice structures. These were fit within subject to remove subject variation.

The statistical model for the regression was:

$$y_{ijk} = \mu + S_i + P_j + (SP)_{ij} + \beta_1 A_k + \beta_2 A_k^2 + \beta_3 (SA)_{ik} + \beta_4 (SA^2)_{ik} + e_{ijk}$$

where: $y_{ijk}$ is the amount of garment slippage for a specific sleeve/bodice structure i, subject j and shoulder position angle k

$\mu$ is the intercept

$S_i$ is sleeve/bodice structure, i= 1,2,3,4

$P_j$ is the subject, j= 1,2,3,4

$(SP)_{ij}$ is interaction of sleeve structure and subject

$A_k$ is the shoulder position angle, k= -45°...155°

$\beta_1$ is the linear regression of the dependent variable on shoulder position angle k

$\beta_2$ is the quadratic regression of the dependent variable on shoulder position angle k

$\beta_3$ is linear deviation for regression of the dependent variable on shoulder position angle k for sleeve structure i

$\beta_4$ is quadratic deviation for regression of the dependent variable on shoulder position angle k for sleeve structure i.

# CHAPTER V

## RESULTS AND CONCLUSIONS

From review of related literature it was determined that for different arm movements the shoulder complex uses different joints and muscles. For the same body position reconfiguration of the shoulder complex is consistent. The four sleeve/bodice structures studied were developed from the same set-in sleeve pattern. Differences between patterns for the four sleeve/bodice structures are due to pattern development. Therefore when the body moves, garments made from the developed patterns should reconfigure differently due to structural differences between sleeve/bodice structures.

Findings are presented to describe the effects of different shoulder positions and their relationship to different sleeve/bodice structures. Effects which are discussed are garment slippage at the wrist, waist and center back measured as a linear distance change in inches. The change in the center back/waistline angle was measured in degrees. The null hypotheses are presented and tested in each appropriate section of this chapter. The level of significance was set at the .05 level.

## Garment Slippage At Wrist

Null Hypothesis I: There will be no differences in the amount of garment slippage at the wrist among all shoulder positions due to the differences between the four sleeve/bodice structures. This was tested using the analysis of variance. There were significant differences at the .05 level for the shoulder position-by-sleeve interaction, therefore the null hypothesis was rejected (Table 7). This significant interaction would explain that the relative slippage at the wrist, as the shoulder position changed, varied from structure to structure.

The differences between the amount of slippage at the wrist for each sleeve/bodice structure across all shoulder positions and all subjects were not found significant. The mean square for the subject and sleeve interaction was used to test sleeve differences. The variation caused by differences between the subjects was removed by the use of subject in the statistical model.

The shoulder positions were significantly different. The mean square of the subject by position interaction was used to test the shoulder position variation. With the variation due to the subjects removed, differences in the amount of slippage at the wrist varied

Table 7

Analysis of Variance for Slippage at Wrist

| Source | df | Mean Squares | F value | PR > F |
|---|---|---|---|---|
| Subject | 3 | 1.6708 | 9.95 | .0001 |
| Position | 11 | 21.3258 | 56.53 | .0001 |
| Subj*Position | 33 | .3773 | 2.25 | .0011 |
| Sleeve | 3 | 1.3902 | 1.15 | .3807 |
| Subj*Sleeve | 9 | 1.2086 | 7.20 | .0001 |
| Position*Sleeve | 33 | 0.2711 | 1.62 | .0368 |
| Residual | 99 | 0.1673 | | |
| Total | 191 | | | |

PR > F = level of significance

for each shoulder position when all sleeve/bodice structures were analyzed together.

In the analysis of variance, the subject variable and its interactions with the sleeve and position variables were found significant. These significant differences would imply that there were different amounts of garment slippage at the wrist among the subjects across all positions and all sleeves. Certain subjects fit the various sleeve/bodice structures and the shoulder positions differently from other subjects. From this analysis it is apparent that the use of one subject when fitting sleeve/bodice structures may not be sufficient.

Further investigation was needed to determine the relationships between the sleeve/bodice structures and the shoulder positions. The shoulder positions were divided into three planes of motion. Some positions are reported in two planes of motion since the plane of motion is determined by various movements of the arm, not a single static position. The positions reported in two planes were 155 degrees in the sagittal and frontal planes; 90 degrees in the sagittal and 0 degrees in the transverse plane; and 90 degrees in the frontal and transverse planes.

The amounts of garment slippage at the wrist for the various positions are reported as means in Table 8. The bar graph in Figure 9 is a visual representation of the least square means of each sleeve/bodice structure for each position. A Tukey pairwise comparison was used to test the differences between the sleeve/bodice structures for specific shoulder positions. The analysis of each sleeve/bodice structure compared with each of the other structures by position is reported in Table 9.

From the Tukey pairwise comparison, it was determined that significant differences between the sleeve/bodice structures' slippage at the wrist occurred at two arm positions. These were adduction or flexion at 155 degrees and adduction to 120 degrees. The kimono sleeve exhibited significantly greater garment slippage at the wrist at 155 degrees when compared with each of the other sleeve/bodice structures. For an arm position at 120 degrees in the frontal plane of motion, the kimono sleeve's slippage at the wrist was significantly greater than that of the set-in and gusseted sleeves. This analysis would infer that the kimono sleeve would be the least appropriate for arm movements over 120 degrees in the frontal plane of motion if garment slippage at the wrist was a concern.

A regression analysis was used to determine the relationship between the four sleeve/bodice structures

Table 8

Amount of Slippage at Wrist

(Means are reported in Inches)

| | Sleeve/Bodice Structure | | | |
|---|---|---|---|---|
| Arm Position | Set-in | Kimono | Raglan | Gusset |
| Sagittal Plane | | | | |
| at $155^0$ | 3.70 | 4.68 | 3.54 | 3.84 |
| at $120^0$ | 2.54 | 3.07 | 2.41 | 2.61 |
| at $90^0$ | 2.08 | 2.42 | 1.76 | 2.15 |
| at $60^0$ | 1.44 | 1.19 | 1.01 | 1.19 |
| at $-30^0$ | 0.61 | 0.48 | 0.20 | 0.17 |
| Frontal Plane | | | | |
| at $155^0$ | 3.70 | 4.68 | 3.54 | 3.84 |
| at $120^0$ | 2.23 | 3.26 | 2.53 | 1.92 |
| at $90^0$ | 1.42 | 1.55 | 1.02 | 1.20 |
| at $60^0$ | 0.29 | 0.10 | 0.41 | 0.26 |
| Transverse Plane | | | | |
| at $-45^0$ | 2.10 | 2.38 | 1.84 | 1.90 |
| at $0^0$ | 2.08 | 2.42 | 1.76 | 2.15 |
| at $45^0$ | 1.50 | 2.03 | 1.47 | 1.37 |
| at $90^0$ | 1.42 | 1.55 | 1.02 | 1.20 |
| at $130^0$ | 1.10 | 0.88 | 0.72 | 1.08 |

Standard Error= 0.205

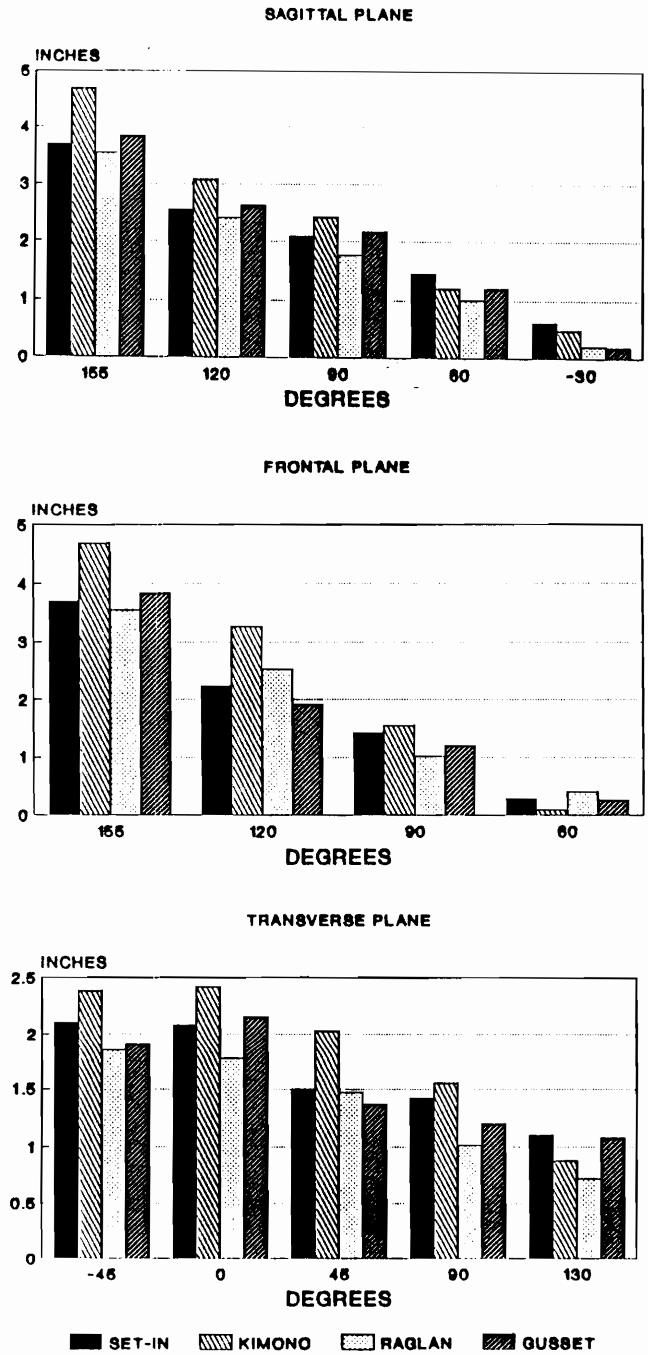



Figure 10
Bar Graph of Slippage at Wrist

Table 9

Comparison of Slippage at Wrist Between Sleeves
(Differences reported in Inches)

| | Sleeve/Bodice Structures | | | | | |
|---|---|---|---|---|---|---|
| | Set-in – Kimono | Set-in – Raglan | Set-in – Gusset | Kimono – Raglan | Kimono – Gusset | Raglan – Gusset |
| **Arm Position in Sagittal Plane** | | | | | | |
| at 155° | -.98* | .16 | -.14 | 1.14* | .84* | -.30 |
| at 120° | -.53 | .13 | -.07 | .66 | .46 | -.20 |
| at 90° | -.34 | .32 | -.07 | .66 | .27 | -.39 |
| at 60° | .25 | .43 | .25 | .18 | .00 | -.18 |
| at -30° | .13 | .41 | .44 | .28 | .31 | .03 |
| **Arm Position in Frontal Plane** | | | | | | |
| at 155° | -.98* | .16 | -.14 | 1.14* | .84* | -.30 |
| at 120° | -1.03* | -.30 | .31 | .73 | 1.34* | .61 |
| at 90° | -.13 | .40 | .22 | .53 | .35 | -.18 |
| at 60° | .19 | -.12 | .03 | -.31 | -.16 | .15 |
| **Arm Position in Transverse Plane** | | | | | | |
| at -45° | -.28 | .26 | .20 | .54 | .48 | -.06 |
| at 0° | -.34 | .32 | -.07 | .66 | .27 | -.39 |
| at 45° | -.53 | .03 | .13 | .56 | .66 | .10 |
| at 90° | -.13 | .40 | .22 | .53 | .35 | -.18 |
| at 130° | .22 | .38 | .02 | .16 | -.20 | -.36 |

* differs significantly ($p<.05$)

Tukey Critical Value = .74 at .05 level

at the different shoulder positions (Table 10). From the regression analysis the intercept, linear, and quadratic coefficients for the individual sleeve/bodice structures were calculated for the three planes of motion. The coefficients are reported in Table 11 and illustrated in Figure 10. From the illustrated lines in Figure 10, it can be seen that the lines for each of the sleeve/bodice structures are similar, illustrating that the position-by-sleeve interactions were not significant.

