FIT AND SIZING EVALUATION OF LIMITED-USE PROTECTIVE COVERALLS

by

Margaret Brown Prevatt

Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Clothing and Textiles

APPROVED:

Lois M. Gurel, Co-Chairman

Carolyn L. Moore, Co-Chairman

Rinn M. Cloud

Dennis E. Hinkle

Vera B. Keeble

April 1991

Blacksburg, Virginia

FIT AND SIZING EVALUATION OF LIMITED-USE PROTECTIVE COVERALLS

by

Margaret B. Prevatt

Committee Chairmen: Lois M. Gurel and Carolyn L. Moore
Clothing and Textiles

(ABSTRACT)

Garment fit is a complex concept made up of objective and subjective variables. It can be measured in terms of functional ease, garment ease, comfort, and appearance. The success of any garment design is dependent upon the suitability of fit for intended end use. Garment fit is fundamental to user satisfaction. One type of garment where fit is essential is protective clothing. Protective clothing should minimize discomfort to the wearer, maximize the level of environmental protection, and provide minimum interference with the task being performed. Because of consumer complaints about the fit of protective clothing, a recommendation for revision of current sizing specifications has been made by the Industrial Safety Equipment Association (ISEA). The purpose of this research was to evaluate the fit of limited-use protective clothing manufactured to the proposed size revision of ANSI/ISEA 101-1985 Men's Limited-Use and Disposable Protective Coveralls Sizing and Labeling Requirements.

Garments which met minimum specifications were provided in three styles by manufacturers. Subjects were obtained at agricultural conferences sponsored by the Virginia Cooperative Extension Service. After selecting garments according to height and weight measurements, subjects were asked to wear the garments while completing an exercise

work protocol designed to represent common body movements. Data were collected with a questionnaire concerning overall fit, ability to perform a job while wearing the garment, and whether the garment was too large or too small. Results were used to analyze and make recommendations concerning 1) static fit and dynamic fit, 2) key body measurements other than height and weight needed to select garments, 3) required ease, and 4) the effects of design on fit.

Significant results made it possible to make recommendations concerning amounts of ease necessary for overall fit as well as dynamic and static fit. However, evidence was inconclusive in regard to garment design. Comparisons between body and garment measurements were not definitive enough to make recommendations for use of any body dimensions other than height and weight for size selection. Recommendations were made that more anthropometric data be collected for this purpose.

ACKNOWLEDGEMENTS

Words cannot express the appreciation I feel for my advisors and friends. Dr. Lois Gurel, Dr. Vera Keeble, and Dr. Carolyn Moore have been not only advisors, but also friends who have guided me and given me inspiration. Without their assistance, encouragement, and moral support, I would not have been able to undertake and complete this research. My thanks also go to Dr. Rinn Cloud and Dr. Dennis Hinkle who listened when I had problems, provided invaluable editing assistance, and whose guidance led me to become a better researcher. I owe a special thanks to them all.

I also wish to thank Abandaco, Kappler, Durafab, and DuPont who supported this research by providing garments for testing and financial assistance. Their willingness to help made this research project possible. Their interest in the results will be directly translated into improved products for the consumer.

I am especially indebted to my fellow graduate students, particularly Susan Henson, Farrell Doss, and Dabney Huckabay, who spent many hours helping with this project. I also want to thank Peggy Quesenberry and other department personnel who provided many hours of assistance through all stages of this project.

Finally, I wish to express my love and appreciation to my husband Bruce and our children Julie, Ross, and Robert. Without their total support, personal sacrifices, and love I could not have undertaken this step in life, much less completed it. Their faith in me has made all the sacrifices worthwhile.

Table of Contents

List of Figures

List of Tables

CHAPTER I

INTRODUCTION

Considering the relationships between human beings and technical developments has increased the interest in human factors as a discipline. A brief perusal through many types of current literature readily shows this interest in human factors with the increasing awareness of hazardous environmental conditions and the concern for worker safety. Considering human factors early in the design phase of apparel accomplishes two major objectives: enhancing the effectiveness and efficiency with which activities are carried out and enhancing certain desirable human values such as improved safety, reduced fatigue and stress, increased comfort, greater user acceptance, increased job satisfaction, and improved quality of life (Sanders & McCormick, 1987). As technological advancements increase, pollutants sometimes invade the environment and result in harmful effects to its inhabitants. Use of pesticides to increase crop production, asbestos abatement procedures required for asbestos free habitats, chemicals or paints used in production processes, and cleanup procedures for removal of toxic substances are just a few examples of processes that create environmental conditions which place workers in contact with harmful substances. Protective clothing is one means of safeguarding workers from these environmental risks. Protective clothing must be both effective and acceptable to the wearer to be successful in providing protection. It should also be economically feasible for the purchasers to acquire.

Protective clothing should minimize discomfort to the wearer, provide minimum interference with the task being performed, and maximize the level of environmental protection (Shirley Institute, 1982). It must not only be available, but it must actually be worn if it is to shield workers from harmful environmental exposure (Watson, 1989). A frequent complaint of those needing to wear protective clothing is the poor fit, which may adversely affect body mobility and consequently the ability of the wearer to perform the job. Restrictions on body mobility not only make simple tasks more difficult, but also increase the energy costs of work (Veghte, 1989). Because of limited mobility and increased energy requirements needed to perform the work the wearer then becomes less productive. Consequently, workers sometimes risk exposure to harmful substances rather than wear garments that inhibit body mobility. When protective clothing fit is extremely poor, the garment may actually become a hazard and contribute to injuries rather than to protection (Huck, 1988). Poor fit can result in exposed body areas, thereby reducing the amount of environmental protection provided by the garment.

Garment fit can be described as the relationship between the size and shape of the garment and the size and shape of the body (Shishoo, 1990). The difference between the measurements of the garment and the measurements of the person wearing that garment is the garment ease. That difference may be composed of two types of garment ease: functional ease and styling ease. Functional ease is the amount of extra fabric necessary for body mobility. The amount is influenced by fabric properties and the way the fabric contributes to or restricts body movement. Styling ease is the additional fabric needed because of the specific style of the garment. Garment dimensions include the addition of both functional ease and style ease to the body dimensions. For example, a garment designed to fit a 36" chest may require 6" of functional and styling ease in the chest area. Therefore, the finished garment actually measures 42" even though the size definition says it is for a 36" chest. These differences can be seen when looking at garment manufacturing specifications and the corresponding body dimensions for each of the stated sizes.

Appropriate fit also requires wearer satisfaction in both static fit and dynamic fit. Static fit is evaluated when the wearer of the garment assumes a stationary stance; dynamic fit is evaluated as the wearer moves and carries out typical activities associated with the garment use (Gordon, 1986). Static and dynamic fit tests are the basis for subjective evaluation of fit. A comparison of body measurements with corresponding garment measurements and subjective evaluations of fit contribute to the development of satisfactory sizing scales and specification tables.

Garment fit is not only a key factor in defining sizing specifications but it is also fundamental to user satisfaction (Delk & Cassill, 1989). Consumer complaints have indicated the need for a revision in current sizing of protective clothing (American Society for

Testing and Materials F23 - Committee on protective clothing, personal communication, 1988). The Industrial Safety Equipment Association (ISEA), the organization that develops standards for allied areas, has recommended a revision of the current sizing specification -- ANSI/ISEA 101-1985 Men's Limited Use & Disposable Protective Coveralls - Sizing & Labeling Requirements (Appendix A). A sizing scale has been proposed based on height and weight that covers seven sizes from Extra Small (XS) to Extra Extra Extra Large (3XL). This expansion of sizes is an attempt to fit a broader range of consumers including women and larger men. This research project involved evaluating the fit of garments constructed according to the specifications of the proposed ANSI/ISEA sizing standard. Conducting an anthropometric fit test early in the development cycle of the sizing standard revision is cost-effective, allowing modifications to be made before production begins rather than re-doing procedures, a process that often provides less than satisfactory results (McConville, 1986).

The purpose of this study was to evaluate the fit of protective clothing manufactured to the proposed revision of the ANSI/ISEA 101-1985 sizing standard. The research was supported by three manufacturers of protective clothing and the manufacturer of the fabric used in the garments. Recommendations based on the findings of this research were reported to ISEA and the participating manufacturers.

CHAPTER II

REVIEW OF LITERATURE

When environmental situations endanger the health or safety of a worker, action should be taken to provide some protective measures. When possible, the best solution is to engineer a change in the operational process producing the hazard since mechanical changes and/or design processes are generally more reliable than human behavior changes (Srachta, 1985). If the hazard cannot be eliminated through engineering revisions such as mechanized handling systems that eliminate manual handling, then the next best solution is administrative controls, i.e. substitution of less toxic materials or limiting the exposure time of any one employee (Sanders & McCormick, 1987). If engineering and administrative controls do not remove the problem, then the use of protective equipment (a behavioral change) is the most commonly used alternative. Even when engineering and administrative modifications do control the problem, protective clothing is often advisable as an additional safeguard. Occupational Safety and Health Administration (OSHA) regulations require the use of protective equipment, including protective clothing, in a variety of work situations which include "hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered that are capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact" (Srachta, 1985). Of the three main types of environmental exposure -- dermal, ingestion, and inhalation -- dermal exposure poses a greater health hazard than the others in many occupations (Reinert & Severn, 1985; Wolfe, Durham, & Armstrong, 1967). Protective coveralls are the only significant type of dermal barrier available to many workers (Ehntholt et al., 1988; Gohlke, 1989; Keeble, Norton, & Drake, 1987; Nielsen & Moraski, 1986).

Although many types of protective garments are available, this research focused on limited-use protective coveralls. As is the case with most research projects, this one has many dimensions. The review of literature is divided into sections dealing with use of protective clothing, benefits of disposable protective clothing, product certification and standards, fit and body movement, fit and sizing of limited-use protective coveralls, fit evaluation, and product development.

Use of Protective Clothing

Protective clothing is used for a wide variety of occupations and purposes. It may be used for simply keeping workers from getting dirty or for protecting them from toxic substances. Laws requiring protection for workers date back to the late 1800's. In England, the Factory and Workshop Act of 1891 required suitable overalls, protecting the "neck, arms, and ordinary clothing" to be worn by workers in occupations that included handling animal hides, paint manufacturing, enamelling processes involving arsenic, match manufacturing, and explosives production (deMarley, 1987). These "overalls" were actually smocks that were worn with trousers. One-piece coveralls were introduced around 1900 and worn over street clothing by members of the working class such as chimney sweeps (Fig. 2.1) (deMarley, 1987). They were also popular for persons who worked around machinery since the reduced amount of fullness helped prevent loose fabric from being caught in moving parts. One-piece coveralls first appeared in the Sears, Roebuck and Company catalog in 1915. They were described as a "Two-in-one union suit overall garment, specially adapted for machinists, automobilists and anyone in need of a dirt repelling garment" (Fig. 2.2) (1915 Fall/Winter Sears, Roebuck and Company Catalog, p. 587). In 1969 disposable coveralls first appeared in the Sears catalog. They were described as "...Lightweight yet durable.....May be shortened with scissors. No laundry or repair bills. Ideal for industrial, medical, research, institutional, service installation workers..." (Fig. 2.3) (1969 Spring/Summer Sears, Roebuck and Company Catalog, p. 493). The raglan sleeves, convertible collar, and zipper front styling looked very similar to coveralls available today.

Disposable garments are often referred to as "limited-use" garments by manufacturers. A widely used fabric for limited-use coveralls is DuPont's Tyvek®, a spunbonded olefin non-woven fabric made from high density polyethylene fibers, (DuPont, 1990). The coveralls are designed to protect workers from skin contact and undergarment contamination by harmful substances. Dupont lists the following as properties of Tyvek: high level barrier protection, light weight for

Figure 2.1. Chimney sweep - 1900. (deMarley, 1986).

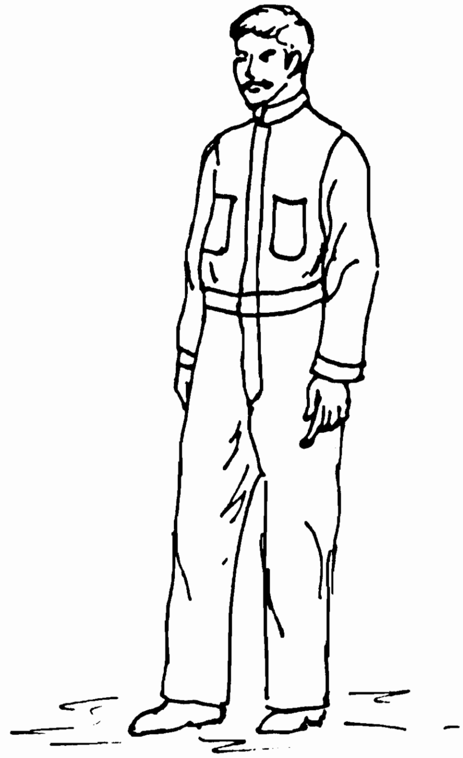


Figure 2.2. Union suit - 1915. (1915 Fall/Winter Sears, Roebuck and Company Catalog).

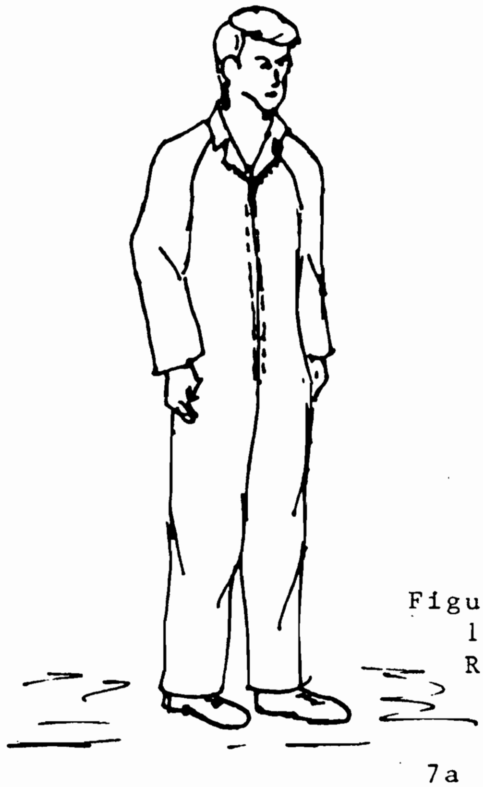


Figure 2.3. Disposable coveralls - 1969. (1969 Spring/Summer Sears, Roebuck and Company Catalog).

comfort and ease of movement, flexibility, disposability for convenience and reduced contamination, durability with high wet and dry tear resistance, and economy for regular use (DuPont, H-19690-1, 1990). Limited-use Tyvek® garments are often used in the drug and pharmaceutical industries, for cleanup of hazardous materials, for asbestos abatement, and in cleanrooms where the product (rather than the worker) must be protected from contaminants and perspiration (Katzel, 1985). Tyvek® provides an excellent barrier against paints, lead dust, asbestos, bacteria, some agricultural chemicals, fiberglass, carbon black, resins, nuclear particulate, and many kinds of liquid splash. Nigg, Stamper, and Queen (1986) determined that Tyvek® coveralls reduced dermal exposure from pesticides by 40 percent. With the addition of a coating, Tyvek® also offers protection from hydrocarbons, acids, agricultural insecticides, and hazardous spills (Goldstein, 1985).