From this regression analysis the position$^2$ was found significant at the .05 level for the three planes of motion. This significance would imply that the quadratic variable for the regression equations was significantly different between the shoulder positions for an individual sleeve/bodice structure.

For the three planes of motion, regression equations were developed to describe the relationship between a specific sleeve/bodice structure and any shoulder position. It was assumed that the relationship between the amount of slippage and the shoulder position angle would be predictable. The position-by-sleeve and the position$^2$-by-sleeve interactions were not significant at the .05 level. The lines which were calculated for each of the sleeve/bodice structures were not significantly different from each other. Because the position$^2$-by-sleeve

Table 10
Significance of Regression for Slippage at Wrist

| Source | df | Mean Square | F value | Pr>F |
|---|---|---|---|---|
| Sagittal Plane | | | | |
| Subject | 3 | .8178 | 1.10 | .3551 |
| Sleeve | 3 | .1979 | .63 | .6142 |
| Sleeve*Subject | 9 | .3144 | .42 | .9189 |
| Position | 1 | 2.4263 | 3.26 | .0751 |
| Position*Sleeve | 3 | .0192 | .03 | .9943 |
| $Position^2$ | 1 | 5.9521 | 8.00 | .0061 |
| $Position^2$*Sleeve | 3 | .0466 | .06 | .9794 |
| Residual | 72 | .7439 | | |
| Total | 95 | | | |
| Frontal Plane | | | | |
| Subject | 3 | .9465 | 3.41 | .0235 |
| Sleeve | 3 | .0115 | .01 | .9974 |
| Sleeve*Subject | 9 | .7834 | 2.83 | .0082 |
| Position | 1 | .1703 | .61 | .4366 |
| Position*Sleeve | 3 | .0512 | .18 | .9064 |
| $Position^2$ | 1 | 19.6490 | 76.86 | .0001 |
| $Position^2$*Sleeve | 3 | .1789 | .65 | .5890 |
| Residual | 56 | .2773 | | |
| Total | 79 | | | |
| Transverse Plane | | | | |
| Subject | 3 | 1.0097 | 6.34 | .0009 |
| Sleeve | 3 | .8185 | .87 | .4938 |
| Sleeve*Subject | 9 | .9462 | 5.94 | .0001 |
| Position | 1 | 1.7685 | 11.10 | .0015 |
| Position*Sleeve | 3 | .0392 | .08 | .9695 |
| $Position^2$ | 1 | .6335 | 3.98 | .0510 |
| $Position^2$*Sleeve | 3 | .1052 | .66 | .5801 |
| Residual | 56 | .1593 | | |
| Total | 79 | | | |

Table 11

Regression Coefficients for Slippage at Wrist

| Sleeve Type | Intercept | Linear Slope | Quadratic Slope |
|---|---|---|---|
| Sagittal Plane ($R^2$ = .735) | | | |
| Set-in | .896 | .0058 | 7.48E-5 |
| Kimono | .743 | .0082 | 1.04E-4 |
| Raglan | .613 | .0061 | 7.89E-5 |
| Gusset | .739 | .0080 | 7.17E-5 |
| Frontal Plane ($R^2$ = .923) | | | |
| Set-in | - .046 | - .0003 | 1.60E-4 |
| Kimono | - .125 | - .0035 | 2.33E-4 |
| Raglan | - .044 | - .0006 | 1.59E-4 |
| Gusset | .001 | - .0069 | 2.02E-4 |
| Transverse Plane ($R^2$ = .769) | | | |
| Set-in | 1.92 | - .0055 | 6.24E-6 |
| Kimono | 2.36 | - .0036 | 6.01E-5 |
| Raglan | 1.71 | - .0046 | 2.55E-5 |
| Gusset | 1.84 | - .0048 | 2.06E-5 |

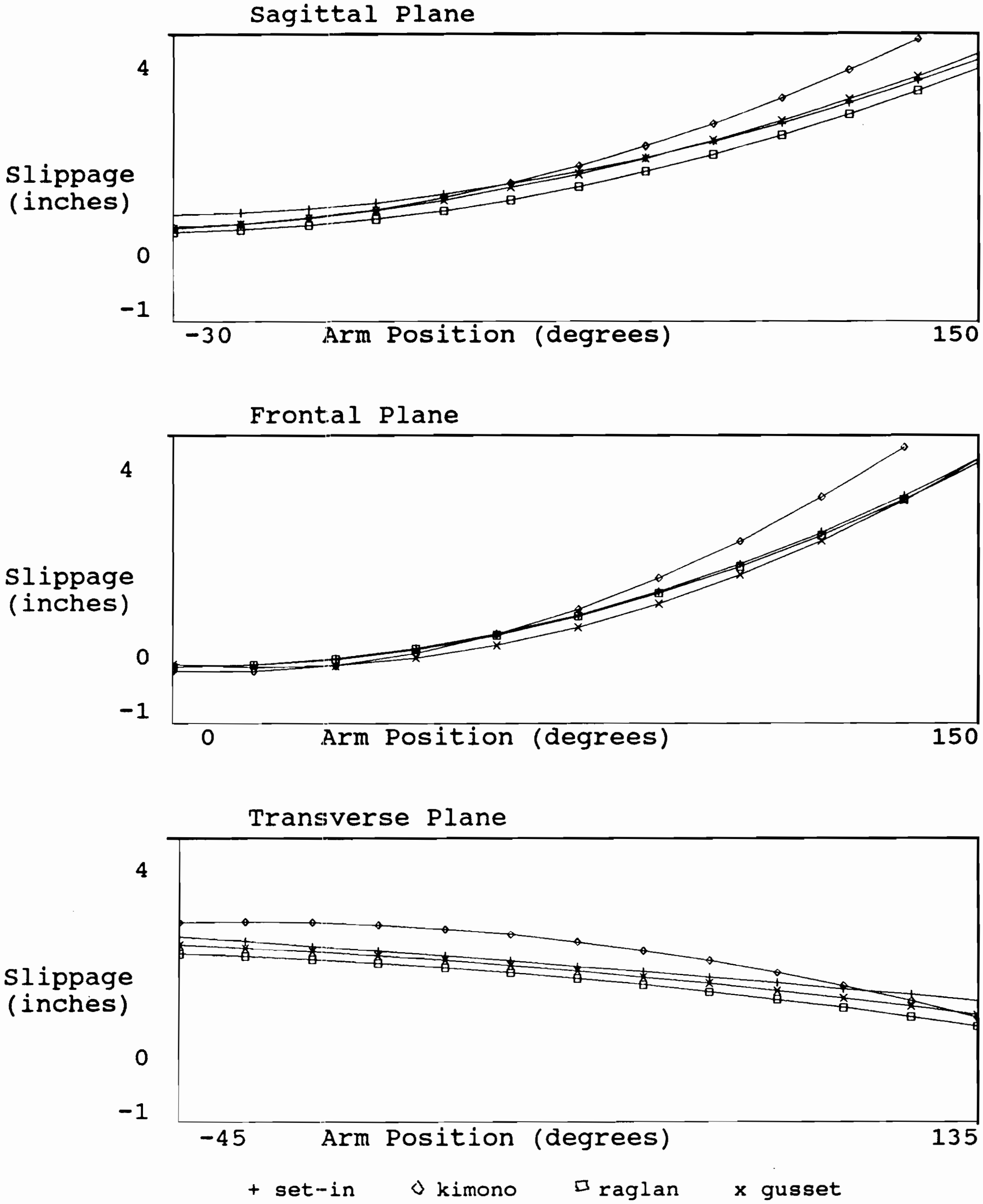



Figure 11
Plots of Wrist Regression Equations

interaction was not significant, the individual quadratic coefficients for a given position did not vary among the structures.

The regression analysis supported the findings from the analysis of variance; there were no significant differences between the sleeve/bodice structures when pooled across all subjects and shoulder positions. This would infer that the sleeve/bodice structures did not differ enough structurally to exhibit differences in garment slippage at the wrist.

The position and $position^2$ were significant in the analysis, and are illustrated by the lines' slopes or defined change of the lines from arm position to arm position. There is a defined change in all of the lines from the smaller arm position angles to the larger angles. At the larger arm position angles, the kimono sleeve's regression line is separated from the other lines. This supports the significant differences found in the Tukey pairwise comparison in which the garment slippage at the wrist for the kimono sleeve was significantly different from the other structures for arm positions of 155 and 120 degrees in the frontal plane of motion.

## Garment Slippage at Waist

Null Hypothesis II: There will be no differences in the amount of garment slippage at the waist among all shoulder positions due to differences between the four sleeve/bodice structures. This was tested using the same methods of analysis which were used for the garment slippage at the wrist. From this analysis it was determined that there were significant differences between the amount of garment slippage at the waist for all variables and the interactions between the variables (Table 12). Null hypothesis II was rejected.

Further investigation was needed to determine the relationship between the sleeve/bodice structures and the shoulder positions. The amounts of garment slippage at the waist for the various positions are reported as means in Table 13 and a bar graph is used to illustrate the means (Figure 11). The shoulder positions are divided into various planes of motion. A Tukey pairwise comparison was used to determine differences between the sleeve/bodice structures for specific shoulder positions. The analysis of each sleeve/bodice structure compared with each of the other structures by position is reported in Table 14.