One of the largest problems currently facing industries is the need for workers to understand the necessity of using personal protective equipment and wearing personal protective clothing properly ("Advancing the," 1990; Ashdown, 1989; Breisch, 1990; Conforti & Grunberg, 1987; Gabele, 1989; Katzel, 1985; Minter, 1987; Srachta, 1985). Workers often either do not perceive themselves as being at risk from the chemicals they use or they feel that ordinary work clothing provides any necessary protection from dermal exposure (DeJonge, Vredevoogd, & Henry, 1983-84; Keeble, et al., 1987; Norton, Drake, & Young, 1988; Rucker et al., 1988).

In addition to the necessity of knowing about the hazard being encountered, workers also need to be aware of the consequences of exposure if they are not protected (Minter, 1987). One sector of the population especially at risk is the agricultural pesticide applicator. Moraski and Nielsen (1985) found the major source of occupational exposure to toxic chemicals to be in agriculture. Due to the nature of their work, enforcement of protective clothing regulations is often impossible. Many pesticide applicators work individually on their own property or for independent farmers and are not under the supervision of environmental professionals who would normally monitor such activities.

Zach Mansdorf, president and chief health scientist of S.Z. Mansdorf & Associates Inc., believes that more must be done to help employers and employees understand the hazards of the work place. He feels the responsibility for education rests with the hazardous materials suppliers and protective clothing manufacturers as well as the employer ("Advancing the," 1990). In an interview with Breisch (1990), Mike Fagel, corporate safety director at Aurora Packing Company, Inc., stated that "it is our responsibility to offer a safe and healthy environment so our employees can leave work in the same condition they arrived. That is not only our legal obligation, but it is also our moral obligation" (p. 63).

Benefits of Disposable Protective Clothing

Reusable protective garments are usually job specific and often very expensive (Gabele, 1989). They are durable but, in many cases, not very comfortable since they may weigh from five to fourteen pounds each. After use they must be properly decontaminated and any chemical residue properly disposed. In certain situations these garments are necessary, but in many cases disposable garments are equally acceptable. A recent study combining field and laboratory testing of disposable Tyvek® and reusable treated twill protective coveralls found the garments made from Tyvek® offered better protection from test pesticides than the reusable garments (Nigg, Stamper, Easter, Mahon & DeJonge, 1990).

One of the reasons disposable garments have become a popular form of protection is that the cleaning of permeated materials isn't always effective (Minetos, 1988). Workers may be re-exposed when they put the garments back on (Laughlin, 1990). Knowing if a piece of protective clothing has been decontaminated is difficult and sometimes impossible (Minter, 1987). This problem is especially prevalent with agricultural pesticide applicators since their garments are usually laundered in the home (Crown & Rigakis, 1989; Keeble, 1988). Use of disposable garments eliminates this problem and often saves considerable money on cleaning and decontamination costs while providing acceptable barrier protection (Martin, 1987).

Work with some hazardous substances, such as asbestos or PCB hydrocarbons, requires contaminated garments to be disposed of rather than processed in home or commercial laundries (Goldstein, 1985). In these situations disposable garments are the only reasonable cost effective alternative. Sometimes limited-use garments are worn over more expensive protective gear to prevent the contamination of the expensive garment and avoid costly decontamination. Worker productivity is also an important cost factor. Protective garments must be easy to put on over regular clothing yet not be so bulky as to hamper job performance or produce risk to the wearer (Kelly, 1989). Some conventional protective garments weigh as much as 14 pounds whereas a typical Tyvek® garment weighs less than one pound. Wearers of limited-use garments report feeling less claustrophobic in a limited-use garment (Goldstein, 1985) than in conventional types and thus are potentially more productive.

Product Certification and Standards

The Safety Equipment Institute (SEI), a non-profit organization that oversees voluntary, third-party testing procedures that verify a product's integrity and assures workers the best possible equipment, works to encourage customer confidence in safety products through its certification program (Katzel, 1985). SEI is involved in product certification rather than developing standards. Initial certification is granted after product testing and is followed by an on-going program of quality assurance audits. Rigorous performance tests are based on design and performance criteria which use the best available published standards that have been developed and approved by organizations such as the American National Standards Institute (ANSI), the Industrial Safety Equipment Association (ISEA), and the American Society for Testing and Materials (ASTM). The quality assurance audits are conducted at least once a year at manufacturing sites to assure that all products are made with the same attention to given quality as the originally tested items. Once a product has been certified, the manufacturer may affix the SEI label to the product and use the certification in advertising.

The current ANSI/ISEA 101-1985 standard for size and labeling of limited-use disposable protective coveralls was developed by the ISEA and approved by ANSI in 1985. A standard did not exist previously and there was considerable confusion among coverall buyers as to what a standard size actually was (Smith, 1987). Under the SEI procedure, all coveralls must meet uniform sizing, labeling, and packaging requirements. Each garment is measured and must meet minimum dimensions in the chest, leg inseam, sleeve outseam length from center back point, body length, sleeve opening, leg opening, and finished front opening length (Appendix A).

Fit and Body Movement

Garment fit has been described as the relationship between the size and shape of the garment and the size and shape of the body (Shishoo, 1990). Kallal (1985) described it as the garment form in relation to the structural human form. This can be clarified by thinking of fit as the relationship between the shape of the garment and the contours of the body wearing the garment.

Consumer dissatisfaction with garment fit is a major industry problem that is not restricted just to protective clothing (LeBat, 1987; Sieben, 1988). Physical dimensions of the garment often do not correspond to body dimensions to provide the desired comfort and appearance (LeBat, 1987). Traditional methods used by consumers to deal with fit problems include selecting separates to fit individual body shapes better, consistently selecting clothing from a manufacturer that makes items for their body type, having alterations made to ready-to-wear, or having custom sewn clothes where patterns have been altered to reflect body proportions. None of these options are viable for limited-use protective clothing.

Although largely subjective, fit can be evaluated by two criteria: appearance and comfort. Standards are available in most clothing construction books that provide guidelines for appearance. Comfort is a more difficult concept to identify and it is subject to the experiences of the person wearing the garment (Laing and Ingham, 1985). Sontag (1985) described physical comfort with respect to clothing as

> a mental state of physical well-being expressive of satisfaction with physical attributes of a garment such as air, moisture, and heat transfer properties, mechanical properties such as elasticity and flexibility, bulk, weight, texture, and construction. (p. 10)

This research looked at comfort in terms of mechanical properties as they influence fit but excluded thermal properties.

Comfort is often cited as the ability for the body to move in the garment without restriction (Clulow, 1983; LeBat, 1987). Garments that bind or restrict, as well as those that are too large, affect safety as well as comfort. A crotch length that is too long may prevent workers from moving quickly or may tear and leave them unprotected. Sleeves that are too long or too wide may catch on equipment and pull workers into moving parts of machinery. For protective clothing, proper fit becomes imperative to the protection of the worker. Fuzek (1981) found that fit was the most important factor in the subjective evaluation of comfort. Jobs involving extensive physical activity require fit for comfort and ease of movement (Farmer & Gotwals, 1982). Clulow (1983), Eiser (1988) and Henry (1980) all found that if protective clothing is not comfortable, the worker will find excuses for not wearing them.

Fourt & Hollies (1970) reported several studies on the individual energy costs of physical activity. They pointed out that both the weight and fit of clothing add to the personal energy costs of performing any activity. The more the body must work against the clothing, the greater the person's energy costs. Heavy protective clothing places demands on the body metabolism which increases the energy expenditure associated with simply wearing the garments (Rosenblad-Wallin, 1985). If people are unable to perform their jobs well while wearing protective gear, they are unlikely to wear it (Minter, 1987).

Commercially made garments are traditionally fit on a non-moving, rigid body form, however humans rarely spend time in this stationary stance. Heisey, Brown, and Johnson (1988) described two types of fit, structural and functional, in their paper on the theory of three-dimensional pattern drafting. Structural fit is described as that which accommodates the dimensions of the stationary body and functional fit is defined as the fit that accommodates the body during the motion and activities of the wearer. Gordon (1988) used the terms "static" instead of "structural" and "dynamic" instead of "functional" in describing the two types of fit. The terms, "static fit" and "dynamic fit", will be used throughout this research.

An understanding of the body movements that affect fit, particularly dynamic fit, is important when researching literature related to fit. Work related activities require a variety of motions by the various body parts. Terms that describe body movement include flexion, extension, abduction, adduction, circumduction, and rotation. Body movements that occur at joints are referred to in terms of starting from and returning to the anatomical position, the basic stature (Fig. 2.4) where one stands erect with legs straight, feet flat on the floor, heels together, and the arms hanging straight down with the palms forward (Kroemer, Kroemer, & Kroemer-Elbert, 1986; Watkins, 1984). Body movement is then described in reference to this position and in terms of three bisecting planes and the axis of rotation of the body (Fig. 2.5) (Huck, 1988; Kallal, 1985; Kroemer, et al., 1986; Watkins). The planes divide the body from front to back (frontal), left to right (sagittal), and into upper and lower sections (transverse). Watkins described the axes as "lines around which motion occurs. It may be easiest to think

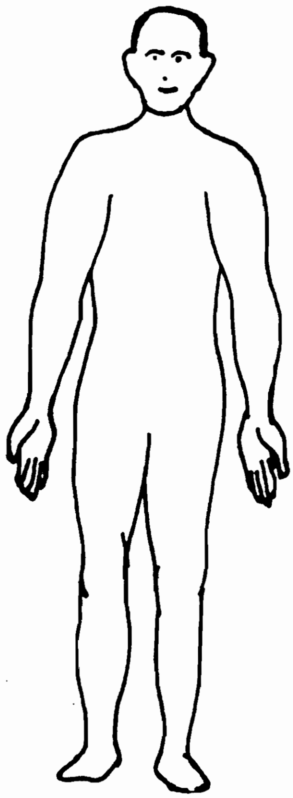


Figure 2.4. Anatomical Position.

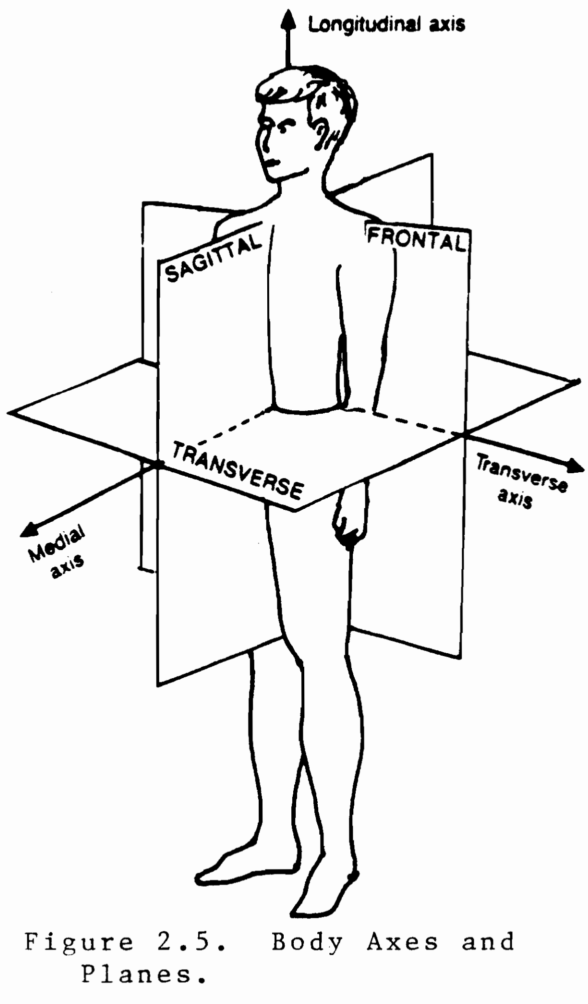


Figure 2.5. Body Axes and Planes.

of them as pins or rods passing through a body joint in a specific direction" (pg. 147).

Flexion is bending, extension is straightening, abduction is movement away from the midline of the body while adduction is movement toward the body. Circumduction can be thought of as a cone like movement with the point of the cone being a joint. Rotation occurs when a body part moves around its own axis. An example of rotation is the hand movement when it rotates from facing front to facing back. These terms in combination with the plane and the body axis form a descriptive terminology for any body movement. Kallal (1985) provides the following description of body movement.

> The movement of the body unit and its segments is produced by the forced motion of bones at joint articulation points. The direction of body limb movement is dependent upon the joint type involved. The hinge joints of the elbow and knee permit flexion (bending) in only one direction. Flexion also occurs at the neck, shoulder, spine, and hip, but usually in more than one direction. In addition, body segments rotate at the neck, shoulder, trunk (waist), and elbow. The shoulders can be elevated or lowered. Circumduction occurs at the neck, shoulder, waist hip, wrist, and ankles.
>
> Movement of the limbs creates simultaneous changes in their length and circumference. When you flex your elbow or knee, these joints each lengthen about 35 to 40 percent. Elbow circumference increases an average 15 to 22 percent, whereas knee circumference increases an average 12 to 14 percent. Reaching forward extends the back about 13 to 16 percent while the seat increases about 4 to 6 percent. (p. 75).

These changes in the body that result from movement provide the basis for establishing and incorporating ease into garments. The location and amount of movement necessary to function must be considered when determining garment dimensions and functional ease based on body dimensions. Use of the scientific terminology for body movement gives the researcher a descriptive picture of what is happening. However, since the terminology is not common in the lay person's language, it is not necessarily the best method to use when explaining body movement to subjects participating in a research project.