Table 12

Analysis of Variance for Slippage at Waist

| Source | df | Mean Squares | F value | PR > F |
| --- | --- | --- | --- | --- |
| Subject | 3 | 12.3930 | 137.05 | .0001 |
| Position | 11 | 13.3829 | 38.25 | .0001 |
| Subj*Position | 33 | 0.3498 | 3.87 | .0001 |
| Sleeve | 3 | 7.1929 | 7.08 | .0096 |
| Subj*Sleeve | 9 | 1.0163 | 11.24 | .0001 |
| Position*Sleeve | 33 | 0.3295 | 3.64 | .0001 |
| Residual | 99 | 0.0904 | | |
| Total | 191 | | | |

PR > F = level of significance

Table 13

Amount of Slippage at Waist

(Means are reported in Inches)

| Arm Position | Sleeve/Bodice Structure | | | |
|---|---|---|---|---|
| | Set-in | Kimono | Raglan | Gusset |
| Sagittal Plane | | | | |
| to $155^0$ | 3.95 | 2.89 | 3.41 | 2.74 |
| to $120^0$ | 2.69 | 1.16 | 2.44 | 1.70 |
| to $90^0$ | 1.58 | 0.45 | 1.52 | 1.19 |
| to $60^0$ | 0.79 | 0.32 | 0.50 | 0.71 |
| to $-30^0$ | 0.78 | 0.13 | 0.41 | 0.54 |
| Frontal Plane | | | | |
| to $155^0$ | 3.95 | 2.89 | 3.41 | 2.74 |
| to $120^0$ | 2.96 | 1.61 | 2.40 | 1.61 |
| to $90^0$ | 1.60 | 0.77 | 1.52 | 1.29 |
| to $60^0$ | 0.37 | 0.09 | 0.22 | 0.42 |
| Transverse Plane | | | | |
| to $-45^0$ | 2.21 | 1.30 | 2.12 | 1.18 |
| to $0^0$ | 1.58 | 0.45 | 1.52 | 1.19 |
| to $45^0$ | 1.70 | 0.34 | 1.15 | 1.01 |
| to $90^0$ | 1.60 | 0.77 | 1.52 | 1.29 |
| to $130^0$ | 1.76 | 0.58 | 1.83 | 1.49 |

Standard Error=0.1503

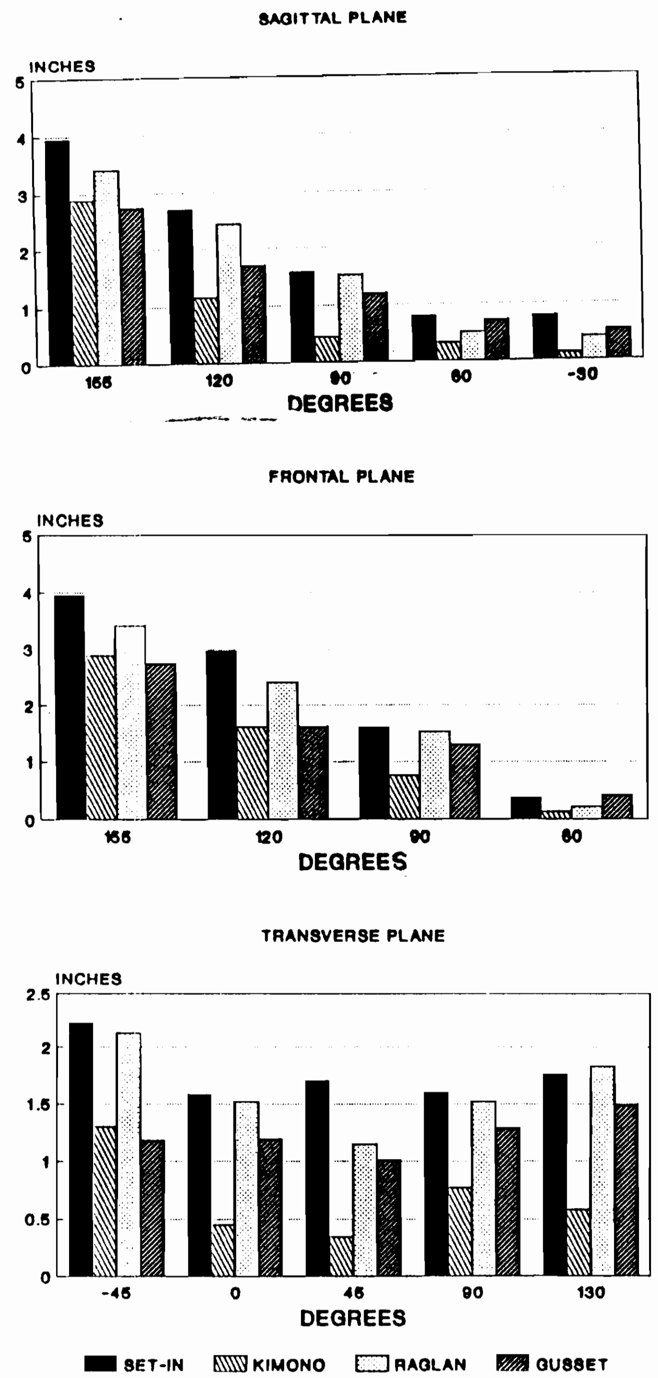



Figure 12
Bar Graph of Slippage at Waist

Table 14
Comparison of Slippage at Waist Between Sleeves
(Differences reported in Inches)

| | Sleeve/bodice Structures | | | | | |
|---|---|---|---|---|---|---|
| | Set-in – Kimono | Set-in – Raglan | Set-in – Gusset | Kimono – Raglan | Kimono – Gusset | Raglan – Gusset |
| Arm Position in Sagittal Plane | | | | | | |
| at 155° | 1.06* | .54 | 1.21* | -.52 | .15 | .67* |
| at 120° | 1.53* | .25 | .99* | -1.28* | -.54 | .74* |
| at 90° | 1.13* | .06 | .39 | -1.07* | -.74* | .33 |
| at 60° | .47 | .29 | .08 | -.18 | -.39 | -.21 |
| at -30° | .65* | .37 | .24 | -.28 | -.41 | -.13 |
| Arm Position in Frontal Plane | | | | | | |
| at 155° | 1.06* | .54 | 1.21* | -.52 | .15 | .67* |
| at 120° | 1.35* | .56* | 1.35* | -.79* | .00 | .79* |
| at 90° | .83* | .08 | .31 | -.75* | -.52 | .23 |
| at 60° | .28 | .16 | -.05 | -.13 | -.33 | -.20 |
| Arm Position in Transverse Plane | | | | | | |
| at -45° | .91* | .09 | 1.03* | -.82* | .12 | .94* |
| at 0° | 1.13* | .06 | .39 | -1.07* | -.74* | .33 |
| at 45° | 1.36* | .55* | .69* | -.81* | -.67* | .14 |
| at 90° | .83* | .08 | .31 | -.75* | -.52 | .23 |
| at 130° | 1.18* | -.07 | .27 | -1.25* | -.91* | .34 |

* differs significantly (p<.05)

Tukey Critical Value = .55 at .05 level

For the Tukey pairwise comparison, it was determined that significant differences occurred for shoulder positions greater than or equal to 90 degrees between the kimono and set-in sleeve/bodice structures. The kimono sleeve had consistently less slippage at the waist. In the transverse plane of motion, the kimono sleeve had significantly less slippage at the waist when compared with the raglan sleeve/bodice structure. This analysis would infer that the kimono sleeve may have the least amount of slippage at the waist when compared with the other sleeve/bodice structures for particular shoulder positions.

The gusset sleeve/bodice structure had significantly less slippage at the extreme arm positions in all three planes of motion when compared to the set-in sleeve and raglan sleeve. In the transverse plane of motion the kimono with gusset sleeve had significantly more slippage at the waist than the kimono sleeve. This would imply that the kimono with gusset sleeve which is applied to the underarm of this sleeve/bodice structure would not reduce garment slippage at the waist for arm positions in the transverse plane of motion. In the sagittal and frontal planes of motion, the kimono with gusset sleeve and kimono sleeve were similar. The similar amounts of slippage may be due to the similarity between these two sleeve/bodice structures.

A regression analysis was used to determine the changes occurring as shoulder positions were moved to various angles. From the regression analysis, the position$^2$ was found significant in all three planes of motion, indicating more slippage of the garments at extreme arm position angles (Table 15). For the transverse plane, the position, position$^2$ and the position$^2$ by sleeve were all significant. The significance of the linear and quadratic coefficients infers that slippage varies from one arm position to another. The position$^2$-by- sleeve interaction indicates that the quadratic coefficients were different for each sleeve/bodice structure.

To illustrate the relationships between the garment slippage at the waist and shoulder position in three planes of motion, the regression equations are listed in Table 16 and then plotted in Figure 12. The lines for the sleeve/bodice structures in the sagittal and frontal planes of motion are similar in shape, but the amount of slippage changes for each arm position.

In the graph of the transverse plane, the sleeve/bodice structures' lines are spread apart from each other and vary for different arm positions, thus illustrating more variability among slippage of the sleeve/bodice structures when viewed in the transverse plane. In the transverse

Table 15

Significance of Regression for Slippage at Waist

| Source | df | Mean Square | F value | Pr>F |
|---|---|---|---|---|
| Sagittal Plane | | | | |
| Subject | 3 | 4.9092 | 14.32 | .0001 |
| Sleeve | 3 | .9344 | 2.44 | .1308 |
| Sleeve*Subject | 9 | .3821 | 1.11 | .3636 |
| Position | 1 | .4394 | 1.28 | .2613 |
| Position*Sleeve | 3 | .0322 | .09 | .9631 |
| $Position^2$ | 1 | 5.9548 | 46.55 | .0001 |
| $Position^2$*Sleeve | 3 | .1365 | .40 | .9794 |
| Residual | 72 | .3428 | | |
| Total | 95 | | | |
| Frontal Plane | | | | |
| Subject | 3 | 4.5715 | 17.91 | .0001 |
| Sleeve | 3 | .0086 | .02 | .9956 |
| Sleeve*Subject | 9 | .4142 | 1.62 | .1310 |
| Position | 1 | .0641 | .25 | .6182 |
| Position*Sleeve | 3 | .1657 | .65 | .5866 |
| $Position^2$ | 1 | 9.3879 | 36.79 | .0001 |
| $Position^2$*Sleeve | 3 | .1552 | .61 | .6124 |
| Residual | 56 | .2552 | | |
| Total | 79 | | | |
| Transverse Plane | | | | |
| Subject | 3 | 6.5520 | 55.40 | .0001 |
| Sleeve | 3 | 2.3501 | 3.29 | .0719 |
| Sleeve*Subject | 9 | .7133 | 6.03 | .0001 |
| Position | 1 | 3.2939 | 27.85 | .0001 |
| Position*Sleeve | 3 | .3290 | 2.78 | .0493 |
| $Position^2$ | 1 | 2.6933 | 22.78 | .0001 |
| $Position^2$*Sleeve | 3 | .2484 | 2.10 | .1105 |
| Residual | 56 | .1183 | | |
| Total | 79 | | | |

Table 16

Regression Coefficients for Slippage at Waist

| Sleeve Type | Intercept | Linear Slope | Quadratic Slope |
|---|---|---|---|
| Sagittal Plane ($R^2$ = .842) | | | |
| Set-in | .653 | -.0037 | 1.63E-4 |
| Kimono | .071 | -.0049 | 1.40E-4 |
| Raglan | .506 | -.0015 | 1.33E-4 |
| Gusset | .503 | -.0018 | 1.03E-4 |
| Frontal Plane ($R^2$ = .908) | | | |
| Set-in | -.101 | .0051 | 1.44E-4 |
| Kimono | -.021 | -.0066 | 1.65E-4 |
| Raglan | -.094 | .0041 | 1.25E-4 |
| Gusset | -.017 | .0043 | 8.61E-5 |
| Transverse Plane ($R^2$ = .870) | | | |
| Set-in | 1.75 | -.0064 | 5.18E-5 |
| Kimono | 0.65 | -.0086 | 7.09E-5 |
| Raglan | 1.49 | -.0096 | 9.66E-5 |
| Gusset | 1.13 | -.0007 | 1.26E-5 |