Fit and Sizing of Limited-Use Protective Coveralls

It is necessary for the fit of protective clothing to provide enough ease to allow for the needed range of motion without restricting body movement. Sizing systems designed for both males and females have unique problems due to the varied body types. In early attempts at integrated (male and female) sizing systems the female often was considered a scaled down version of the male. The dimensions most likely to be adjusted were height and body segment lengths (Robinette, Churchill, & McConville, 1979). Analysis of anthropometric data from their research showed that for nearly 80% of the dimensions under study, the scaled-down male did not represent the female and often more problems were created than solved. Two of the studies available for review on integrated sizing systems were conducted for the military (Robinette, Churchill, & Tebbetts, 1981; Gordon, 1986); both investigated separated upper and lower body garments rather than one-piece coveralls. Robinette et al. (1981) found that identification of the key body dimensions used in garment sizing are crucial to the success of any sizing program. Two descriptive dimensions of the intended user are usually required, one to control the vertical variance and one to control the horizontal variance (Robinette, 1986). Shoulder circumference was found to be much more critical to the fit of a shirt than chest or hip circumference, so shoulder circumference and stature were selected as the key dimensions for upper body garments. Since the waist could be adjusted, hip circumference and crotch height were found to provide the best indicator of size for lower body garments. The Army selected a 20-size system as the best to significantly reduce fit problems on integrated sized garments (Gordon, 1986). Both Robinette and Gordon also determined that instead of the customary single master pattern that is graded to all sizes in the system, the integrated system required three master patterns graded to different ranges within the one sizing system. This information about the multiple master patterns is presented only as a background for the development of integrated sizing systems and not as information integral to the proposed research project.

Sizing problems for protective clothing are more serious than those for traditional clothing since poor fit can be hazardous as well as hamper the worker's performance (Robinette, 1986). In a survey of 468 users of protective equipment conducted by the Human Factors Subcommittee (F23.51) of the ASTM Committee on Protective Clothing (F23) approximately 55 percent of the respondents reported that fit of garments affected their performance (ASTM, 1989). The problems they most frequently reported with coveralls were tearing and ripping of the garment, excess material bulk, restricted overhead reach, and problems with ascending/descending ladders/stairs.

Light weight, good fitting garments often result in better worker morale and increased productivity (Goldstein, 1985). Smith (1987), who is affiliated with SEI, reported that before the adoption of the current ANSI/ISEA standard

> there were some sub-standard products being marketed, and by cutting corners on the size, workers were not assured of a good fit. In a potentially hazardous situation, where performance of the coveralls is vital, the seams of an incorrect size garment may split when movement takes place, exposing the worker to the hazard. Also a wrong size garment could restrict a workers movements - a potential cause of additional risk. (p.55).

DuPont revised the recommended sizing scale to include seven sizes and requires all manufacturers who make garments using the Tyvek® trademark and meeting ANSI sizing standards to include a height/weight chart with each case of garments. This chart gives consumers access to information on the recommended size coverall for their body dimensions (DuPont H-24827, 1990). DuPont claims that a better fit means better protection. Their effort to expand the sizing scale to seven sizes is evidence of the need for the expanded ANSI/ISEA sizing standard. Problems resulting from the current ANSI/ISEA five size scale could be construed as problems with Tyvek® garments and not the sizing. DuPont wants to avoid implications detrimental to the reputation of Tyvek® and puts the following disclaimer on the height/weight sizing chart that accompanies garments made from Tyvek®: "This chart is a guide for garment selection, but proper fit varies with individual body shape and underclothing. Test for proper fit before use. Garment performance depends on selecting appropriate size" (Appendix B).

The problem of fit in limited-use coveralls is compounded by the fact that the sizing system must fit both the male and female population. Alterations are not a viable option, these garments are available as one piece coveralls rather than separates, and although made by several different manufacturers, all are made to the same sizing standard and are usually purchased in bulk by the employer regardless of body types of employees (wearers of the garment.) Also, Tyvek® and other barrier fabrics are not generally available to consumers in the form of yard goods. Alterations, other than shortening arms and legs by cutting off excess length, are not cost effective since alterations are expensive relative to the cost and the limited-use/disposability of the garments. Also, seam allowances, generally 1/4", are not adequate for letting out the garment.

The loose style of the coveralls (see Fig. 3.1) alleviates some of the fit problems, but body measurements must still be considered. In addition, the coveralls use alpha sizing (ie. S, M, L, etc.) rather than numerical sizing (ie. 34, 36, 38, etc.). Manufacturers often try to fit everyone into a limited set of sizes (Robinette, 1986) which is obviously advantageous in regards to inventory and record keeping. As a result, each size designation must fit a larger proportion of the population. The current sizing standard defines five sizes ranging from Small (S) to Extra, Extra Large (2XL); the proposed revision will expand the sizing designation to include seven sizes from Extra Small (XS) to Extra, Extra, Extra Large (3XL). This revision is an attempt to improve fit that results when a smaller proportion of the user population are included in each size designation.

A common problem with limited-use garments are tears that result from poor fit or from catching on projections. The tendency for many workers is to ignore the tears and continue working (Ashdown, 1989). A tear provides ventilation which allows the worker to be cooler but decreases protection. Mending the tear with duct tape, as is the common practice, is time consuming and interrupts the work process. OSHA not only requires employers to provide workers with protective clothing if they are exposed to asbestos, but also that a "competent person" be at the worksite to periodically examine clothing for rips and tears, and to mend with tape or replace that clothing when necessary (Conforti & Grunberg, 1987).

Fit Evaluation

The initial step to any fit evaluation project is a scientific method of measurement. Anthropometry provides standard terminology and measurement methods (Kroemer, et al. 1986). Procedures, definitions, illustrations, and anatomical landmarks used for measurements can be found in the Anthropometric Source Book published by NASA (1978). Landmark definition or interpretation may differ slightly unless all measurers (anthropometrists) are highly trained (NASA, 1978). Anthropometric measures are traditionally taken and reported in the metric system (Kroemer et al.).

Since there is often very little correlation between major definitive body dimensions such as chest girth and body length (Kroemer, 1989), it is necessary to measure the wearer in a variety of body areas. Sizing scales based on that anthropometric data are developed in an effort to satisfy a wide a range of wearers. The need to define a sizing scale that provides adequate fit for both males and females compounds the problem. Anthropometric tables and the current sizing standard for protective clothing define body measurements and garment dimensions that are used for size definition.

Anthropometric fit testing (hands-on fit testing) is the most reliable means of determining the correct dimensions for protective clothing designed to meet a specific need (McConville, 1986). If the item being tested is designed for a variety of uses by many different subjects then the test should take place at several sites and with a wide variety of subjects. If the item is designed for a specialized population, then the test garments should be worn by members of the user population who are knowledgeable about the item being tested and are able to wear the item under the conditions for which it was designed. McConville separated the fit test into three phases: 1) preparation, 2) testing and evaluation, and 3) analysis and reporting. During the preparation stage, a sample is selected from the user population if possible. A test sample of at least 20 subjects is preferable but if availability of appropriate subjects is a problem, then McConville recommends at least three to five subjects for each size of the test item. This sample group should cover 90 to 98 percent of the body size variability for the anthropometric variables of interest.

Variables of interest in the fit of the item should be examined. McConville (1986) recommended selecting the two variables that best define the size and constructing a bivariate table so that the representativeness of the sample can be monitored. Height and weight are the two variables used by DuPont for determining the sizing chart for Tyvek® limited-use coveralls.

Anthropometric fit tests often employ two data forms (McConville, 1986). One is used to collect biographical and physical data on the participant. The other generally seeks subjective information concerning the fit of the garment. Construction of the questionnaires requires careful planning in order to design clear, comprehensive, easily completed forms. McConville advocated leaving space for user comments about the test item. He also stressed the importance of checking the sizes of items being tested if the items are prototypes since, due to their developmental nature, prototypes have a higher incidence of mislabeling and are more likely to deviate from standards than regular production items.

Working with a team of investigators during testing and evaluation is recommended for improved accuracy (McConville, 1986). A procedure that starts with briefly explaining the project to each subject, though repetitive, puts the subject at ease and gains his or her full cooperation. One investigator then measures the variables of interest while the other one records them. The recorder locates the subject on the prepared bivariate table to determine the proper size garment for testing and to keep a record of the distribution of subjects within each division on the bivariate sizing table. Once the subject has been assigned a proper garment, he or she dons the garment in the manner in which it will be worn in the field. That is, if it is to be worn over other clothing, then it is tested in that manner. The subject is then led through an exercise protocol representative of the actual user situation. The investigators watch for indications of restricted ability or mobility such as stress lines on the garment. Although a camera is not essential, McConville highly recommends it as a means of documenting and illustrating the findings. Once the subject has conducted the fit test, debriefing can be achieved by using a questionnaire about the test item's performance.

The final phase of McConville's (1986) fit test is the analysis and reporting. One step of this is documenting the representativeness of the sample by analyzing the original bivariate table. The other is assessing the acceptability of the item. Whenever possible, he recommends quantifying the data. One way of doing this is to record the number of participants who judged the fit to be good or poor; another is to calculate the percentage who were not well fitted within their size range. In addition to reporting the findings, McConville believes the investigators should recommend modifications that would improve the fit and function of the tested item. It is then up to the manufacturers whether or not they act upon these recommendations. Gordon (1986) recommended a similar procedure for fit testing. She emphasized the importance of collecting dimensional data on the test garments prior to testing for the purpose of quality control. Qualitative and quantitative data are necessary for both static and dynamic fit. Static fit is judged by how well the garment fits when the subject is in a stationary stance while dynamic fit is judged by how well the garment fits when the subject is performing task related movements.

Several other published studies also use task related movements as the basis for evaluation (Ashdown, 1989; Crow & Dewar, 1986; Henry, 1980; Huck, 1988; Johnson & Stull, 1988; Keeble, 1988; Kirk & Ibrahim, 1966; vanSchoor, 1989; Watkins, 1977). Ashdown studied the movements of asbestos abatement workers in a training session, an actual removal project, and a laboratory setting in order to discover problems associated with protective coveralls. She made design modifications to the garments based on observations and conducted field and laboratory testing on the redesigned items.

The study by Crow & Dewar (1986) focused on seam strength. They used a series of body movements and stances designed to determine where maximum stresses on seams occur as well as the stresses occurring when the subject donned the garment. One of the garments used for evaluation was a one-piece coverall. Body positions found to produce maximum stress for the upper body portion of the garment were arms crossed in front with the hands on opposite shoulders and, for the lower portion of the garment, squatting. They also found that the degree of stress put on clothing was related more to muscular development than hip or chest dimensions.

Huck (1988), using a series of body movements to evaluate joint mobility, investigated various types of fire fighter turnout gear. The measurement of restriction to joint mobility determined the effect of the garment design on body mobility.

The relationship between skin extensibility (stretch) during body movement and garment fit was the subject of research conducted by Kirk & Ibrahim (1966). The amount of strain on the fabric was evaluated by the actual amount of skin extension. The critical strain areas identified on the body were the knee, the seat, the back, and the elbows. The evaluation of stretch fabrics and their relationship to comfort and fabric performance was the object of the study. Johnson and Stull (1988) evaluated the integrity of totally encapsulating chemical protective (TECP) suits, those that completely encapsulate the worker and include a head covering with face mask, a breathing apparatus, and hand and foot covering in addition to the body coverall. They are generally not disposable. The integrity of the suit must be maintained during use if a high degree of safety for the worker is to be assured. This study was conducted in conjunction with the U.S. Coast Guard, the U.S. Occupational Safety and Health Administration, and the U.S. Fire Administration.

An exercise protocol was developed to test the reliability of the TECP suit in a laboratory setting. The exercises were designed to represent typical work related movements (J.O. Stull, personal communication, July 2, 1990). Standing in place was used to evaluate the static integrity of the TECP suit. A series of four exercises were specified for determining the dynamic integrity of the suit. These included: 1) raising the arms above the head, completing at least 15 raising motions per minute, 2) walking in place, completing at least 15 raising motions per minute of each leg, 3) touching the toes, making at least 10 complete motions per minute of the arms from above the head to the toes, and 4) performing deep knee bends, making at least 10 complete standing and squatting motions per minute. This protocol was used in the development of an ASTM Standard Practice for chemical leak rate. The resulting standard, ASTM Standard Practice F 1154-88 for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles, uses a variation of the original exercise protocol.

A survey conducted by vanSchoor (1989) and used in the design process of disposable protective coveralls for pesticide applicators in agriculture found the most common activities of the intended user were bending, climbing on machinery, sitting, walking, squatting, turning, and donning and doffing the garment. These movements were verified for that study by field observations and by viewing films of pesticide application.

DuPont developed an exercise protocol consisting of seven test movements for licensing purposes on garments made of Tyvek® (A.M Torrence, personal communication, December 18, 1989). Requirements for licensure involved having an independent laboratory test garments using the following exercise protocol:

1) Kneel on both knees, lean forward and place both hands on the floor 18" in front of knees. Crawl forward 10" on hands and knees.
2) Climb ladder at least four steps
3) Position hands at chest level with palms out. Reach directly overhead, interlock thumbs, extend arms fully.
4) Kneel on right knee, place left foot on floor with left knee bent 90 degrees. Touch thumb of right hand to toe of left shoe.
5) Extend arms fully in front of body, lock thumbs together, twist upper body 90 degrees left and right.
6) Stand with feet shoulder width apart, arms at sides. Raise until they are parallel to floor in front of body. Squat down as far as possible.
7) Kneel as in Movement 4, left arm hanging loosely at side. Raise left arm fully overhead.

DuPont required two complete size sets of each garment to be submitted for testing. One garment of each size would be tested. If one tear occurred during the testing of the first garment the second garment of each size would be tested. The garments passed if no tears occurred. If more than one tear occurred while testing the first set of garments or if any tears occurred while testing the second set of garments, the garments failed the test and permission to use the Tyvek® trademark would not be granted.

Product use testing for protective equipment design has also been conducted in sports-related situations. Watkins (1977), studying the protective equipment worn by hockey players, viewed body movements in training and game films, and replicated them in the laboratory. The resulting data on joint movement was used for making design decisions about new equipment.

In her textbook on functional clothing, Watkins (1984) illustrated the use of wrinkle analysis as a method of collecting data on the fit of clothing. The subject assumes the work related position and the researcher notes the location and type of wrinkles that result from the stress and strains on the garment. These wrinkles can provide considerable information for the trained observer. They point to the area causing the problem and the type of wrinkle (loose or taut folds) provides information regarding the cause of the problem.

These studies show that some research involving body movement for fit evaluation involves a generalized series of movements whereas other research uses movements specific to the task for which the garment is designed. Most of the research on movement studies involve existing articles of clothing rather than prototypes (Ashdown, 1989). Use of wear testing in the design process and for the evaluation of prototypes can be very cost effective by solving potential problems before they have a chance to materialize. Results of these tests can be used to recommend modifications that improve the fit and function of the item. If the problem does not become apparent until the item has been manufactured, then the measures to correct it are often "quick-fix" or "band-aid" procedures that seldom hold up over the life cycle of the item (McConville, 1986). Thus having actual users of the garment involved early in the production process can be beneficial to the manufacturer as well as providing improved products for the user.