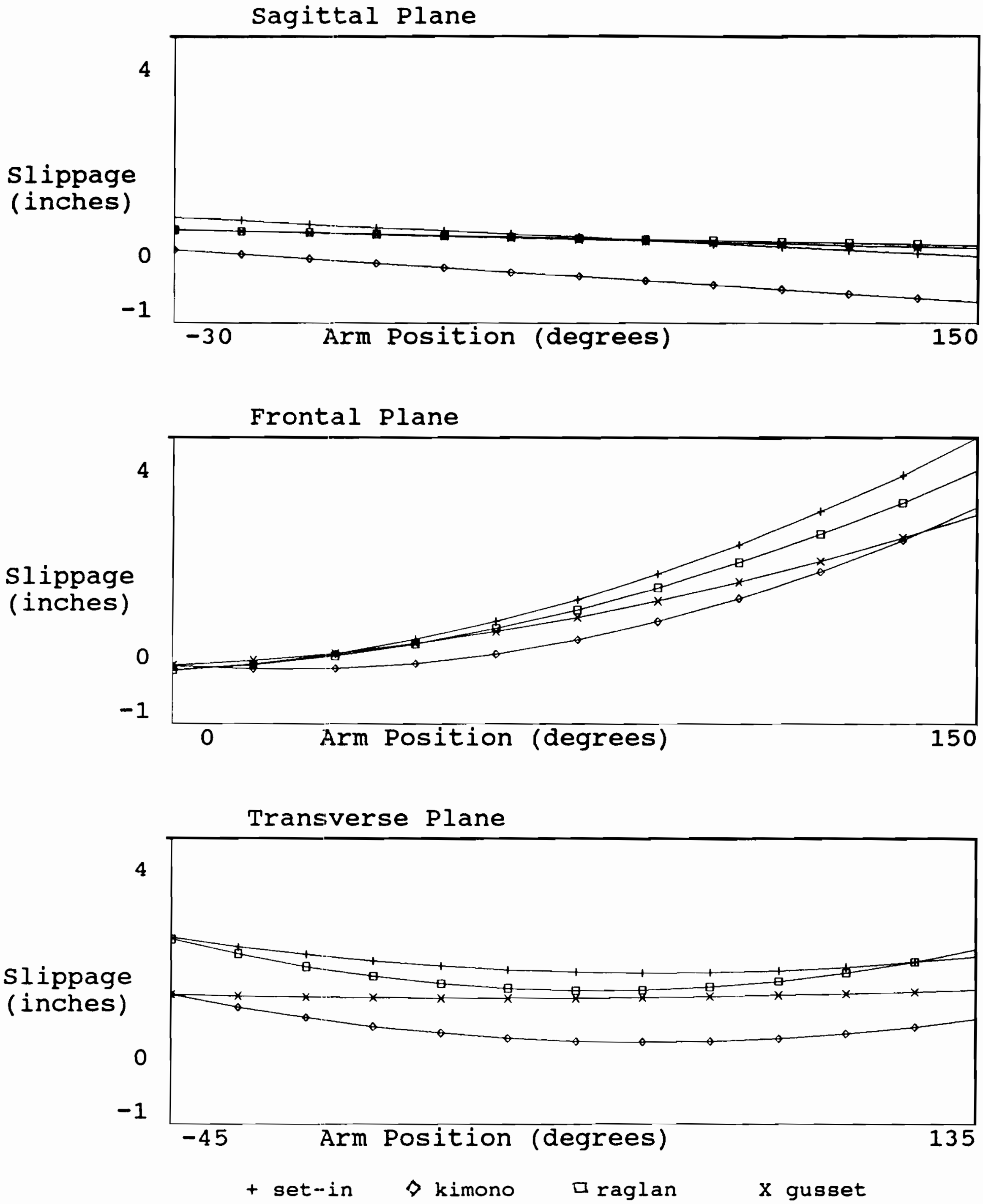



Figure 13
Plots of Waist Regression Equations

graph the significant results of the Tukey's pairwise comparison are evident in that the lines for the set-in sleeve and raglan sleeve are similar, and the kimono sleeve and kimono with gusset sleeve, both lie below the set-in sleeve's and raglan sleeve's lines. The kimono sleeve's slippage is significantly less at the waist through all angles.

## Garment Slippage at Center Back Location

Null Hypothesis III: There will be no differences in the amount of garment slippage at the center back/waistline location among all shoulder positions due to differences between the four sleeve/bodice structures. To test this hypothesis a 4 X 4 X 8 factorial analysis was used, the results of which are presented in Table 17. From the analysis it was determined that there were significant differences between the shoulder position-by-sleeve type interaction. The null hypothesis was therefore rejected.

Since null hypothesis III was rejected, further investigation was needed to determine the relationship between the sleeve/bodice structures and the shoulder positions. The amount of center back slippage for the various positions are reported as means in Table 18 and are illustrated in Figure 13. The shoulder positions are

Table 17

Analysis of Variance for Slippage at Center Back Location

| Source | df | Mean Square | F value | PR >F |
|---|---|---|---|---|
| Subject | 3 | .7640 | 64.12 | .0001 |
| Position | 7 | .3283 | 10.41 | .0001 |
| Subj*Position | 21 | .0315 | 2.65 | .0015 |
| Sleeve | 3 | .3348 | 6.07 | .0152 |
| Subj*Sleeve | 9 | .0552 | 4.63 | .0001 |
| Position*Sleeve | 21 | .0255 | 2.14 | .0107 |
| Residual | 63 | .0119 | | |
| Total | 127 | | | |

PR > F = level of significance

Table 18

Amount of Slippage at Center Back Location

(Means are reported in Inches)

| Arm Position | Sleeve/Bodice Structure | | | |
|---|---|---|---|---|
| | Set-in | Kimono | Raglan | Gusset |
| **Sagittal Plane** | | | | |
| to $155^0$ | .70 | .36 | .43 | .43 |
| to $120^0$ | .44 | .23 | .55 | .31 |
| to $90^0$ | .34 | .09 | .50 | .22 |
| **Frontal Plane** | | | | |
| to $155^0$ | .70 | .36 | .43 | .43 |
| to $120^0$ | .50 | .16 | .37 | .34 |
| to $90^0$ | .23 | .13 | .26 | .14 |
| **Transverse Plane** | | | | |
| to $-45^0$ | .37 | .17 | .48 | .36 |
| to $0^0$ | .34 | .09 | .50 | .22 |
| to $90^0$ | .23 | .13 | .26 | .14 |
| to $130^0$ | .40 | .16 | .37 | .19 |

Standard Error= .05

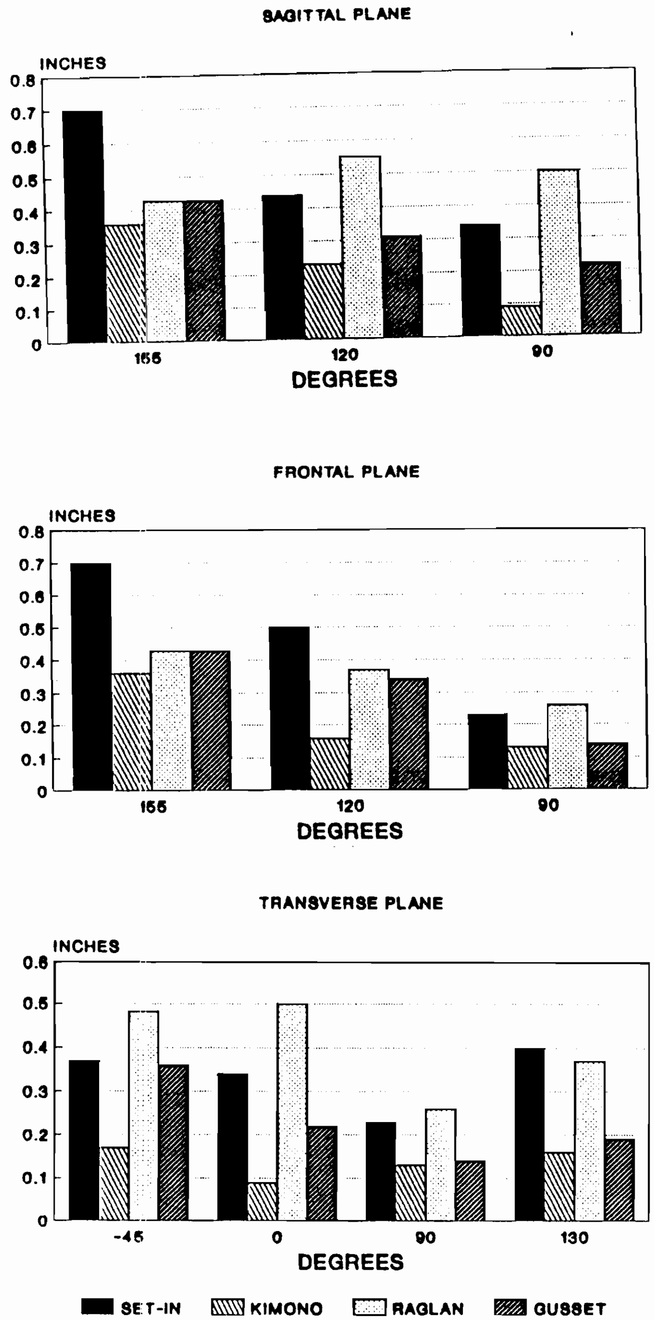



Figure 14
Bar Graph of Slippage at Center Back Location

divided into various planes of motions. A Tukey pairwise comparison was used to determine differences between the sleeve/bodice structures for specific shoulder positions. The analysis of each sleeve/bodice structure compared with each of the other structures by position is reported in Table 19.

In the Tukey pairwise comparison, significant differences occurred between the set-in sleeve when compared to the three other sleeve/bodice structures for the arm position set at 155 degrees. The set-in sleeve also had consistently greater slippage at the center back when compared to the kimono sleeve. In the transverse plane of motion, the kimono sleeve had significantly less slippage at the center back position when compared with the raglan sleeve. The small amount of slippage at the center back for the kimono sleeve was reflected by the kimono sleeve's small amount of slippage at the waist.

A regression analysis was used to determine the relationship between the four sleeve/bodice structures at particular shoulder positions (Table 20). In the sagittal and frontal planes of motion, subject was the only variable found significant. Position and position$^2$ were significant in the transverse plane of motion. This significance would explain that the amount of garment slippage for each sleeve/bodice structure was similar to

Table 19

Comparison of Slippage at Center Back Location
Between Sleeves
(Differences reported in Inches)

| | Sleeve/bodice Structures | | | | | |
|---|---|---|---|---|---|---|
| | Set-in – Kimono | Set-in – Raglan | Set-in – Gusset | Kimono – Raglan | Kimono – Gusset | Raglan – Gusset |
| Arm Position in Sagittal Plane | | | | | | |
| at 155° | .34* | .27* | .27* | -.07 | -.07 | .00 |
| at 120° | .21* | -.11 | .13 | -.32* | -.08 | .24* |
| at 90° | .25* | -.16 | .12 | -.41* | -.13 | .28* |
| Arm Position in Frontal Plane | | | | | | |
| at 155° | .34* | .27* | .27* | -.07 | -.07 | .00 |
| at 120° | .34* | .13 | .16 | -.21* | -.18 | .03 |
| at 90° | .10 | -.03 | .09 | -.13 | -.01 | .12 |
| Arm Position in Transverse Plane | | | | | | |
| at -45° | .20* | -.11 | .02 | -.31* | -.18 | .13 |
| at 0° | .25* | -.16 | .12 | -.41* | -.13 | .28* |
| at 90° | .10 | -.03 | .10 | -.18 | -.01 | .12 |
| at 130° | .24* | .03 | .21* | -.21* | -.03 | .18 |

* differs significantly at .05 level

Tukey Critical Value = .20 at .05 level of significance

Table 20

Significance of Regression for
Slippage at Center Back Location

| Source | df | Mean Square | F value | Pr>F |
|---|---|---|---|---|
| Sagittal Plane | | | | |
| Subject | 3 | .3112 | 6.95 | .0007 |
| Sleeve | 3 | .0623 | 1.92 | .1976 |
| Sleeve*Subject | 9 | .0325 | .73 | .6827 |
| Position | 1 | .0173 | .39 | .5378 |
| Position*Sleeve | 3 | .0290 | .66 | .5797 |
| $Position^2$ | 1 | .0034 | .08 | .7834 |
| $Position^2$*Sleeve | 3 | .0388 | .87 | .4667 |
| Residual | 40 | .0448 | | |
| Total | 63 | | | |
| Frontal Plane | | | | |
| Subject | 3 | .2581 | 12.24 | .0001 |
| Sleeve | 3 | .0000 | .00 | .9999 |
| Sleeve*Subject | 9 | .0273 | 1.30 | .2692 |
| Position | 1 | .0211 | 1.00 | .3234 |
| Position*Sleeve | 3 | .0114 | .54 | .6589 |
| $Position^2$ | 1 | .0709 | 3.37 | .0740 |
| $Position^2$*Sleeve | 3 | .0144 | .68 | .5688 |
| Residual | 40 | .0211 | | |
| Total | 63 | | | |
| Transverse Plane | | | | |
| Subject | 3 | .3906 | 42.42 | .0001 |
| Sleeve | 3 | .1183 | 2.68 | .1096 |
| Sleeve*Subject | 9 | .0441 | 4.79 | .0002 |
| Position | 1 | .1487 | 16.15 | .0003 |
| Position*Sleeve | 3 | .0055 | .59 | .6220 |
| $Position^2$ | 1 | .0810 | 8.80 | .0051 |
| $Position^2$*Sleeve | 3 | .0028 | .30 | .8226 |
| Residual | 40 | .0092 | | |
| Total | 63 | | | |

the others at each arm position, but the amount of slippage across all structures did vary between the arm positions.

To illustrate the relationships between the center back slippage and shoulder position in three planes of motion, the regression equations are listed in Table 21 and then plotted in Figure 15. Due to the lack of significance of the variables in the regression analysis, the lines plotted for the sagittal and frontal planes are not significantly different. For the transverse plane, position and position$^2$ were significant. Therefore, the graph for the transverse plane does illustrate that the amount of slippage for all the sleeve/bodice structures varies similarly for each arm position, declining at the smaller angles.

From the plots, relationships between the sleeve/bodice structures can been seen. In each plot, the raglan sleeve exhibits the greatest slippage, then the set-in sleeve, kimono sleeve and then the kimono sleeve with gusset in descending order. The kimono sleeve and kimono sleeve with gusset consistently have the least slippage, and the plots of the regression equation seem to be parallel. This would support the similarities been the two sleeve/bodice structures and would imply that the gusset which is applied to a kimono sleeve might prevent some additional slippage at the center back/waistline position, although the difference may not necessarily be statistically significant.

Table 21
Regression Coefficients for
Slippage at Center Back Location

| Sleeve Type | Intercept | Linear Slope | Quadratic Slope |
|---|---|---|---|
| Sagittal Plane ($R^2$ = .6472) | | | |
| Set-in | .1725 | -0.0016 | 3.21E-5 |
| Kimono | .0440 | 2.57E-5 | 1.29E-5 |
| Raglan | .2512 | 0.00703 | -3.80E-5 |
| Gusset | .1121 | 3.58E-4 | 1.09E-5 |
| Frontal Plane ($R^2$ = .8078) | | | |
| Set-in | -.0036 | 8.55E-4 | 2.43E-5 |
| Kimono | .0029 | -4.10E-4 | 1.68E-5 |
| Raglan | -.0016 | 0.0034 | -3.54E-6 |
| Gusset | -.0014 | 5.72E-4 | 1.50E-5 |
| Transverse Plane ($R^2$ = .8711) | | | |
| Set-in | .2951 | -0.0015 | 1.63E-5 |
| Kimono | .1037 | -8.7E-4 | 1.07E-5 |
| Raglan | .4308 | -0.0017 | 6.89E-6 |
| Gusset | .2186 | -0.0024 | 1.66E-5 |

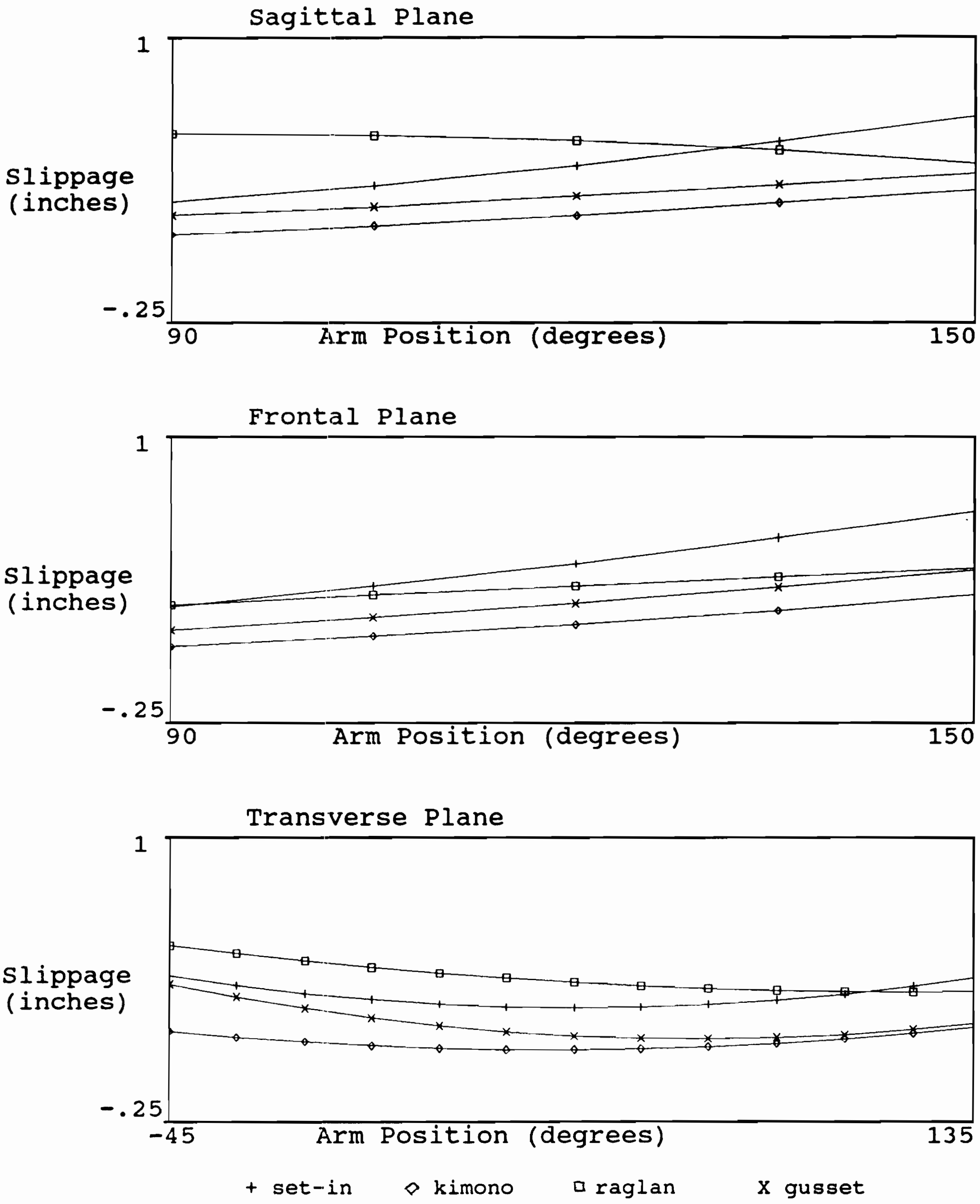



Figure 15
Plots of Center Back Location Regression Equations

## Change in Center Back Angle

Null Hypothesis IV: There will be no differences in the angle at the center back/waistline location among selected shoulder positions due to differences between the four sleeve/bodice structures. To test this hypothesis the information presented in Table 22 was used. From the analysis it was found that there was a significant difference for the position-by-sleeve interaction. Therefore the null hypothesis was rejected.

Since Null Hypothesis IV was rejected, further investigation was needed to determine the relationship between the sleeve/bodice structures and the shoulder positions. The amount of change in the center back angle for the various positions was reported as means in Table 23, which are illustrated in bar graphs in Figure 16. The larger the center back angle, the less slippage had occurred. The shoulder positions have been divided into various planes of motions. A Tukey pairwise comparison was used to determine the difference between the sleeve/bodice structures for specific shoulder positions. The analysis of each sleeve/bodice structure compared with each of the other structures by position was reported in Table 24.