Product Development

Consumer satisfaction is important in the adaptation and use of protective clothing (Coletta, 1985; Fraser & Keeble, 1988; Eiser, 1988; Lloyd, 1986). Fit of garments is consistently listed as being of primary importance to consumers (Bergeron & Carver, 1988; Hogge, Baer, & Kang-Park, 1988; Lebat, 1987; Sieben, 1988). The obvious reason for this, according to LeBat, is that the physical dimensions of the garment do not necessarily conform to those required by the body. If consumers are to be satisfied, this problem of fit must be addressed and the optimum time to do this is prior to garment production (McConville, 1986). Rosenblad-Wallin (1985) related consumer satisfaction to product development in her "user-oriented product development theory" which provides for systematic product design based on demands of the user and the use-situation. Both functional and symbolic values of a product are considered in the analysis of use-demands. The symbolic values of clothing are reflected in the impressions the clothing imparts to the wearer and the observer. Important values clothing should offer include self-esteem, respectability, group-membership, status, and confidence.

Implementation of Rosenblad-Wallin's (1985) theory begins with a detailed list of demands gathered from a combination of objective and subjective data on the user and demands arising from the use situation. These demands are then classified as variables and assigned priorities from the standpoint of importance; the most important are then transformed into specifications of the respective demand. Although symbolic values are often difficult to measure they must be kept in mind during the product development phase. Rosenblad-Wallin emphasized that as functional demands become more important, the symbolic values become less important. After the development of ideas, the solution is evaluated and modified and a prototype made. Final evaluation completes the process. This method of product development differs from conventional product development which generally starts with market need and typically deals with consumers as buyers, their choices and preferences, and the exchange value of the product.

Product planning with the end-user is an accurate way to predict and fulfill the needs of the consumer (Kincade & Cassill, 1989). While working on a "product development model", Gaskill (1990) found that understanding the customer was of primary importance since knowledge of that customer drives all product development. User-oriented product development deals with the users, the use demands, and the use value of the product (Rosenblad-Wallin, 1985). In research focused on the future survival of the apparel industry, Kincade (1991) found that an important strategy was for the manufacturer to get involved with the customer and that success of a product could be improved if the product was planned with input from them.

A panel of practicing human factors professionals discussed the challenges of applying human factors to the design of commercial products at the 33rd Annual Meeting of the Human Factors Society held in 1989. Employing human factors in the development process involves two objectives: functional effectiveness and human welfare (Sanders & McCormick, 1987). Fisher (1989) defined the role of human factors in the design process as the responsibility for ensuring that the product is usable. Testing to confirm the usability objectives then becomes a part of the product development cycle. Hoffman (1989) suggested borrowing the marketing technique of pre-released products to allow working with users of a product. Exploring new product design concepts with customers would allow consumer input during the design phase so that user comments and needs could be an integral part of the product design.

The opinion of Watkins (1989) in a paper on basic human needs supports the role of research in product development. She feels that

> home economists, as individuals who are concerned about human survival, have a responsibility to work not only toward research that will help establish effective design development but toward conditions in which ultimate users, e.g., workers, are actually protected" (p. 20).

Starting the design process with worker's needs insures that actual protection is one of the design objectives. The position paper by Pedersen (1989) on clothing as a basic human need refered to Maslow's hierarchy of needs which starts with the need to satisfy the body's basic physiological requirements for existence and is followed by the need for safety. Protection from environmental risks is fundamental for the safety of the worker. When occupational hazards require the use of protective clothing the functional design process can improve the safety of the worker by providing maximum function and comfort (Shannon, 1987).

McConville (1986) also supports the concept of user needs in product development. He maintains that using anthropometric tests early in the development cycle improves the fit and function of the item. Waiting until the item has been produced results in last-minute, "quick fix" solutions. These solutions often shorten the life cycle of the item and result in costly and time-consuming resizing or redesign (McConville). Ashdown's (1989) research illustrated this. Asbestos removal workers tape their garments with duct tape to make them fit. This results in a distortion to the design which may inhibit its ability to allow easy movement or even its protective ability. One of the major problems she found with limited-use garments was the problem of tears. Taping of garments could very well contribute to this problem by creating garments that are too tight in some areas or garments with projections of loose fabric that easily catch and tear, thus reducing the function of the garment.

The manufacturing cost and the user cost of the garment are both important considerations in the production of protective clothing. Litchfield (1988) noted that garment cost often takes precedence over the more critical safety aspects. A user preference study conducted with agricultural workers indicated that when all facts about protective garments were known, the wearers were more influenced by the cost than the protective properties or the comfort (Litchfield). The costs of raw materials and production each contribute to what the user must pay. Determining the minimum number of sizes that will adequately cover the needs of the population helps keep manufacturing costs down by reducing the amount of required inventory. Fit requirements directly affect the span of the size range and, consequently, the total number of required sizes that will satisfy the needs of consumers.

Summary of the Problem

Protection and comfort are the most important functional values of protective clothing (Rosenblad-Wallin, 1985). These contributing factors include protection from the environment and fit. The adaptability of the clothing to body movement and the pressure of the clothing against the body are factors in fit comfort. This research project is designed to investigate the fit of limited-use protective coveralls in an effort to improve their wearability and therefore, their acceptability. LaBar (1990) pointed out that acceptability is important since the real level of protection is determined by whether or not employees can be motivated to wear protective equipment. This research does not involve the designation of sizes or the original design of garments (and master patterns) but only the fit of garments manufactured to the proposed revision to ANSI/ISEA 101-1985 sizing standard.

CHAPTER III

STATEMENT OF THE PROBLEM

Worker safety is a major concern in many industries. Contact with hazardous chemicals or dangerous materials requires the use of protective clothing if workers are to be safeguarded from these environmental risks. An important contribution to a worker's performance is body flexibility which is directly affected by garment fit. If protective clothing is to be effective in shielding workers from harmful environmental exposure it must be wearable (Watson, 1989). Restrictions on body mobility not only make simple tasks more difficult, but they increase the energy costs of work (Veghte, 1989). Workers may risk exposure rather than wear clothing that inhibits body mobility.

Garment fit reflects the relationship between the size and shape of the garment and the size and shape of the body (Shishoo, 1990). Garment ease is the difference between the dimensions of the body the garment is designed for and the actual dimensions of the garment. The function of the garment determines the appropriate amount of ease. Sizing specifications for limited use coveralls include the amount of ease the Industrial Safety Equipment Association (ISEA) considers necessary for a person to function while wearing the garment. Appropriate fit for the task requirements is fundamental to user satisfaction.

Consumer complaints have indicated the need for a revision in current sizing of protective clothing. A survey of users of protective equipment conducted by the Human Factors Subcommittee (F23.51) of the American Society for Testing and Materials (ASTM) Committee on Protective Clothing (F23) revealed that approximately 55 percent of the respondents reported that fit affected their performance (ASTM, 1989). ISEA has recommended a revision of the current sizing specification -- ANSI/ISEA 101-1985 Men's Limited-Use & Disposable Protective Coveralls - Sizing & Labeling Requirements (Appendix A). A sizing scale based on height and weight and covering seven sizes from Extra Small (XS) to Extra, Extra, Extra Large (3XL) has been proposed (Appendix B). This expansion to the sizing standard is an attemp to fit a broader range of consumers which includes women and large sized men. These limited-use protective coveralls are available in three predominant styles: a set-in sleeve, a raglan sleeve, and a yoke with cut-on sleeve (Fig. 3.1). Each style is made by a different manufacturer. All have long sleeves, a convertible collar and a front zipper. Although all styles are sometimes made with elastic at the wrists and ankles, the ones specified in the ANSI/ISEA 101-1985 Sizing Standard have straight sleeves and legs with no elastic.

The ASTM Committee F-23 on Protective Clothing is interested in promoting worker safety through the use of protective clothing and their F-23.51 Human Factors Subcommittee has been considering the need for the sizing revision. At the January, 1990 meeting of that committee it was reported that ISEA was in the process of revising their standard on the sizing of men's coveralls. A portion of the minutes of that meeting read:

> Members expressed a desire to evaluate the fit of coveralls made to either the existing ISEA standard or the revised one. The objectives would be to compare body measurements of both men and women to garment measurements, to evaluate the fit of the coverall that people selected for themselves as compared to the correct size, and to examine coveralls with set-in, dolman (yoke with cut-on), and raglan sleeves.

This research was designed to respond to the needs expressed by ASTM F-23.51 Human Factors Subcommittee on Protective Clothing.

Purpose

This study was designed to evaluate the fit of limited- use protective clothing manufactured to the proposed size revision of ANSI/ISEA 101-1985 Men's Limited-Use & Disposable Protective Coveralls - Sizing & Labeling Requirements. The end purpose was to make recommendations for improving fit of limited-use coveralls thereby increasing their wearability and, therefore, their acceptability.

Objectives

The objectives for this research were:

1. To identify key body measurements needed to select protective clothing manufactured to the proposed revision of the ANSI/ISEA 101-1985 sizing standard.
2. To evaluate the static and dynamic fit of protective clothing manufactured to the proposed revision of the ANSI/ISEA 101-1985 sizing standard.

3. To determine minimum, maximum, and optimal garment ease required for satisfactory fit.
4. To determine the effect of sleeve style on the fit of protective clothing.

Assumptions

The following assumptions were made relative to this research:

1. The size range defined by the proposed revision to the ANSI/ISEA 101-1985 sizing standard adequately covers the user population.
2. Features of the coveralls from all three manufacturers are the same except for the sleeve style.
3. The motions in the fit test are representative of typical body movements that occur in actual work situations.

Limitations

Limitations of this research include:

1. The population being sampled is not necessarily the user population of the protective coveralls.
2. The population, although representative of Virginia, is not necessarily representative of the remainder of the United States.

3. Manufacturers are responsible for making their own patterns, therefore, strict adherence to exact sizing specifications could not be controlled.
4. Due to limitations of equipment and space, not all subjects were video taped.

Delimitations

The scope of this research does not include chemical, biological, or physical protective properties of the fabric used for limited-use protective coveralls. Neither does it involve research of the design process or the modification procedures for the design of the garment except for looking at the effects of the three sleeve styles. Other delimitations included:

1. Fit is subjective and closely related to comfort. Thermal comfort is not addressed in this research project, however, thermal discomfort may bias subjective feelings on fit.
2. Test environments were not controlled since garments will ultimately be worn in a variety of environmental conditions. However, thermal discomfort associated with the environment may have biased subjective fit ratings.
3. The type of street clothing particpants wore was not controlled since the protective coveralls were designed to be worn over ordinary clothes.

Operational Definitions

Design -- The styling details and shapes of the individual pieces making up a garment.

Dynamic fit -- The fit of the garment on the body when various body parts are in motion.

Static fit -- The fit of the garment on the body when it is in a stationary stance.

Key body-area measurements -- The dimensions specified in the ANSI/ISEA 101-1985 Sizing Standard plus measurements indicated in the literature as being definitive of body size. These include: height, weight, inseam length, arm length from center back, underarm length, shoulder girth, vertical trunk circumference, and chest, hip, waist, thigh and upper-arm (biceps) circumference.

Bivariate size specification -- The minimum and maximum height and weight for each size block in the sizing chart.

Garment ease -- The additional dimensions added to a garment beyond the exact body dimensions. The amount of ease is dependent upon the mobility requirements, the manner in which the garment is to be worn, and the style of the garment.

Maximum ease -- The maximum amount of ease allowable before the volume of the garment interferes with the body movements required for a job.

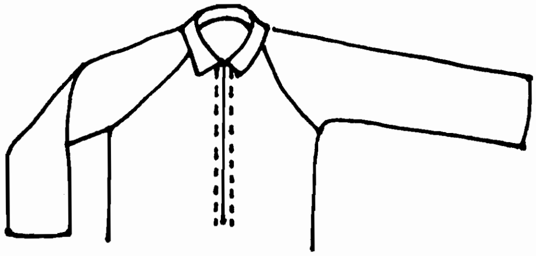
Minimum ease -- The minimum amount of ease necessary in order for a worker to be able to perform his job.

Optimal ease -- The amount of ease required for the wearer to feel comfortable in a garment and to be able to easily perform his job.

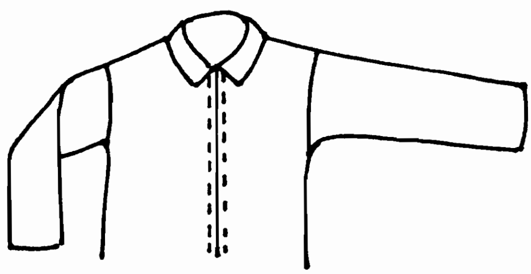
Raglan sleeve -- The style of sleeve that has an underarm seam and is attached to the body of the garment with a seam that runs diagonally from the underarm junction to the neckline in both front and back (Fig. 3.1).

Set-in sleeve -- The style of sleeve that joins the body of the garment at the shoulder joint location with a seam that runs completely around the armhole (Fig. 3.1).

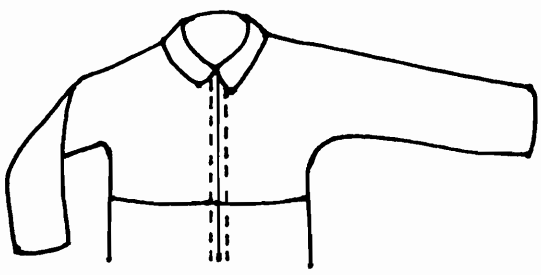
Yoke with cut-on sleeve -- The style of garment that has a yoke seam dividing the body of the garment into upper and lower portions. The sleeve is cut in one piece with the yoke so that the shoulder line is continuous from the neckline to the wrist edge and there is no seam joining the sleeve to the yoke (Fig. 3.1).



Raglan Sleeve



Set-in Sleeve



Yoke with Cut-on Sleeve

FIGURE 3.1. Sleeve Styles on Protective Coveralls.

CHAPTER IV

METHODS AND PROCEDURES

This research involved evaluation of the fit of limited-use protective coveralls. The garments tested were standard Tyvek® coveralls with zippered front, convertible collar, and no elastic at wrists or ankles. Three manufacturers supplied garments made to meet the proposed revision of ANSI/ISEA 101-1985 Men's Limited-Use and Disposable Protective Coveralls - Sizing and Labeling Requirements (Appendix B). Each manufacturer produced a different sleeve structure on the coverall. The styles tested were a set-in sleeve (SSlv), a raglan sleeve (RSlv), and a yoke with cut-on sleeve (YSlv) (Fig. 3.1). Limited-use coveralls are designed to be worn in a variety of situations under a variety of conditions. Therefore, the test methods used were designed to represent general work conditions with extensive body movements rather than a specific job related task.