Table 22

Analysis of Variance for Change in Center Back Angle

| Source | df | Mean Square | F value | PR > F |
|---|---|---|---|---|
| Subject | 3 | 103.0867 | 10.38 | .0001 |
| Position | 7 | 512.5274 | 30.47 | .0001 |
| Subj*Position | 21 | 16.8193 | 1.69 | .0561 |
| Sleeve | 3 | 207.6434 | 5.78 | .0174 |
| Subj*Sleeve | 9 | 35.8955 | 3.61 | .0011 |
| Position*Sleeve | 21 | 36.5553 | 3.68 | .0001 |
| Residual | 63 | 9.9297 | | |
| Total | 127 | | | |

Table 23

Angles at Center Back

(Means are reported in Degrees)

| Arm Position | Sleeve/Bodice Structure | | | |
|---|---|---|---|---|
| | Set-in | Kimono | Raglan | Gusset |
| Anatomical | 83.93 | 82.52 | 84.57 | 81.88 |
| Sagittal Plane | | | | |
| to $155^0$ | 66.72 | 68.76 | 79.96 | 68.30 |
| to $120^0$ | 64.50 | 74.39 | 67.44 | 69.85 |
| to $90^0$ | 65.90 | 77.95 | 74.94 | 73.28 |
| Frontal Plane | | | | |
| to $155^0$ | 66.71 | 68.76 | 79.96 | 68.30 |
| to $120^0$ | 71.55 | 77.72 | 73.59 | 77.60 |
| to $90^0$ | 75.80 | 81.86 | 77.65 | 77.16 |
| Transverse Plane | | | | |
| to $-45^0$ | 65.77 | 72.71 | 67.74 | 67.98 |
| to $0^0$ | 65.90 | 77.95 | 74.94 | 73.28 |
| to $90^0$ | 75.80 | 81.85 | 77.65 | 77.16 |
| to $130^0$ | 79.12 | 86.09 | 80.84 | 82.04 |

Standard Error= 1.58

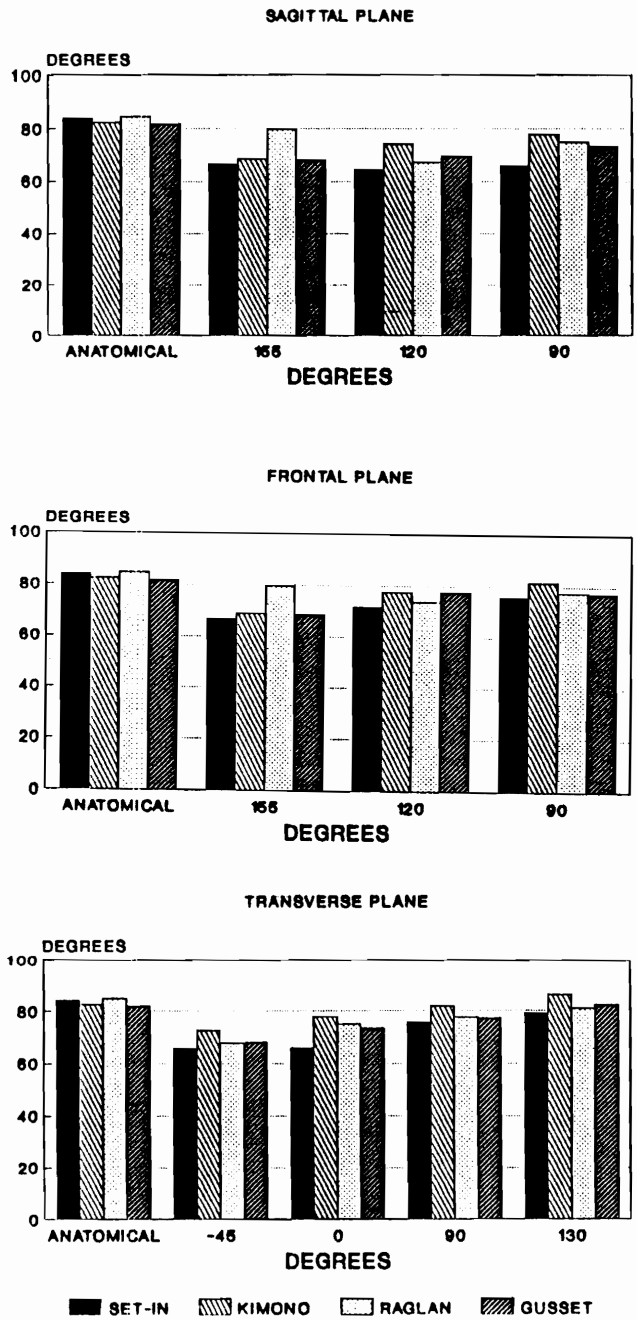



Figure 16
Bar Graph of Center Back Angles

Table 24

Comparison of Center Back Angles Between Sleeves

(Differences reported in Degrees)

| | Sleeve/bodice Structures | | | | | |
|---|---|---|---|---|---|---|
| | Set-in – Kimono | Set-in – Raglan | Set-in – Gusset | Kimono – Raglan | Kimono – Gusset | Raglan – Gusset |
| **Arm Position in Sagittal Plane** | | | | | | |
| at 155° | -2.04 | -13.25* | -1.58 | -11.20* | .46 | 11.66* |
| at 120° | -9.89* | - 2.93 | -5.35 | 6.96 | 4.54 | -2.41 |
| at 90° | -12.05* | - 9.04* | -7.38* | 3.02 | 4.68 | 1.66 |
| **Arm Position in Frontal Plane** | | | | | | |
| at 155° | -2.04 | -13.25* | -1.58 | -11.20* | .46 | 11.66* |
| at 120° | -6.17* | - 2.05 | -6.05* | 4.12 | .12 | - 4.01 |
| at 90° | -6.06* | - 1.85 | -1.37 | 4.20 | 4.69 | .48 |
| **Arm Position in Transverse Plane** | | | | | | |
| at -45° | -6.94* | - 1.97 | - 2.21 | 4.97 | 4.75 | - .24 |
| at 0° | -12.06* | - 9.04* | - 7.38* | 3.01 | 4.67 | 1.66 |
| at 90° | - 6.06* | - 1.85 | - 1.37 | 4.20 | 4.69 | .49 |
| at 130° | - 6.97* | - 1.72 | - 2.93 | 5.25 | 4.04 | -1.20 |

* differs significantly at .05 level

Tukey Critical Value = 5.72 at .05 level of significance

For the Tukey pairwise comparison, it was determined that significant differences occurred between the set-in sleeve when compared with the kimono sleeve for all arm positions in the transverse plane of motion and at 120 and 90 degrees in the sagittal and frontal planes of motion. The set-in sleeve and the raglan sleeve were also significantly different for the extreme arm position of 155 degrees. The smaller center back angle which resulted for the set-in sleeve was supported by the greater slippage at the waist recorded for the set-in sleeve.

A regression analysis was used to determine the relationship between the four sleeve/bodice structures as shoulder positions changed (Table 25). To illustrate the relationships between the changes in the center back angle and shoulder positions in three planes of motion, the regression coefficients are listed in Table 26 and then plotted in Figures 17.

In the regression analysis for the sagittal plane, linear change was significant, but the interaction with sleeve type was not. The $position^2$-by-sleeve interaction was also significant for the sagittal plane. This is illustrated mostly by the raglan sleeve, which had the least slippage at 155 degrees, whereas the others exhibited greater slippage at 155 degrees. The reason for the smaller amount of change in the center back angle for the raglan is

Table 25

Significance of Regression for
Center Back Angle

| Source | df | Mean Square | F value | Pr>F |
|---|---|---|---|---|
| Sagittal Plane | | | | |
| Subject | 3 | 29.7039 | .80 | .5000 |
| Sleeve | 3 | 47.2622 | 2.11 | .1689 |
| Sleeve*Subject | 9 | 22.3804 | .60 | .7856 |
| Position | 1 | 252.8301 | 6.83 | .0126 |
| Position*Sleeve | 3 | 92.5323 | 2.50 | .0733 |
| $Position^2$ | 1 | 121.4979 | 3.28 | .0776 |
| $Position^2$*Sleeve | 3 | 108.7302 | 2.94 | .0448 |
| Residual | 40 | 37.0239 | | |
| Total | 63 | | | |
| Frontal Plane | | | | |
| Subject | 3 | 47.4667 | 2.99 | .0424 |
| Sleeve | 3 | 7.7294 | .41 | .7481 |
| Sleeve*Subject | 9 | 18.7370 | 1.18 | .3344 |
| Position | 1 | 11.8866 | .75 | .3923 |
| Position*Sleeve | 3 | 74.0389 | 4.66 | .0069 |
| $Position^2$ | 1 | 48.6076 | 3.06 | .0880 |
| $Position^2$*Sleeve | 3 | 95.5349 | 6.01 | .0018 |
| Residual | 40 | 15.8928 | | |
| Total | 63 | | | |
| Transverse Plane | | | | |
| Subject | 3 | 47.6048 | 4.69 | .0067 |
| Sleeve | 3 | 105.1112 | 5.82 | .0171 |
| Sleeve*Subject | 9 | 18.6121 | 1.78 | .1028 |
| Position | 1 | 321.3908 | 31.67 | .0001 |
| Position*Sleeve | 3 | 4.0313 | .40 | .7557 |
| $Position^2$ | 1 | 0.3949 | .04 | .8446 |
| $Position^2$*Sleeve | 3 | 30.3284 | 1.00 | .4045 |
| Residual | 40 | 10.1486 | | |
| Total | 63 | | | |

Table 26
Regression Coefficients for
Change in Center Back Angle

| Sleeve Type | Intercept | Linear Slope | Quadratic Slope |
|---|---|---|---|
| Sagittal Plane ($R^2$ = .5947) | | | |
| Set-in | 74.92 | -.2030 | 9.68E-4 |
| Kimono | 80.24 | .0382 | -7.24E-4 |
| Raglan | 79.76 | -.4593 | 2.97E-3 |
| Gusset | 77.58 | -.0799 | 1.29E-4 |
| Frontal Plane ($R^2$ = .7731) | | | |
| Set-in | 83.95 | -.0658 | -2.96E-4 |
| Kimono | 82.49 | .1115 | -1.29E-3 |
| Raglan | 84.77 | -.1875 | 9.70E-4 |
| Gusset | 81.70 | .0377 | -7.67E-4 |
| Transverse Plane ($R^2$ = .8605) | | | |
| Set-in | 66.99 | .0534 | 3.37E-4 |
| Kimono | 76.84 | .0760 | -7.56E-5 |
| Raglan | 73.47 | .0955 | -3.49E-4 |
| Gusset | 72.02 | .0746 | -2.36E-5 |

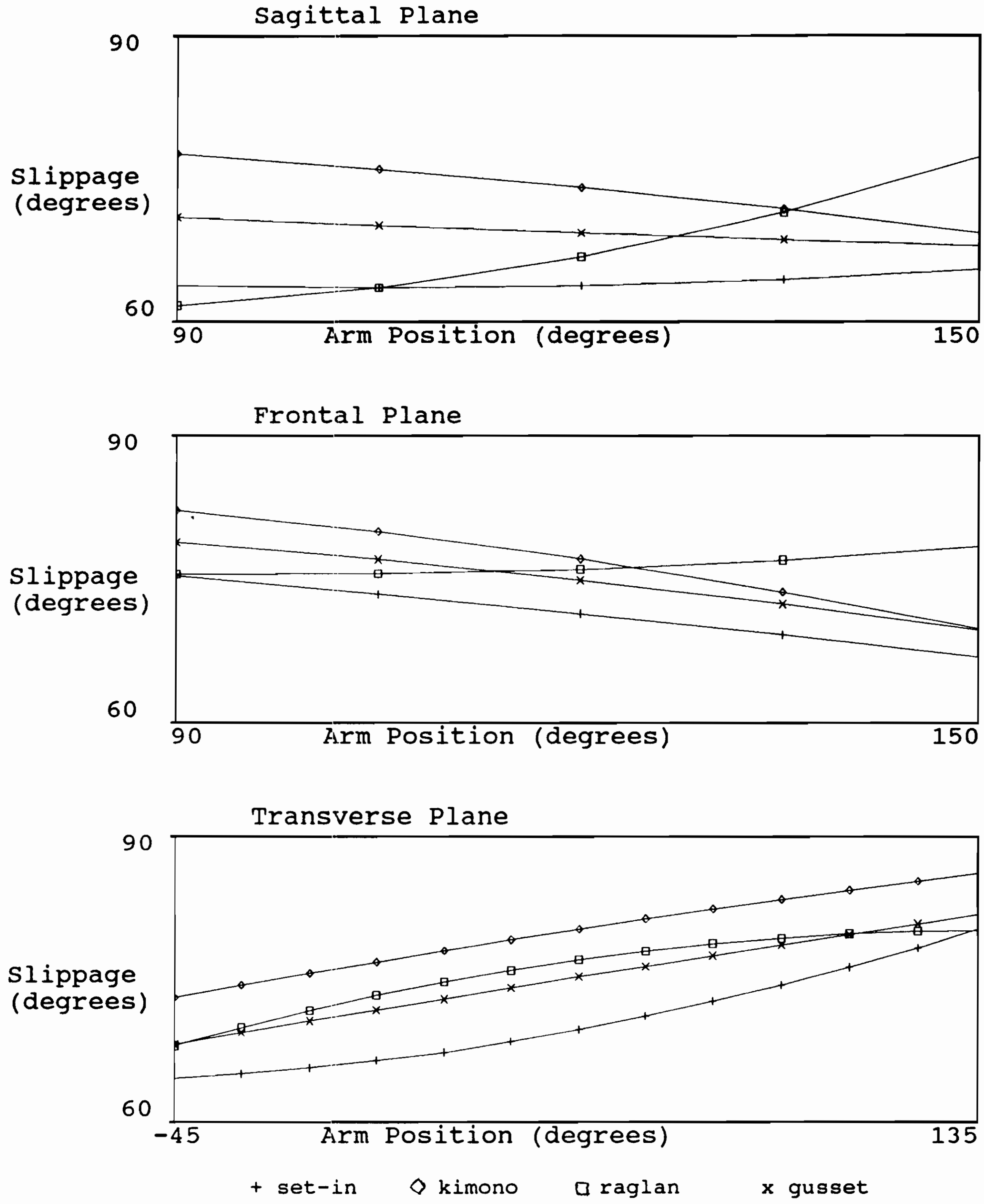



Figure 17
Plots of Center Back Angle Regression Equations

not fully understood. From observations made of the slides from which the data were collected, it appears that the raglan sleeve had the tendency to move or slip as one unit. Therefore the angle did not change because the entire garment slipped, not just the waist.

In the frontal plane, the linear and quadratic interactions with sleeve/bodice structure were significant. The regression lines for each structure are different. In general, the center back angle decreased in size as the arm position increased, which indicates more slippage as the arm is raised. The raglan sleeve had more slippage at 120 degrees and 90 degrees than at 155 degrees. This would imply that the raglan sleeve would be appropriate for the arm positions at 155 degrees. As determined for the sagittal plane, the entire raglan sleeve must be able to move to maintain the larger center back angle. The slippage of the entire garment may not be desirable.

For the transverse plane of motion the quadratic variable was not significant but the linear variable was significant. This is due to all sleeve/bodice structures slipping more at the center back angle as the arm position angle increased.

In each plane of motion, the positioning of the lines for the kimono sleeve, kimono sleeve with gusset and set-in sleeve remain in the same order. In the plots, the larger the center back angle recorded, the less slippage had occurred. Therefore, the lines plotted for the center/back angle are similar to those plotted for the slippage at the center back/waistline location. This would support the obvious assumption that when the center back/waistline location moved, the center back/waistline angle would similarly change.

## Conclusions

The theoretical framework of this study was developed from understanding the anatomical reconfiguration of the shoulder joint when the arm changes positions and the structural differences between four sleeve/bodice structures. From this understanding, garment slippage was predicted from changes in arm position. It is known that when the arm moves, different joints contribute to the action. The shoulder area of the body changes shape. Sleeve/bodice structures which are made to cover the shoulder area have different structural dimensions. When a sleeve/bodice structure is worn over the shoulder area, the structure can not simulate the actions of the shoulder. The garment's reaction to shoulder movement is to slip, or wrinkle or stretch.

From an analysis of variance it was determined that there were significant differences in the amount of garment slippage which occurred at the wrist, waist, center back/waistline location and the center back/waistline angle for the shoulder position-by-sleeve interaction. These differences would explain that, given a particular shoulder position, garment slippage varied between the four sleeve/bodice structures.

In each analysis of variance, subjects were found significant. This would imply that there were different amounts of slippage that occurred between subjects. The use of one subject in this study could not have been representative of the population. For each type of sleeve/bodice structure, subjects accounted for different percentages of the slippage variation. For garment slippage at the wrist the subjects accounted for 1.7% variation; at the waist 15%, at the center back/waistline location 28%, and at the center back angle 4.6%.

Further investigation was needed to determine if structural differences between sleeve/bodice structures were contributing factors. The four sleeve/bodice structures used in this study had different structural dimensions (Table 4). From these dimensions it was assumed that there would be significant differences in the amount of garment slippage which would occur at the wrist and waist when the shoulder complex changed position. Based on the structural dimensions, it could be assumed that the set-in sleeve would show the greatest amount of wrist slippage since it had the shortest underarm seamline length, and the kimono sleeve with gusset would exhibit the least slippage, due to its longest seam length. From a Tukey pairwise comparison of the means for each sleeve/bodice structure by shoulder position, it was determined that this was not true. The kimono sleeve had significantly greater slippage in the amount of wrist slippage when compared with the other three sleeve/bodice structures. The kimono sleeve with gusset, which had the largest underarm length, showed no significant difference when compared with the other sleeve/bodice structures. The exact reason for this lack of difference for the kimono sleeve with gussset is not known, but may infer that the kimono sleeve with gusset is a sleeve/bodice structure that is the most similar to the other sleeve/bodice structures in the amount of ease and structural dimensions.

Based on the theoretical framework of this research, significant differences in waist slippage should occur with the kimono sleeve since it had the shortest side seam length. The kimono sleeve with gusset should have the least slippage since it had the longest side seam length. In the Tukey pairwise test, it was determined that the set-in sleeve had significantly greater slippage, especially when compared to the kimono sleeve. The kimono sleeve also had significantly less slippage at the waist than the kimono sleeve with gusset. From the comparison of the amount of slippage which occurred for each of the sleeve/bodice structures, it is concluded that garment slippage at the wrist and waist are not necessarily related to the length of a specific seam. The kimono sleeve compensated for its short total length by slipping primarily at the wrist. The lack of significant differences in the amount of slippage exhibited by the kimono sleeve with gusset is not fully understood considering that the total underarm length was .44 inches longer than the raglan sleeve and 2.13 inches longer than the set-in sleeve. The amount of garment slippage at the wrist or waist was not proportional to these measured differences, otherwise the regression lines would have been equally spaced between the sleeve/bodice structures.

Additional analyses were done to determine if the movement of the center back/waistline position and the center back angle varied significantly for selected arm positions. Significant differences were found for the different sleeve/bodice structures and the interaction between the sleeve and shoulder position at the .05 level of significance for the center back/waistline location and angle. These differences may be due to the structural differences, specifically the structural position of the grain of the fabric across the shoulder area and the amount of ease incorporated into the style of the sleeve/bodice structure. The effect of the garment slippage at the center back/waistline location and the change in the center back angle were similar. From the regression equations plotted in Figures 15 and 17, it can be seen that the kimono sleeve consistently had the least amount of slippage at center back followed by the kimono sleeve with gusset and then the set-in sleeve. The set-in sleeve had the least amount of ease in the shoulder area which may account for the significant difference in the slippage at the center back when compared to the kimono sleeve, which had the greatest ease. The raglan sleeve was similar to the set-in sleeve in the amount of ease in the bodice area of the structure, and therefore was significantly different from the kimono sleeve. The grain or cut of the raglan's sleeve may have made it differ less from the other sleeve/bodice structures. Additional study is needed to determine what structural differences would account for the significant difference in the change of the center back location and angle.

When comparing the slippage at the wrist, waist, center back/waistline position and the center/back angle as a whole, there were general trends which occurred in the data.

These trends were: the set-in sleeve/bodice structure consistently exhibited the greatest amount of slippage; the kimono sleeve/bodice structure exhibited the least. From the plots of the regression coefficients the amount of slippage illustrated for the raglan sleeve/bodice structure were of similar slope to those of the set-in sleeve/bodice structure, where the kimono sleeve with gusset's slippage were more closely related to the slippage of the kimono sleeve. The similarities were most likely due to the structural similarities between the sleeve/bodice structures. Additional structural information would need to be investigated to determine why the raglan sleeve did not exhibit the same amount of slippage as the set-in sleeve or why the kimono sleeve with gusset did not have less slippage than the kimono sleeve.

This study does provide additional information to clothing designers so that the translation of body movements to final garment designs would not have to rely entirely on creative integration of the data. The results of this study could be used by designers in two manners. First, a designer could compare the four sleeve/bodice structures at a particular shoulder position to determine which structure would exhibit the greatest or least amount of slippage. This information could reduce the number of wear-tests necessary to determine if the garment's structure was suitable for a particular movement. Second, the regression equations which were estimated could be used to determine where and how much additional ease would be needed in a particular sleeve/bodice structure given a specific arm position.

## CHAPTER VI

## SUMMARY

In an apparel design process, a researcher may systematically follow steps which lead to a final design. In this process, data or information are provided to eliminate or reduce the need for intuitive solutions to a clothing problem. Since freedom of body movement may be a need which clothing must address, data which contribute to selecting apparel components based on body movements are useful.

A review of the literature indicated that the emphasis has been to change the garment structure to solve specific movement problems. These changes have been based on such data as garment fit (Ashdown, 1990) and fabric stretch (Kirk & Ibrahim, 1966), or on the researcher's "creative integration" of garment structures or components (McCormick, 1986; Mullet, 1984). A thorough understanding of a garment's structure and its relationship to body movements is lacking.

Though clothing covers the body, the fabric and garment structure can not duplicate the elastic quality of the body articulations. For clothing design, researchers either select the anatomical or a different body position on which to base structural garment dimensions. Changes in body position are often thought to be of lesser importance and thus not considered for a garment's design. Study of the shoulder complex indicated that when the body moves, the bones, muscles, joints, and skin reconfigure. A garment which covers the body can not duplicate the same actions as the body. The garment's reaction to body movement is to slip, wrinkle, stretch, or restrict the wearer.