A sample of subjects matching the height/weight range of each size in the proposed revision was selected. The goal was to have a minimum of 10 subjects per size covering

at least 90 percent of the body size variability within each size block.

Anthropometric methods were used to measure the subjects. Each participant donned the protective clothing and engaged in a wear test consisting of a series of exercises developed to represent typical work related body movements. The subjects then completed a survey designed to evaluate the garment for both static and dynamic fit. They repeated this procedure wearing the same size garment made in each of the three different styles. The objectives of the research provided the basis for analysis of the completed evaluation forms.

Garment Preparation

The test garments required a two step preparation before the actual wear test. First, since they were prototype garments, 40 percent were measured for all the dimensions specified by the proposed revision to the ANSI/ISEA 101-1985 sizing standard in order to determine the mean garment dimensions. The measurements specified on the sizing standard are chest, leg inseam, sleeve outseam length from center back point, body length, sleeve opening, leg opening, and finished front-opening length (Appendix A). Two additional measurements were taken for the purpose of evaluating fit based on body size. These were biceps taken 1" below the sleeve body intersection and thigh taken 1" below the crotch intersection. Both measurements were taken perpendicular to the outside folded edge (Appendix C). These two additional measurements were selected because the research of Crow and Dewar (1986) showed that stress was more a factor of muscular development than of body dimensions. All measurements were recorded on a peel-off sticker attached to the coverall.

Since each subject tested three garments, the second step was to randomize the order for wearing the garments. Systematic ordering of the garments is called counterbalancing (Keppel, 1973). This method increases internal validity and negates the effect of fatigue. Use of three items allowed two degrees of freedom, therefore, the total number of possible combinations was six. Table 4.1 illustrates this arrangement.

Balancing the order in which the three coveralls were tested spread the influence of uncontrolled variables associated with the garments equally over the trials. This also removed bias resulting from sensitization to the test procedure which occurs when responses to the second and third testings are affected by virtue of having previously completed the entire procedure (Huck, Cormier, & Bounds, 1974). The order was repeated as necessary to accommodate

TABLE 4.1.

Counterbalanced Arrangement of Test Items

Testing Order of Coverall Style*	
Trial 1	123
Trial 2	231
Trial 3	312
Trial 4	321
Trial 5	132
Trial 6	213

* 1 = yoke with cut on sleeve
2 = set-in sleeve
3 = raglan sleeve

the number of testings for each style. Each coverall was identified by its size, style, and trial number. This information was recorded on the sticker containing the dimensional information. For coveralls where dimensional data were not recorded, the testing order was placed on a sticker on the coverall. All three coveralls were placed in a 12 x 15 inch manilla envelope which was labeled with a packet number consisting of the size and the numerical order for that size (ie. packet number M9 was the ninth packet in size medium whereas packet number L9 was the ninth packet in size large).

Subject Selection

Agricultural workers were targeted as subjects for the study for several reasons. A survey of protective equipment users conducted by ASTM Committee F-23 on Protective Clothing Sub-committee .51 on Human Factors (ASTM, 1989) found that the largest percentage of respondents were involved with chemical handling or mixing. Research by Moraski & Nielsen (1985) found the major source of occupational exposure to toxic chemicals to be in agricultural settings. This research was conducted in conjunction with the Virginia Cooperative Extension Service.

The Agri-Tech Conference, held on the Virginia Tech campus July 12-13, 1990, was chosen for the initial testing because of the large number of attenders and the diversity of agricultural related occupations, as well as the racial and gender mix represented. This annual event was sponsored by the College of Agriculture and Life Sciences, Virginia Cooperative Extension Service, Virginia-Maryland Regional College of Veterinary Medicine, Virginia Agricultural Experiment Stations, and

Virginia's agricultural industries, businesses, and associations. Additional testing was conducted at Experiment Station Field Days, which are educational experiences sponsored by the Virginia Cooperative Extension Service and held within localized divisions. These field days were selected because their audiences tend to be people who regularly deal with pesticide application. Additional subjects were solicited directly because there were not enough volunteers wearing size XSmall and 3XLarge. Data collection at the College of Human Resources was set up for subjects not participating at the conferences. Data collection took place on the following days and locations:

July 11, 12	Agri-Tech Conference	Virginia Tech
July 31	College of Human Resource	Virginia Tech
August 23	Tidewater Field Day	Suffolk, VA
August 28	Virginia State Field Day	Petersburg, VA
September 19	Turfgrass Field Day	Virginia Tech
September 25	College of Human Resources	Virginia Tech

Subjects were recruited with a brochure given to conference attenders asking for volunteers who used protective clothing as well as those who had experienced problems in the fit of protective clothing. The participants in the study were given the three test garments to keep. By offering the garments as an incentive, participants tended to be individuals who used or had an interest in personal protective clothing. The sites for data collection included both air conditioned spaces and outdoor spaces thereby providing a variety of testing atmospheres.

Development of Exercise Protocol

The exercise protocol used for the wear test was developed from several sources and designed to incorporate typical work postures and movements. Limited-use coveralls are designed to be worn in a variety of situations under a variety of conditions. Therefore the exercise protocol was designed to represent common body movements rather than specific job related tasks. The exercise protocol included the following activities:

1. Stand in place.
2. Raise the arms above the head, completing at least 5 raising motions.
3. Walk in place, completing at least 5 raising motions of each leg.
4. Reach towards the toes, making at least 5 complete motions of the arms from above the head to the toes. While bending over, twist from side to side.
5. Perform deep knee bends, making at least 5 complete standing and squatting motions.
6. Stand erect, raise arms out to side, cross arms in front of body and place hands on opposite shoulders making at least 5 complete motions.

7. Kneel on one knee, place the opposite foot on floor with knee bent 90 degrees and arms hanging loosely at side; then alternately raise each arm fully overhead 15 times.

The first five exercises were adapted from the exercise protocol used by the American Society for Testing Materials (ASTM) in developing their method for testing the integrity of totally encapsulated chemical protective suits (ASTM Standard Practice F 11.54). They were selected for this standard because they encompass a wide variety of body movements and because they are brief (Johnson & Stull, 1988). Additional information was obtained through interviews with users of personal protective clothing. Originally Exercise 4 involved only reaching towards the toes. Twisting from side to side was added after the initial pretest with emergency squad workers indicated that environmental clean-up might also involve a sweeping motion or spreading absorbent materials on the ground. Exercise 6 was selected as a result of the research by Crow & Dewar (1986) which found the described movements to be those that created the most stress on the upper body garment. Exercise 7 was an adaptation of one designed by DuPont for use with Tyvek® garments (DuPont, personal communication, Dec. 18,1989).

The exercises also replicated the movements found by vanSchoor (1989) to be most representative of the activities reported by the pesticide handlers who participated in her research. Five repetitions were selected for each of the exercise activities. Since each subject would be required to repeat the exercise series three times (once for each garment), there was concern that some subjects would not be able to complete more than a total of fifteen repetitions for some of the exercises. Also, during preliminary testing, it was found that subjects who split or burst the garments did so within the first three repetitions of the exercises.

McConville (1986) recommended individual explanation to each subject so they would fully understand the nature of the project. Therefore, an instructional video that explained the project and demonstrated the exercise protocol was made for the participants to view. Use of this video put the subjects at ease and allowed more natural participation in the research project (McConville). Posters were also developed to aid participants in following the exercise protocol (Appendix D).

Data Collection

Two data forms were developed for each participant, the first to gather demographic and dimensional data (Appendix E). The second was a subjective questionnaire that allowed the respondent to evaluate each of the three coveralls worn during the wear test (Appendix F). The questionnaire was a Likert scale that assessed the quality of static and dynamic fit, the ability to move during the various exercises, the ease of donning the coverall, and the participant's perception of his/her ability to perform a job wearing the coverall. It also gave the participants an opportunity to make additional comments about the coveralls.

Pretest

The final step of preparation was the pretest which isolated confusing statements and ambiguous questions (Dillman, 1978). Open-ended questions on the pretest were used to pinpoint areas that had been overlooked. Also, giving the questionnaire to colleagues provided valuable feedback on the construction of the questionnaire. Two other groups ideal for pretests are potential users and those from the population to be surveyed. Each brings a different perspective to the process. Dillman recommended verbal feedback if possible because the respondents could explain any problems or questions they had.

The pretest of the exercise protocol was also important for logistic reasons. When more than one person works with several subjects simultaneously, the procedures can get out of hand. Running through the test ahead of the actual data collection phase can resolve some of these difficulties.

Two groups were selected for the pretest, a group of fire department volunteers who work with the emergency squad and a group of university lawn care workers. University colleagues also reviewed the questionnaire. Several changes were made including the addition of items and the rewording of others. One change was made in the exercise protocol as a result of feedback from the emergency squad personnel.

Testing Procedure

The research was conducted by three teams of investigative assistants. All participants were first assigned an identification number and given an Informed Consent Form to sign which briefly explained the research and informed the subjects of their right to withdraw from the wear test at any time (Appendix G). The first team collected demographic and dimensional data for each subject. One assistant measured the subject while another recorded the information. The information for each participant included their height, weight, identification number, whether or not they were users of protective clothing and, if they were, a description of their occupation and the frequency with which they used it. Body dimensions that were recorded at this time corresponded to the areas measured on the coveralls as specified by the proposed ANSI/ISEA standard. Measurements were taken over street clothing since that is how limited-use protective garments are normally worn. Inseam length, arm length, shoulder girth, vertical trunk circumference, flexed biceps circumference and thigh, chest, hip and waist circumference measurements were taken. The NASA Anthropometric Source Book (NASA, 1978) was used as a guide for taking the measurements (Appendix H). Shoulder girth was included in addition because Robinette (1986) found this girth to be more critical to fit than the traditional chest and hip measurements when working with integrated sizing systems.

The second team of investigative assistants assigned the protective coveralls to each participant based on the size indicated by their height and weight. If participants fell outside one of the size blocks (Appendix B) the size was determinde by the dimension that was greater than the size block. Generally, height was used if the subject fell above the size blocks on the bivariate chart and weight was used if the subject fell below the size block. The participant's identification number was added to the coverall identification sticker so that body dimensions could be paired with wear test information. The assistants instructed the participant on the testing procedure by showing the instructional video and answering any questions. This team recorded the participants height and weight on the bivariate chart indicating the size distribution (Appendix I, Fig. I.1). That allowed control to be maintained over the distribution of subjects. When any one area of the size distribution chart became over represented, volunteers falling within that range were no longer accepted. For any areas of the size distribution lacking sufficient representation, subjects were recruited on subsequent test days.

The third team of investigative assistants directed the exercise protocol and administered the questionnaire. Since more than one subject performed the exercise protocol at any given time, each subject had a designated area marked in which to carry out the requested tasks. There were from one to three exercise stations depending upon the data collection date and location. At least one assistant was assigned to each exercise area. Two video cameras were set up to video tape one of the exercise areas. One camera captured the subject from the side front and the other from the side back. McConville (1986) recommended photographs as an excellent means of documenting and illustrating test findings. The video allowed verification of the evaluations of each of the styles on the same subject.

No attempt was made to control the type of street clothes the participants wore other than the necessity for female participants to wear pants or shorts rather than skirts. The coveralls were designed to be worn over ordinary clothes so the normal variety of street clothing was beneficial to the validity of the wear test. Each subject then completed the exercise protocol wearing each style of protective garment. For the first garment, the assistant led the participant through the exercises to assure adherence to the procedure. The subjects were encouraged to complete the exercises at their own speed but as quickly as was comfortable. A chart showing the exercises was also displayed at each exercise station to aid the participant (see Appendix D).

After finishing the exercise protocol in each garment, subjects completed a questionnaire rating the garment for static and dynamic fit. Therefore, each subject completed the exercise protocol and a questionnaire three times. The identification sticker from each protective suit was affixed to the corresponding questionnaire so that objective and subjective data could be compared. The investigative assistant also had the opportunity to make comments on the evaluation form if any garment areas interfered with the subjects ability to perform the designated exercises. If the garment burst or split, the location and time of occurrence for the tear was noted. All forms including the demographic data form and the informed consent form were placed in the original manilla envelope which was identified with the packet number.

Data Analysis

The data were analyzed based on the objectives of the study. Each subject wore three different garments which provided three times the number of observations as subjects. Frequency counts and relative frequency distributions (percentages) were calculated on all responses both for the entire sample and for individual size groups. Descriptive information including means and standard deviations were calculated on ranked responses and on measurements of both garments and subjects.

Multiple regression analysis on job performanace with static and dynamic fit ratings was conducted to determine if any static or dynamic fit indicators were predictors of ability to perform a job. Multiple regression was also conducted on fit and body dimensions to determine which measurements were predictors of good fit.

Data were analyzed comparing the measurements of the coveralls with those of the subjects to determine minimum, maximum and optimal amounts of ease for comfort and fit. Regression analysis was used to determine the effect of fit on job performance. Factor analysis and repeated measures analysis of variance were used to analyze differences in styles for both static and dynamic fit.

CHAPTER V

RESULTS AND DISCUSSION

The purpose of this research was to evaluate the fit of limited-use protective coveralls manufactured to the proposed size revision of ANSI/ISEA 101-1985 Men's Limited-Use and Disposable Protective Coveralls - Sizing and Labeling Requirements. The garments tested were provided by three manufacturers of protective clothing who each routinely produce a different sleeve treatment on their coveralls. The Tyvek® test garments were made in the seven sizes proposed for the new standard. They were styled with zippered front, convertible collar, no elastic at wrists or ankles, and either a set-in (SSlv), raglan (RSlv), or yoke-with-cut-on sleeve (YSlv).

Measurements of garment dimensions, specified by the proposed revision to the ANSI/ISEA 101-1985 sizing standard, were taken on 40 percent of the test garments to determine the mean garment dimensions. Demographic and dimensional data were collected for each subject. In addition to height and weight, body dimensions, corresponding to ANSI/ISEA specified coverall dimensions, were measured.

Each of the 166 subjects who volunteered to participate in the study were assigned a coverall size based on their height and weight as specified by the sizing chart designated by the proposed ANSI/ISEA standard (Appendix B). The exercise protocol for the wear test was designed to incorporate typical work postures and movements rather than specific job related tasks since the coveralls were designed to be worn in a variety of work situations under a variety of work conditions (Appendix D).

All of the subjects wore protective coveralls and completed the series of exercises in each of the three styles. After finishing the exercise protocol in each garment, they evaluated the garment for both static and dynamic fit. Static fit described the fit which accommodated the dimensions of the stationary body while dynamic fit described the fit that accommodated the body during the motions and activities of the wearer.