When different garment structures have different physical dimensions, each may be affected differently when the body changes position. In different garment designs the structural dimensions may not be the same even when the garment is made to fit the same body position. There needs to be some means to predict the effect on the structure of different body positions. This information will enable researchers to select or eliminate possible garment structures based on body movements before a prototype is made and a wear-test conducted.

## Purpose

The purpose of this research was to investigate the reaction of different sleeve/bodice structures to different shoulder positions. Since sleeves may have numerous variations and design details incorporated into the structure only four basic structures were investigated. These were the set-in sleeve, the kimono sleeve, the raglan sleeve and the kimono sleeve with gusset. The variables used to determine the reaction of the structures to different shoulder positions were movements of the garment from various body locations. Garment slippage was defined as the movement of a garment away from a set anatomical body position. For this study, the data collected was the garment displacement at the wrist, waist, and center back/waistline locations measured in inches, and by the angular displacement of the center back/waistline angle of the garment.

## Research Hypotheses

The research hypotheses were stated to test if there were significant differences in the garment slippage and center back angle for all sleeve/bodice structures and all shoulder positions. When the null hypotheses were rejected additional post hoc analyses were performed to determine the specific differences which occurred.

Research Hypothesis I: There will be a difference in the amount of garment slippage at the wrist among all shoulder positions due to differences between the four sleeve/bodice structures.

Research Hypothesis II: There will be a difference in the amount of garment slippage at the waist among all shoulder positions due to differences between the four sleeve/bodice structures.

Rationale: The movement of the arm results in the use of the different shoulder joints as different arm angles are assumed. The amount of wrist and waist slippage for each of the four sleeve/bodice structures should vary because of the physical structural differences between these structures. There should be significant differences between the amount of slippage at the various shoulder positions. The smaller the arm position angle, the smaller the amount of slippage which should occur.

Research Hypothesis III: There will be a difference in the amount of garment slippage at the center back/waistline location among selected shoulder positions due to differences between the four sleeve/bodice structures.

Research Hypothesis IV: There will be a difference in the angle at the center back/waistline location among selected shoulder positions due to differences between all sleeve/bodice structures.

Rationale: The angle and center back/waistline location movement should provide additional information as to effects structural differences may have between the sleeves. For the four different sleeve/bodice structures the amount of ease and position of the fabric grain line are different. Therefore, significant differences in garment slippage or change in the center back angle should occur for the sleeve/bodice structures at the various shoulder positions.

## Procedure

The areas discussed in the procedure were the development of the four sleeve/bodice structures, selection of the subjects, and the shoulder positions assumed by the subjects while wearing the sleeve/bodice structures for the measurement of garment slippage and center back angle.

A commercial pattern was fitted to the subjects in order to develop a basic sloper. From the sloper, the set-in, kimono, raglan, and kimono with gusset sleeve/bodice structures were developed. For consistency and repeatability, Armstrong's (1987) Patternmaking for Fashion Design pattern development techniques were used. Fabric variables which may contribute to a sleeve's function were controlled by using one inch gingham check fabric. This fabric was used because the grain was easily recognized and the stretch of the fabric was minimal. One garment of each of the four sleeve/bodice structures was developed for each of the four subjects, for a total of 16 garments. The fit of each garment was evaluated using the guidelines described in most fitting texts.

Since most patternmaking texts deal with design for women's clothing, four female subjects of misses proportions were selected for this study. Each subject was measured with a goniometer to ensure that she was capable of assuming the desired shoulder positions. The twelve shoulder positions selected for this study are those performed by most individuals in daily activities.

To facilitate the collection of data, 35mm slides were taken of four female subjects at each of the twelve selected shoulder positions wearing each of the four sleeve/bodice structures. The slides were then projected onto a digitizer screen, and the data were recorded. The data could be recorded as life-size measurements since the digitizer scale could be adjusted. The exact scale on each slide was known since the sleeve/bodice structures were constructed from one inch gingham fabric.

## Results

The null hypotheses were tested by analyses of variance with factorial treatments in a split plot design, where subjects were whole plots. If an effect was significant, a Tukey pairwise comparison was used to determine garment slippage mean differences between each of the sleeve/bodice structures for specific shoulder positions. A regression analysis was used to determine the relationship between each sleeve/bodice structure and the shoulder positions.

Significant differences were found at the .05 level in the amount of garment slippage at the wrist, waist, center back/waistline location, and the center back/waistline angle for the shoulder position-by-sleeve interaction. These differences would explain that given a particular shoulder position, the garment slippage between the four sleeve/bodice structures varied.

Further investigation was needed to determine if the structural differences between each of the sleeve/bodice structures were contributing factors. The four sleeve/bodice structures used in this study had different structural dimensions. From these dimensions it was assumed that there would be significant differences in the amount of garment slippage which would occur at the wrist and waist when the shoulder complex changed position. Based on the structural dimensions it could be assumed that the set-in sleeve would show the greatest amount of slippage at the wrist since it had the shortest underarm seamline length, and the kimono sleeve with gusset would exhibit the least slippage, due to its longest seam length. From a Tukey pairwise comparison of the means for each sleeve/bodice structure by shoulder position it was determined that this was not true. The kimono sleeve was significantly different in the amount of slippage at the wrist when compared with the other three sleeve/bodice structures. The kimono sleeve with gusset, which had the largest underarm length, showed no significant difference when compared with the other sleeve/bodice structures. The exact reason for this lack of significant difference for the kimono sleeve with gussset is not known, but one may infer that the kimono sleeve with gusset is a sleeve/bodice structure that is the most similar to the other sleeve/bodice structures.

Based on the theoretical framework of this research, significant differences in slippage at the waist should occur with the kimono sleeve since it had the shortest side seam length. The kimono sleeve with gusset should have the least slippage since it had the greatest side seam length. In the Tukey pairwise test, it was determined that the set-in sleeve was significantly greater in slippage, especially when compared to the kimono sleeve. The kimono sleeve also had significantly less slippage at the waist than the kimono sleeve with gusset. From the comparison of the amount of slippage which occurred between the sleeve/bodice structures, it is assumed that the garment slippage at the wrist and waist are not necessarily related to the measurement of a specific seam. For the kimono sleeve/bodice structure, the structure compensated for its short total length by slipping primarily at the wrist. The lack of significant differences in the amount of slippage exhibited by the kimono sleeve with gusset is not fully understood considering the fact that the total underarm length was .44 inches longer than the raglan sleeve and 2.13 inches longer than the set-in sleeve.

Additional analyses were done to determine if the movement of the center back and the angle formed at the center back/waistline location varied significantly for selected arm positions. Significant differences were found for the different sleeve/bodice structures and the interaction between the sleeve and shoulder position at the .05 level of significance for the center back/waistline location and angle. These differences may be due to the structural differences, specifically the structural position of the grain of the fabric across the shoulder area and the amount of ease incorporated into the style of the sleeve/bodice structure. The effect of the garment slippage at the center back/waistline location and the change in the center back angle were similar. The set-in had the least amount of ease in the shoulder area which may account for the significant difference in the center back slippage when compared to the kimono sleeve, which had the greatest ease. The raglan sleeve was similar to the set-in sleeve in the amount of ease in the bodice area of the structure and therefore was significantly different from the kimono sleeve. Additional study is needed to determine what the structural differences are which would account for the significant difference in the change of the center back location and angle.

This study determined that garment slippage was significantly different for the four different sleeve/bodice structures at various shoulder positions. The significant differences found were not necessarily the same as those hypothesized in the theoretical framework. Based on this research, one can not assume that there is a direct correlation between structural dimensions of a garment and the amount of slippage which will occur due to arm movement.

The results of this study could be used by designers in two manners. First, a designer could compare the four sleeve/bodice structures at a particular shoulder position to determine which structure would exhibit the greatest or least amount of slippage. This information could eliminate the need for a wear test of a garment to determine if the structure was suitable for a particular movement. Second, the regression equations which were calculated could be used to determine where and how much additional ease would be needed in a particular sleeve/bodice structure given a specific arm position.

CHAPTER VII

# SUGGESTIONS FOR FURTHER RESEARCH

This research was prompted by problems encountered when using an apparel design process to solve paddling jacket needs for male kayakers. The physical movements performed by the user have been measured through biomechanical analysis, but direct translation of those movements into a garment design have been based on the researcher's "creative integration." Further research is needed to provide data or valid testing procedures that can correlate the body movements to basic garment structures. These data or tests would enable researchers to select appropriate garment structures for specific end uses, just as textile testing enables researchers to select appropriate fabric for specific end uses.

This study was limited to four sleeve/bodice structures. Additional research is needed to determine the variation in results which may be due to structural characteristics not measured in this study of the basic sleeve/bodice structures. Such research would provide data on which structural characteristic may be the leading contributor to the garments' slippage or movement capabilities. Structural changes that may be explored are position of grainline or the seamline location which vary among the structures. The kimono with gusset would be of particular interest due to its lack of significant differences from the other sleeve/bodice structures, even though it had the greatest total underarm seam length.

Structural variations of the sleeve/bodice structures could be explored by varying the type of fabric used to construct the garments. In this study, the fabric type was the same for each sleeve type used, and was not a factor in the analysis. Fabric type variation may provide additional data which could be used by designers. Discovering relationships between the type of the fabric used and the structure would enable designers to eliminate possible garment designs before a wear-test is conducted.

In this research, the sample consisted of females of approximately the same size. Further research is recommended that explores the results of garment reconfiguration when subjects of a variety and diverse number of sizes are used. In the review of literature, Laubach (1970) and Emanuel and Barter (1967) found subject size was not a significant contributor to variation in joint movement or linear distance changes over the joints. A study is needed to determine if this is also true for garment structures.

The use of male subjects in a study of sleeve/bodice structures is needed. In functional design, males have been the major user group for the clothing problems explored. The application of this study's results to male subjects may not be appropriate. Further research is needed to determine if garment slippage would be similar for both males and females.

The present research provided knowledge to help designers make logical selections of sleeve/bodice structures based on specific body positions. Suggestions for further research included in this chapter were: the development of additional information on other basic garment structures, as well as variations of fabric and seamlines of the structures; the use of a more diverse sample to include females of different sizes and to include males. These studies would provide the objective data and valid test needed to reduce the "creative integration" of the apparel design process.

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# Vita

Kathy K. Mullet was born January 14, 1958 in Asheville, North Carolina and graduated from The Asheville School in 1976. In September 1976, she entered Sweet Briar College, and then transferred to Virginia Polytechnic Institute and State University in 1977. She completed her B.S. degree with an option in Apparel Design and Fashion Merchandising in March 1980. From 1980 to June 1981, Kathy continued her studies in Clothing and Textiles as a graduate student. She completed her Master's of Science degree in March 1984 and continued her studies toward a doctoral degree.

Her work experience has included graduate teaching assistantships for courses in clothing construction, tailoring and apparel design. Kathy was self-employed from 1982 to 1984 as a designer of custom kayaking gear, and has continued to the present as a design consultant. In 1984, she was employed as a temporary Apparel Design Instructor at Virginia Tech. In 1985, she was hired as a Instructor in the Department of Design at Radford University. She has continued in this position teaching and developing the core of Fashion Design courses.

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