The questionnaire used to evaluate the garment was a Likert scale that assessed the fit, the ability to move during the various exercises, the ease of donning the coverall, and the participant's perception of his/her ability to perform a job wearing the coverall (Appendix F). Three questionnaires were provided to each subject, one for each of the test garments.

The questionnaires were analyzed based on the objective of the study:

1. To evaluate the static and dynamic fit of protective coveralls manufactured to the proposed revision of ANSI/ISEA 101-1985 Sizing Standard;
2. To identify key body measurements needed to select protective clothing manufactured to the proposed revision of ANSI/ISEA 101-1985 Sizing Standard;

3. To determine the minimum, maximum, and optimal garment ease required for satisfactory fit; and
4. To determine the effect of sleeve style on the fit of protective clothing.

Demographics

All sizes specified in the bivariate sizing chart, based on height and weight, were represented in the sample. Most subjects were volunteers attending an Agri-Tech Conference at Virginia Tech. After the initial days of testing additional subject were obtained at other test sites. When there were no;t sufficient volunteers to fill all the size blocks, subjects of specific sizes were recruited. Since there were no volunteers wearing the smallest size all of the subjects in this category were recruited. The size breakdown for the study is shown in Appendix J, Table J.1.

Of the 166 subjects, 110 (66.3%) were male and 56 (33.7%) were female. Males were represented in all size groups except XSmall and females were represented in all seven size groups. Only 6.4% (7/110) of the males were in sizes smaller than Large and 8.9% (5/56) of the females wore sizes bigger than Large (Appendix J, Table J.2).

Due to the volunteer nature of selecting the sample, the goal of 90% representativeness for each size group was not controllable. When looking at where the subjects fell on the size chart, neither 90% of the males or females fell within the designated size blocks (Appendix I, I.1, I.2, & I.3). Twenty (18%) of the males fell outside the designated size blocks. Nine (16%) of the females fell outside the designated size blocks. If the sample is representative of users of protective clothing, then the sizes designated by the proposed chart are not adequate to cover 90% of the population. Analysis of anthropometric data sets would identify the limitations necessary to cover 90% of the population.

The subjects ages ranged from 15 to 75. The ranges for each size are shown in Appendix J, Table J.1. The subjects' ages were divided into five groups: less than or equal to 18 years, 19-25 years, 26-35 years, 36-50 years, and 51 years or older. The greatest number (59) of respondents fell in the 36-50 age group with the next largest group (40) in the 26-35 age group (Appendix J, Table J.3).

Racial groups represented in the sample included Caucasian, Hispanic, Black, and Oriental. One subject checked other as racial group and 3 gave no response. The largest number of subjects (130) were Caucasian with Blacks (25) the second largest group. The complete racial mix of the sample is shown in Appendix J, Table J.4.

Geographically, 104 of the subjects participating in the research represented 46 counties in Virginia with the largest number, 36 (21.7%), from Montgomery County where Virginia Tech is located. The largest number from any other individual county was seven. Twelve subjects were from states other than Virginia: Florida, Louisiana, North Carolina, Pennsylvania, Maryland, Michigan, and West Virginia. Seven subjects were from other countries: China, Korea, Malaysia, Peru, Kenya, and

Zuni. Listing of a home address was optional so 43 subjects did not supply that information.

Three items on the questionnaires of primary interest were overall fit of the garment, whether the subject could perform his/her job wearing the coverall, and whether the subject felt the coverall was too large or too small. The total number of possible responses was the number of subjects multiplied by three since each subject wore three garments and had the opportunity to evaluate each of the garments. The responses on the fit question were collapsed into two categories with "strongly agree", "agree", and "tend to agree" in one and "strongly disagree", "disagree", and "tend to disagree" in the other.

The subjects were fairly evenly divided between those who felt the garment fit well and those who felt it did not (51.2% and 48.8% respectively). When asked if they could perform their job wearing the test garment, 60.9% responded in the affirmative and 39.1% felt they could not perform their job wearing that particular coverall. These responses indicate that some subjects felt they could perform a job wearing the coveralls even if they considered the coverall fit poor. When asked whether they felt the coverall was too large or too small, 29.5 % of the subjects felt it was too large while only 14.5% felt it was too small. The total percentages do not add up to 100% because only subjects who felt the garments were too large or too small were asked to respond to that item on the questionnaire. However, 25 subjects responded to that item even though they did not select "no" on ability to perform a job. Table J.5, Appendix J, shows these responses as well as the breakdown of responses by style for the entire sample. Tables J.6 - J.12 in Appendix J give the same information for each individual size.

Although there was not a significant difference in fit between styles for the entire sample, when individual sizes were analyzed, the raglan sleeve style fit significantly less well in sizes XLarge and 2XLarge than the other two styles. Individual components of fit are discussed with the analysis of static and dynamic fit later in this chapter.

Of the 166 subjects participating in the study, 85 stated that they used protective clothing and 79 did not (two did not respond to that question.) Responses to the three items of interest to the overall question of fit for protective garments were analyzed to determine if users of protective clothing differed from the complete sample. There was no significant difference in the percentages for users compared to the total sample. Therefore it can be assumed that the findings for the entire sample were not significantly different than results would be if ascertained from users only. The percentages are shown in Appendix J, Table J.13.

Before discussing the objectives of the research, it will be helpful to view the relationship between the proposed standard, the actual body measurements and the garment dimensions for each of the three styles of garments. Appendix J includes Figures J.1 - J.5 which illustrate these relationships. Thigh and biceps are included even though they are not a part of the proposed standard because they are indicators of muscular development which was shown to be a determining factor for fit in previous research (Crow & Dewar, 1986). Front opening, leg opening, and sleeve opening were not included since corresponding body measurements cannot clearly be defined.

As can be seen from the charts, the proposed and actual garment measurements generally exceed the actual body measurements. When looking at the relationships involving actual body measurements, the XSmall size and the 3XLarge size should be considered questionable because of the small number of subjects in these size groups. Considering individual measurements, body length varies most with size and style (Appendix J, Fig. J.4). The proposed standard requires body length to be longer than all but one of the actual garments (13.7 cm. longer for Small to 1.1 cm. longer for 3XLarge. Excluding the one garment in one size that measured 3 cm. longer, the garments measured from 2.4 cm. to 9.4 cm. shorter than the proposed standard. Analysis of static and dynamic fit showed that subjects, other than those wearing the largest sizes, generally considered body length either "just right" or "too long" on current garments. Therefore, increasing the length as required by the proposed standard would increase the dissatisfaction with fit.

Analysis of Static and Dynamic Fit

Objective 1 was to evaluate the static and dynamic fit of protective clothing manufactured to the proposed revision of ANSI/ISEA

101-1985 Sizing Standard (Appendix A). The questionnaire was designed with items assessing static and dynamic. Items 1 through 9 assessed static fit with questions concerning the length and tightness of the garment (Appendix E). Items 10 through 19 evaluated dynamic fit with questions concerning ability to move while wearing the garment. Items 20 through 22 assessed the overall fit and performance of the garment. In each of the analyses, the results for the XSmall and the 3XLarge should be considered questionable because of the small number of subjects in these size groups. The results of these two sizes are shown with the plots and graphs because they add to the overall information about the garments.

Static Fit Evaluation

Each of the static fit scales was analyzed using a 7 X 3 repeated measures analysis of variance. A response of 3 indicated the garments were "just right" whereas 4-5 indicated they were "too long" or "too loose" and 1-2 indicated they were "too short" or "too tight". The results for all three length items -- sleeve, leg, and body -- showed a significant difference between sizes, a difference across styles, and a significant interaction between size and style (Appendix J, Tables J.14 - J.16).

Sleeve Length. The plot for the sleeve length (Fig. J.7) shows that the garments differ by style in sizes XLarge, 2XLarge and 3XLarge. All the subjects wearing sizes XSmall and Small felt the sleeves were "a little too long" while the Medium and Large felt all the garments ranged from "just right" to "a little too long." The subjects in size XLarge and 2XLarge felt the YSlv and SSlv styles were close to "just right" in length but the RSlv was perceived as being too long. The subjects in size 3XLarge also perceived the SSlv as being close to "just right" with the RSlv sleeve being "a little too long" and the YSlv sleeve "a little too short."

Leg Length. The plot for the leg length (Appendix J, Fig. J.8) shows an interaction for the subjects in size Small with the subjects in size XSmall indicating the legs were "too long to function" and the subjects wearing size Small indicating the legs were "a little too long." Those wearing sizes Medium and Large perceived the YSLv style as being "just right" with the RSlv being more towards the long side and the SSlv falling between the other two styles. The subjects wearing sizes XLarge and 2XLarge felt both the YSlv and the SSlv styles were close to being "just right" with the RSlv being too long. The size 2XLarge subjects felt the legs approached being too long for them to function. Subjects wearing size 3XLarge perceived the legs of the SSlv and YSlv as being a little on the short side and the RSlv as a little on the long side.

Body Length. The plot for body length (Appendix J, Fig. J.9) shows interaction taking place between the subjects wearing sizes XSmall, Small, and Medium with those wearing the XSmall perceiving body length as being almost "too long to function." The subjects wearing size Small also indicated the body of the garment was "a little too long." Those wearing sizes Medium and Large felt the body length was just about right whereas the subjects wearing sizes XLarge, 2XLarge, and 3XLarge all perceived only the SSlv body length as "just right" with the YSlv style on the short side and the RSlv style on the long side.

Tightness Items.

The results for all four tightness items -- sleeve, leg, chest, and hip -- showed a significant difference between sizes, a difference across styles, and a significant interaction between size and style (Appendix J, Tables J.17 - J.20).

Sleeve Tightness. The plot for sleeve tightness (Appendix J, Fig. J.10) shows the ratings and interaction with all the styles except the YSlv on the loose side in all but size 3XLarge. Subjects wearing sizes Medium, Large, XLarge, and 2XLarge indicated the YSlv and SSlv styles were close to "just right" with the RSlv being loose. A too loose rating was given to the RSlv style in sizes XSmall and 2XLarge and to the SSlv style in the XSmall size. The sleeve tightness in size 3XLarge was closest to "just right" for the SSlv style with the RSlv style too loose and the YSlv style too tight.

Leg Tightness. The leg tightness plot (Appendix J, Fig. J.11) shows the same pattern but with the RSlv also judged close to "just right" for sizes Small, Medium, and XLarge. The leg tightness of the RSlv style is again perceived as being too loose for the 2XLarge size and the 3XLarge size. The YSLv style was judged to be too tight in the leg area for the size 3XLarge.

Chest Tightness. Chest tightness for sizes Small, Medium, and Large were all judged close to just right (Appendix J, Fig. J.12). The chest of the XSmall size was considered on the loose side for all three styles. In sizes XLarge and 2XLarge the RSlv style was judged to be on the loose side with it "too loose" for size 2XLarge. Subjects wearing size 3XLarge once again judged the RSlv style a little loose in the chest and the YSlv style a little tight in the chest.

Hip Tightness. Results for the hip tightness (Appendix J, Fig. J.13) are similar to the chest except that the yoke and set-in sleeve styles also depart from just right in the size 2XLarge with the YSlv style on the tight side and the SSlv style on the loose style. Results of these two ratings were expected to be similar due to the styling of the garments. Since they are made without side seams, garment dimensions for the waist and hip are identical to the chest measurement.

Static Fit Summary

An overview of all the static items shows that the greatest agreement in all categories is in size Small with all the length items being "a little too long" and all the tightness items showing the garments to be "just right." Subjects wearing size XSmall judged the garments to be "a little too long/loose" with the YSlv style closest to "just right." Those wearing sizes Medium and Large viewed all the garments close to "just right" in tightness and length. Subjects wearing sizes XLarge, 2XLarge, and 3XLarge perceived all the garments as being close to "just right" in tightness but the RSlv tends to differ from the other two in length. The ratings approach too long in the XLarge size and continues with ratings peaking on the long side for size 2XLarge. Subjects wearing the 3XLarge also felt the YSlv style was a little small.

Dynamic Fit Evaluation

The dynamic fit indicators were analyzed using factor analysis on Items 10 through 20. This analysis identified three factors. Items 10 through 15 loaded together, Items 16 through 19 loaded together and Item 20 stood by itself. The first group involved upper body movements, the second group involved lower body movements, and the last item was an assessment of overall fit. Factor scores were computed for the first two groups by adding the individual responses together and dividing by the number of items (6 and 4 respectively). Each of the resulting dynamic fit scores was analyzed using a 7 X 3 repeated measures analysis of variance. Responses ranged from 1 to 6 with 2 being agree and 5 being disagree (Appendix F). Responses from 1-3 indicated the garments were unsatisfactory and responses from 4-6 indicated they were acceptable with 3.5 as the dividing point.

Upper Body Factors. The results for the upper body factor scores showed that there was a significant difference between sizes, a difference across styles, and a significant interaction between size and style (Appendix J, Table J.21). Therefore, individual repeated measures ANOVAs were conducted on each of the contributing items.

The first item, number 10, ascertained the difficulty of donning the garments. Although this would seem to involve the entire body, it loaded with the upper body movements in the factor analysis. This may be due to the motions required in putting the garment on. The subjects inserted their feet through the legs of the garment with ease but pulling the garment up onto the shoulders and in place on the body then involved upper body movements. Analysis showed a significant difference within styles for the sizes 2XLarge and 3XLarge (Appendix J, Table J.22) but all three fell in the acceptable range except for the yoke sleeve style in the size 3XLarge (Appendix J, Fig. J.14).

The analysis of whether the garments were binding across the shoulders and whether they were binding through the body area (Items 11 & 12) both showed a significant difference between sizes, across styles, and a significant interaction between size and style (Appendix J, Tables J.23 - J.24). The plots (Appendix J, Figs. J.15 - J.16) show that all the garments are acceptable except for the YSlv style in size 3XLarge. All three styles were similar up through size Large, although they became increasingly different as they increased in size. The RSlv style was given the highest rating on both items showing that it was largest through the shoulders and the YSlv style the lowest, indicating it was the tightest of the three. Both ratings peaked at size 2XLarge and the YSlv style became unsatisfactory for size 3XLarge.

The next three items (numbers 13 - 15) also had similar responses except for the XSmall size. They assessed restricted arm movement, restricted overhead reach, and restricted forward reach (Appendix J, Tables J.25 - J.27). The plots (Appendix J, Figs. J.17 - J.19) show that responses for size XSmall differed on all three styles but were acceptable. All styles had similar ratings for size Small but became increasingly further apart as the sizes increased. The ratings all dropped for the 3XLarge size. The RSlv style maintained the highest rating indicating that it was the loosest and the YSlv had the lowest ratings with it becoming unsatisfactory for arm movement and reaching up.

Lower Body Factors. Analysis of the lower body factor scores showed no significant difference between sizes for the garments. However, there was a significant difference in styles and a significant interaction between size and style (Appendix J, Table J.28). The plot (Appendix J, Fig. J.20) of the lower body factor ratings revealed that for all sizes the responses clustered close to four except for the YSlv style in size XSmall, the RSlv style in size 2XLarge and the RSlv and YSlv styles in the 3XLarge size. These responses indicated that only specific garments in specific sizes differed from the others. The XSmall YSlv style and the RSlv style garments in sizes 2XLarge and 3XLarge were less restricting. Generally, the YSlv style tended to be given lower ratings than the other two styles for all sizes with it becoming unsatisfactory in the 3XLarge size.

Dynamic Fit Summary. An overview of all the dynamic ratings indicated that the greatest agreement as to fit was in sizes XSmall through Large with all the upper body responses indicating that the RSlv and SSlv styles were less restricting than the YSlv style garments. Subjects wearing size XLarge perceived more difference between the styles with the RSlv style the least restricting and the YSlv style the most restrictive. Ratings increased as the sizes increased through size 2XLarge, but then all ratings dropped for size 3XLarge.

It should be noted that in the dynamic fit measures, an acceptable (responses of 4-6) rating did not necessarily indicate good fit in all categories. Garments that are too large in the upper body area may not be restricting even if the fit is very poor. The one area that will be restricted when a garment is too large is leg movement if the body length is too long. A crotch seam that is too low restricts leg movement both in walking/climbing motions and in kneeling movements.

Since dynamic fit indicators did not specifically indicate good fit, one questions whether dynamic fit is a measure of fit or if it is a measure of restriction. Therefore, until this question is investigated further, it is necessary to evaluate both static and dynamic fit when assessing the fit of the garments.

Overall Fit Evaluation

Analysis of the item assessing overall fit (number 20) showed a significant difference between the sizes but not the styles (Appendix J, Table J.29). A significant interaction was indicated between the sizes and styles. The plot (Appendix J, Fig. J.21) indicated that if responses from size XSmall are not considered, the differences occur in either size XLarge or 2XLarge. All other means of the response ratings were obviously close together. In size XSmall it is evident that the YSlv style was considered to have the best fit although the rating was toward the disagree response. An additional analysis of only the responses for sizes XLarge and 2XLarge indicated no significant interaction between the sizes but only a significant difference between styles (Appendix J, Table J.30), therefore, all the significant difference occurred in one size. Reviewing the plot (Appendix J, Fig. J.21) for all sizes indicated the garments and sizes that were least acceptable were the RSlv style in size 2XLarge and all styles in size XSmall. These ratings indicate that something about the group of subjects or the garments for these sizes differ from the other sizes and styles.

Analysis of responses to static fit items and dynamic fit items as well as body measurements were reviewed to see if any explanations were evident. It was obvious that all subjects wearing size XSmall felt the garments were too large. Static and dynamic fit ratings indicated only that there were greater differences in responses for the RSlv style for size 2XLarge, but these differences were not necessarily detrimental to the fit of the garment. An analysis of actual body measurements compared to garment measurements indicated only that the body length for the raglan sleeve style was longer in the size 2XLarge than in any of the other sizes or styles (Appendix J, Fig. J.1). Therefore, in can be concluded that this additional length in the body of the garment was associated with the unsatisfactory fit rating. The analysis of recommended ease discussed later in the results section further describes these measurements.

Ability to perform a job while wearing protective clothing is an additional measure of fit. Regression analysis of job performance with static and dynamic fit ratings was conducted to determine if any of the static fit areas or dynamic fit motions could be used as predictors of this aspect of fit. Four static fit items and three dynamic fit items were identified for the three styles (Appendix J, Table J.31). These items were different for each of the styles with sleeve length and body length being the two static measurements that were identified for at least two of the styles. Although sleeve length was the only length measurement other than body length to be identified, all the body measurements except for biceps and thigh were highly correlated (Appendix J, Table J.33) with one another (0.63 to 0.93). Once one of the corresponding garment measurements was identified, the analyses did not consider the others. Although body length was also highly correlated to the other body measurements (0.64 to 0.71), it also appeared to be a significant contributor to fit. Only one dynamic fit rating was identified by more than one style and that was leg movement which was selected for all three styles. As mentioned previously, leg movement is dependent upon body length of the garment, so this finding supports the importance of the body length rating that was isolated on the static scale.

Key Body Measurements Affecting Fit

The second objective of this study was to identify key body measurements needed to select protective clothing manufactured to the proposed revision of the ANSI/ISEA 101-1985 Sizing Standard. Multiple regression on fit, controlling for size, was conducted with body measurement variables to determine if any of the body measurements could be used as predictors of fit. Height was the only variable identified as significant for any of the styles and it was significant only for the set-in sleeve style (Appendix J, Table J.32). Correlations between body measurements were high for all measurements (Appendix J, Table J.33). The plot (Appendix J, Fig. J.22) of mean body measurements for each size illustrates this correlation between all measurements (means and standard deviations are given in Appendix J, Tables J.35 - J.42). Circumference measurements were divided in half for Fig. J.22 since standards are written for flat garment dimensions which encompass only half of the circumference measurement. Although information from the literature did not support high correlations among body dimensions for the purpose of fit, the degree of correlation considered high is dependent upon the type of fit desired. If fitting an item such as a flight helmet, then .6 to .8 correlations would not be considered high enough to be used as a basis for selecting size. However, loose fitting coveralls allow more flexibility in fit. Therefore, correlations in this study were high enough that no single one could be identified as the best predictor of good fit.

Forward selection multiple regression for predicting fit from body dimensions was conducted to determine if any body measurements other than height could be considered good predictors of fit. For this analyses, height was controlled for by standardizing the body dimensions. This was accomplished by dividing each of the body measurements by height to get a ratio of the measurement to the height of the subject. A significance level of 0.10 was set for the multiple regression analyses. Measurements other than height that were significant predictors of fit were identified for only two sizes and two styles. Table J.34 in Appendix J shows the results of the regression analysis for each of the sizes yielding significant results. Responses for size Small in the SSlv style identified standardized weight and standardized hip measurements as being significant predictors of fit. Responses for size Small in the RSlv style identified standardized weight, standardized chest measurement and standardized arm length as significant predictors of fit. Responses for size XLarge in the SSlv style identified standardized thigh measurement as the only significant predictor of fit. These results were not definitive enough to indicate any body measurements other than height as being significant predictors of fit for the entire size range.

Ease Requirements for Satisfactory Fit

The third objective of the research was to determine minimum, maximum, and optimum ease for satisfactory fit of limited-use protective garments. The first step of this process was to determine which subjects considered the garments to fit well. Appendix J, Table J.35 shows the breakdown by gender and size of subjects who selected strongly agree (response 1) or agree (response 2) to the question of whether the garment fits well. The percentages of the entire sample selecting these responses is given in addition to the proportion of males and females for each size. As can be seen, a larger percentage of males than females said the garment fit well. Also, for the total number of responses per size group, the largest percentages of subjects responding with a 1 or a 2 were in the mid-size ranges. Each of the 166 subjects rated three garments allowing a total of 498 possible observations.

Tables J.36 to J.42 in Appendix J show the proposed standards, body dimensions, means, and standard deviations on each style of garment for all the ANSI/ISEA specified measurements. The thigh and biceps are also included. These tables can be used for reference when looking at the results for the minimum, maximum, and optimum ease analyses.

All garments supplied for the wear test met the minimum standards, yet measurements of body length on the test garments were less than those required by the standard. Further investigation into the body length measurements revealed that measurements of body length are not taken with garments laying on a flat surface as specified by the standard. Instead, body length is measured by pulling the collar point and crotch point to lengthen the garment and take advantage of the longer back length (D. Tatara, personal communication, Jan. 19, 1991).

In order to determine minimum, maximum, and optimum ease, the responses for static fit were analyzed and the respective mean body measurements were compared to the mean garment measurements for each size. If the subject selected Number 3 (just right) in response to an item such as "the body length was:" then the mean body length of those subjects in that size and style was compared to the mean body length of the corresponding size and style of garment. For all circumference measurements, the garment measurement was doubled since flat measurements of the garment represented only half the total garment measurement. Within each size, the number of subjects making that response was multiplied by the difference in the two measurements for each of the three styles. The resulting figures were then summed and divided by the total number of "just right" responses to get an average amount of ease for that size. This procedure was repeated for those who answered Number 2 ("a little too short/tight") and again for Number 4 ("a little too long/loose"). Responses of Number 3 ("just right") were used for optimum ease, Number 2 for minimum ease and Number 4 for maximum ease. Responses 1 ("too short/tight to function") and 5 ("too long/loose to function") were not used because subjects selecting either of those responses felt they could not function while wearing the garment.

When looking at the individual body areas, the subjects wearing smaller sizes generally reported needing less ease than those wearing larger sizes. An exception to this sometimes occurred in the XSmall where all three garment styles were considerably larger on the subjects than for other sizes. In judging the three garments, size XSmall subjects may have rated garments in comparison to one another rather than on how they actually felt each of the garments fit. None of the subjects wearing the XSmall rated any of the garments as too short/tight so there were no observations for that cell.

In some areas, especially the chest and body length, respondents gave conflicting ratings. Some results of the analyses indicated greater amounts of ease necessary for the "short/tight" rating than for the "just right" or "long/loose" rating. Intuitively, that would not be so. These conflicting results may be caused by the overall fit of the garment influencing the respondent's ratings of individual components of fit. Also respondents who fell outside the designated size blocks may have skewed the results.

Table J.43 in Appendix J shows the results for the comparison of the mean chest measurements of the subjects with the mean chest dimensions on the garments. Conflicting ratings were given in the XSmall, Medium and Large size groups. For the required ease to be consistent with the ratings, the derived maximum ease (response Number 4) would be the largest of the three figures and the derived minimum ease (response Number 2) would be the smallest figure. The rating for the chest may be confounded due to the fit of the entire upper body area. A garment that is tight or loose in the armscye or shoulder may feel tight or loose in the chest to the wearer. Observations of respondents on the video tape showed that many of the garments appeared to be tight or binding in the armscye area. Also, the garment rating was completed after the exercise protocol and the ability to move in the garment may have influenced the static fit ratings.

When determining chest ease, the hip measurement must also be considered. Although the ANSI/ISEA standard only designates the chest measurement, the styling of the garment (no side seams) dictates that the chest, waist, and hip on the garment are all the same dimension. Therefore, the chest measurement of the garment should also be compared to the hip measurement of the body. Fig. J.25 in Appendix J illustrates the proposed minimum standard for the chest, and the actual body measurements for chest, waist, and hip. In the smaller sizes the hip is larger than the chest, but as the size increases, they become closer to the same value with the chest slightly exceeding the hip for the largest size. This probably reflects the body type of the majority of subjects in these sizes since most of those wearing the smaller sizes were females and most of those wearing the larger sizes were males.

Appendix J, Table J.44 shows the minimum, maximum, and optimum ease for the hip derived from ratings of fit through the hips, body dimensions for the hip, and chest dimensions on the garment. Size Large results show optimum ease and minimum ease as the same amount and size 2XLarge shows conflicting results. Since waist is usually smaller than hip or chest measurement and the styling of the garment does not define a waistline, it is not necessary to compare the waist to the other dimensions.

Comparison of the mean body length of the subjects with the mean body length of the garments also shows conflicting results for the size Medium and negative outcomes for size 2XLarge and 3XLarge. Negative results indicate that the garment was smaller than the corresponding body dimension. Obviously that would not be satisfactory. It seemed unlikely that subjects would choose those responses unless the overall fit of the garment influenced the perceptions of fit in all areas. The negative amounts ranged from 3.8 - 8.9 cm. (1.5-3.5 in.) with all but one being less than 5.1 cm. (2 in.). Considering the magnitude of the body length measurements, these amounts are not great, but any negative amount would logically be considered poor fit. Since sizes 2XLarge and 3XLarge contained all the negative amounts of ease, those two sizes were not included in the averages across sizes given in Appendix J, Table J.45.

Table J.46 in Appendix J gives the comparison of mean biceps measurements of subjects with mean biceps dimensions of the garments. Conflicting results for minimum ease are reported in sizes Medium and 3XLarge with a significantly smaller amount for size Large. This may occur because evaluating fit in the biceps area would be influenced by ability to move the arms. Therefore, the overall fit in the shoulder and upper body area could influence the subject's perception of fit in the biceps.

Comparison of the mean thigh measurements of the subjects with the mean thigh dimensions of the garments is shown in Appendix J, Table J.47. Conflicting results were reported for maximum ease in sizes Medium and 3XLarge and for minimum ease in sizes Large and 2XLarge. Evaluating fit in the thigh could be influenced by fit in the lower body area with hip and body length being especially crucial to perceptions of fit. Restricted leg movements could be caused by excess body length (a crotch seam falling halfway to the knees) yet attributed to poor fit in the thigh area. Although the average ease for each minimum, maximum, and optimum amount occurs in the logical order, the range of the three is very small and probably does not reflect a range acceptable to users of limited-use protective clothing.

Dynamic fit ratings were not used for the analysis since they were not definitive about good and poor fit. The optimum amount of ease in each of the specified garment areas as derived from static fit ratings can probably be considered as representative of user requirements since larger numbers of observations were included in those analyses. However, the smaller number of observations for minimum and maximum amounts of required ease may not be adequate for making recommendations. A larger sample size might also eliminate the conflicting results for some of the sizes.

The greater number of subjects in the mid-size ranges responding in the affirmative to good fit may be an indication of a pattern grading problem since sample sizes are generally in the mid-size range. Pattern grading then changes each basic garment piece to reflect predicted body dimensions for the other sizes. For this sample the fit deteriorated as the sizes required approached either end of the size-range.

Effect of Design on Fit of Protective Clothing

The fourth objective of this research was to determine the effect of sleeve style on the fit of protective clothing. In order to evaluate the effect of sleeve style the assumption was made that each manufacturer would produce the garments exactly to the standard with only the sleeve treatment being different. However, since current standards only identify minimum dimensions, garments can meet the standard yet be considerably larger than the dimensions specified by the standard. Consequently each manufacturer's garments varied from the standard by differing amounts. Tables J.36 - J.42 in Appendix J describe the dimensions of the individual styles for all sizes.

Observations of the garments with each of the three sleeve styles did provide some general information. The YSlv style tended to bind in the upper arm area and be more restricting than the others when raising the arms overhead. This may have been partially due to the smaller biceps area for the larger sizes. The RSlv style tended to bind in the raglan seam when kneeling and reaching overhead. The SSlv style tended to allow the greatest overhead movements. These remarks are based only on the observations of the researcher and not on data from the subjects. Conducting analyses based on sleeve style was not possible with data from this research since each of the participating manufacturers produced their own pattern and adherence to the minimum specifications was not controllable.

Video Taped Observations

Subjects were video taped only during the first day of the wear testing at the Agri-Tech Conference due to the logistics of transporting video equipment and lighting to the outdoor locations. Video equipment was set up at only one of the three exercise stations as that was all the exercise space would allow. Two cameras were used with one directed towards the subject from the side front and one from the side back. Video taping took place for only 17 subjects which represented 10 percent of the sample. Each subject was video recorded wearing all three garments which resulted in 51 observations. There were 7 females and 10 males with all sizes being represented except for the XSmall. The demographic breakdown is given in Appendix J, Table J.48.

Since a small percentage of subjects were video taped, only general observations were made based on the tapes. These observations are described below. The surface texture and white color of the limited-use garments reflected the light so that details were difficult to distinguish. Therefore from viewing the tape it was not always possible to determine the style of garment the subject was wearing. Also, all the garments tended to be so loose in the body area that stress lines were not definitive.

The subjects tended to conduct the exercises in a fairly slow, methodical manner. This may have allowed them to think about how the garment felt while doing each exercise, but it also reduced the amount of stress placed on the garment which may have affected their ratings of each garment.

The legs and arms of the garment tended to slide freely on the body since the garments were not held close to the body at the ankles or wrists. This may have prevented subjects from feeling the length in the arms and legs was too short while going through the exercise routine. It was observed both from the video tapes and by the investigative teams that garments were often too short to protect the ankles during the exercise protocol yet some subjects still rated the length as being "just right".

It was obvious from viewing the tapes that if the body length was too long, the subject was restricted in leg movements both when stepping in place and when kneeling on one knee. Most of the garments tended to fit close to the body at the underarm-sideseam intersection area. This may be a result of the armscye being too small. Since the biceps girth determines the width of fabric in the sleeve-underarm intersection, an increase in the biceps area would necessitate a larger armscye. Also, more fabric in the underarm area of the sleeve would provide additional ease for movement.

Although the video tapes did not provide enough information for statistical analyses, they did help substantiate findings from the surveys. General information on garment fit and insight into some of the fit problems was gained from viewing the tapes.

CHAPTER VI

CONCLUSIONS

The results of the fit and sizing evaluation of limited-use protective coveralls manufactured to the proposed revision of ANSI/ISEA 101-1985 Sizing Standard were presented in Chapter V. The volunteer sample size was adequate in all sizes except XSmall and 3XLarge. Subjects for these sizes were recruited for the wear test but the numbers in size XSmall remained inadequate to use as a sound basis for making decisions about the sizing standard. However, all subjects in the XSmall size were in the upper half of the designated size block (Appendix I, Fig. I.3) yet they consistently rated the garment as being too large (Appendix J, Table J.6). Also 48 percent of the subjects wearing size Small felt the coveralls were too large. Therefore, consideration should be given to expanding the designated size block for size XSmall to include the lower portion of the current Small designation.

Since only 51 percent of the respondents reported that they were users of protective clothing, items on garment fit and job performance were analyzed to determine if users responded significantly different than non-users. The responses of the two groups were very similar. Therefore, it was assumed that results of the entire sample were representative of the user population. (Appendix J, Table J.13).

Conclusions based on these responses are presented according to the objectives of the research.

Objective 1:

To evaluate static and dynamic fit of protective coveralls manufactured to the proposed revision of ANSI/ISEA 101-1985 Sizing Standard.

Sleeve and Leg Length. It should be noted that in the dynamic fit measures, a rating indicating the garment was not restricting does not necessarily indicate good fit in all categories. Garments that are too large in the upper body area will not be restricting even if the fit is very poor. Therefore, it is necessary to evaluate both static and dynamic fit when accessing the fit of garments.

Analyses of sleeve and leg length indicated that both the sleeve and leg length for the size XSmall could be shortened since subjects wearing that size felt the garments were too long for them to function. Subjects wearing size Small also felt the garments were a little too long. Since Tyvek® does not require a hem, leg and sleeve length can easily be shortened by simply cutting away excess length. Therefore, judging the garments as being too long need not prevent a person from performing a job. However, when making sleeves and arms longer than necessary, excess fabric is used. Manufacturers could increase their fabric efficiency without sacrificing function by reducing the length of sleeves and legs in the XSmall and Small sizes.

Subjects wearing sizes Medium through 2XLarge rated the garments close to "just right" except for the leg in the RSLv style which appeared to be too long for size 2XLarge only. Subjects wearing size 3XLarge rated the yoke sleeve style as being too short in both arm and leg length. An analysis of anthropometric data could verify necessary sleeve and leg lengths once a parameter for the percentage of the population to be fit was established.

Body Length. Body length is a critical dimension for both fit and job performance. If it is too short the garment will not only be very uncomfortable but the crotch seams may split when the wearer becomes active. If the body length is too long it does not cause discomfort when the wearer is stationary but it becomes inhibiting to job performance when the wearer becomes active. A crotch seam that is too low prevents the wearer from moving his/her legs in a normal manner. The wearer will either be restricted in movement or the garment will tear in order to allow the person to move. The inseam measurement is also affected by the body length. The closer the inseam/crotch seam intersection comes to the body, the longer the inseam required for the garment to be an equivalent length on the wearer. Therefore, the body length must be established before a satisfactory inseam length can be determined.

The responses to the static and dynamic fit items indicated the XSmall size as being larger and the 3XLarge was smaller than the other sizes relative to body dimensions of the subjects. A look at the ease requirements suggests that adjustments need to be made for both of these sizes. Since the number of subjects for both of these sizes was smaller than those for the other sizes, additional testing should be conducted for subjects in these sizes.

Objective 2:

To identify key body measurements needed to select protective clothing manufactured to the proposed revision of ANSI/ISEA 101-1985 Sizing Standard.

All measurements taken on subjects in this sample tended to be highly correlated to each other, therefore, no single one could be identified as predictive of fit based on the results of this research. No individual body measurements other than height were identified as predictors of fit for all the sizes. Therefore, additional measurements other than the current two (height and weight) specified on the bivariate sizing chart cannot be recommended.

Objective 3:

To determine the minimum, maximum, and optimum garment ease required for satisfactory fit.

The procedure for deriving minimum, maximum, and optimum ease was described in detail in Chapter 5. The results of these analyses are given in Tables J.43 - J.47. Generally, it was found that the larger sizes required more ease than the smaller sizes. Whether or not to grade patterns using variable grades so that the amount of ease increases as the sizes increase is a decision that producers of the garments would need to make. Two of the key areas for fit - chest circumference and body length - were inconclusive for minimum and maximum amounts of ease necessary for satisfactory fit. Making additional observations and analyzing anthropometric tables for ranges in individual body dimensions for each of the designated size blocks are recommended before making decisions on minimum and maximum ease necessary for satisfactory fit. If it were necessary to make recommendations based on the data from this research, looking at the results from only the Medium, Large, and XLarge is suggested since these three sizes were the ones that were most satisfactory in fit (Appendix J, Table J.35). It should be noted that circumference measurements reported in Appendix J, Tables J.43 - J.47 are total body measurements. When using these tables for determining standards, all circumference measurements (chest, hip, body length, thigh, and biceps) should be divided in half because standards are normally written for flat garment dimensions. Also, when writing standards for garments to fit subjects who fall in designated size blocks such as those defined by the bivariate height-weight sizing chart (Appendix B), the garments must provide adequate fit for subjects at the upper limits of the block rather than be designed just for the average size in the block.

Chest and Hip Dimensions. The results of analysis of chest measurements were inconclusive (Appendix J, Table J.43) with reported minimum ease being greater than optimum ease and maximum ease being less than optimum ease for some sizes. Because of the large number of observations, the optimum ease could probably be considered as representative for this sample. Requirements for hip ease (Table J.44) should also be reviewed when considering chest ease since the garments are styled with the same amounts of ease in the hips as the chest.

Body Length. Results of analyses for necessary ease in the body length showed conflicting and negative ease requirements (Appendix J, Table J.45). Therefore, recommending ease for body length requires additional testing with garments made longer than the actual body length of the subjects. The average optimum ease derived from the Medium, Large, and XLarge sizes would be a logical amount to start with since those are the three sizes that indicated the best fit from the garments (Appendix J, Table J.35).

Biceps and Thigh Dimensions.The averages found from the analyses of responses to biceps fit (Appendix J, Table J.46) appear to be suitable for use as a guide to minimum, maximum, and optimal ease requirements. Analyses for ease requirements in the thigh area showed very little difference between minimum, maximum, and optimum ease (Appendix J, Table J.47). Results for optimum ease could be used but anthropometric tables showing ranges in body measurements should be consulted before specifying minimum and maximum amounts of ease.

Standards Development. Writing standards that provide for satisfactory fit requires two steps. Body dimensions of the population each size is designed to fit must be determined. This information can be gathered from anthropometric data sets or from samples of subjects once the parameters for the size are established. The proposed revision to the ANSI/ISEA 101-1985 sizing standard designates height and weight (Appendix B) as the parameters for establishing size. After the body dimensions have been isolated, the ease requirements must be added to the body dimensions to establish the recommended standard. The advantage to determining minimum, maximum, and optimum ease is that optimum ease can be used to establish the standard and then minimum and maximum ease can be used as tolerances for the standard.

Objective 4:

To determine the effect of sleeve style on the fit of protective clothing.

Analysis of the effect of sleeve style on fit was not possible with the data available from this research. In order to accomplish this objective, it would be necessary for all garments to be manufactured to the same dimensions for all the measurements specified in the standard with only the sleeve treatment being different. The garments secured for this research did not meet that requirement.

Conclusions based on video taped observations. The armscye area appeared to fit very close to the body on all the styles and in all but the smallest sizes. This could affect evaluations of fit in all the upper body areas. Additional fabric in the underarm area would provide additional ease. Care must be taken to keep the armscye from becoming too large or it becomes restrictive in the same way excess body length restricts leg movement.

Length of arms and legs on the garments should be based on anthropometric data and not on subject's evaluations. Since the garments could slide easily over the clothing worn under the coverall, the subject was not necessarily aware of when the legs and sleeves exposed the wrists and ankles during the exercise routine, thereby providing less protection for harmful exposure.

Implications and Recommendations

The underlying purpose of this research was to evaluate the proposed revision of ANSI/ISEA 101-1985 Men's Limited-Use & Disposable Protective Coveralls. The proposed revision attempts to fit females as well as males within the same sizing standard. Objectives one, two, and three of this research were components of this evaluation. Analysis of the individual sizes of garments as well as the specific styles determined if all or just some isolated sizes needed additional adjustments. Since each subject evaluated three different garments, there were three times the number of observations as subjects.

Static fit was used to identify specific areas of fit in relation to the body. The comparison of static fit ratings with body measurements was used to establish optimum differences between garment dimensions and body dimensions.

Dynamic fit tests were used to evaluate the movement ability of a person while wearing the garments. The dynamic fit tests were an integral part of evaluating the proposed standard since ease of movement is essential to job performance for most individuals working in situations that demand protective clothing.

Generally, it was found that subjects wearing garments at the extreme ends of the sizing scale were not satisfied with the fit, whereas, subjects wearing the mid-range sizes felt the fit was satisfactory. The XSmall garments were judged to be too large and portions of the 3XLarge garments were judged to be too small. The responses from subjects wearing Small garments tended to think all the garments were a little large. Those wearing 2XLarge garments had mixed responses; the raglan sleeve style was judged too large, responses to the set-in sleeve style were mixed, and the yoke sleeve style was too small. Subjects wearing Medium, Large, and XLarge generally felt the garments fit well with Medium and Large having the best fit (Appendix J, Tables J.6 - J.12). This was not surprising since mid-sizes are usually used as the sample size for which the pattern is developed and the end sizes are then graded variations of the sample size.

Responses to static fit items on the questionnaires indicated that all the subjects wearing XSmall considered the garments to be too long in the body, too loose in the sleeves, too loose in the legs and loose in the chest and hips (see Figs. 5.12 to 5.16). The responses for both static and dynamic fit indicated that the subjects considered the body length too long for size XSmall and Small. Static fit for body length was judged by the response to Item 5 (the body length was too short/long) and dynamic fit by Item 17 (the coverall restricted leg movement) since a crotch seam that is too low hinders leg movement. A look at the bi-variate sizing chart indicated that all subjects falling within the XSmall size block were in the upper half of the block. Almost half (47.6%) of the subjects who wore size Small also judged those garments to be too large (Appendix J, Table J.7). These findings indicate that the XSmall size block could be expanded to incorporate a portion of the Small size block. An alternative would be to make the garments smaller, however, those who thought that the Small size fit well might find the garments too small.

Only the yoke sleeve style in size 3XLarge was perceived as being too small or restricting on the static and dynamic fit ratings (Appendix J, Figs. J.9 - J.20). Comparison of garment measurements for the three styles in that size (Appendix J, Table J.42) indicates the only area of the yoke sleeve garment that shows a major difference from the other styles (excluding front opening) is in the biceps area; the yoke sleeve style was 8 cm. and 6.2 cm. smaller than the raglan sleeve style and set-in sleeve style respectively. However, comparison of the ratings for chest tightness (Appendix J, Fig. J.12) indicated that the yoke sleeve style is also considered tighter in the chest area than the other two. A comparison of mean body and garment measurements shows the chest of the yoke sleeve style to fall between the other two styles in dimension. A possible reason for these conflicting ratings is that the smaller biceps area resulted in binding across the chest during the exercise protocol. Thus, the subjects may have reported the chest as being restrictive in addition to the sleeves.

Results of analysis for ease requirements also produced conflicting responses. For some sizes minimum ease requirements were greater than maximum ease requirements. Body length ease requirements indicated that minimum, optimum, and maximum garment dimensions were less than actual body measurements for some sizes (Appendix J, Tables J.44 - J.47). Intuitively, this could not be, therefore, something other than actual garment size influenced the subjects' judgement of fit for body length.

This may have resulted because of perceptions influenced by the ability to move during the exercise protocol.

Ratings on fit sometimes conflicted with comparisons of body and garment dimensions. This may have been a result of subjects being unable to separate static and dynamic fit after completing the exercise protocol. If further investigation of static and dynamic fit is conducted, it is recommended that static fit be evaluated before exercising so the ability to move in the garment does not confound the perceptions of static fit.

Since fit was not as satisfactory in the extreme sizes of the sizing standard, it is recommended that either the dimensional specifications for these sizes be adjusted or the size blocks that each size is designed to fit be revised. One recommended revision to the size blocks would be to expand the XSmall size block on the bi-variate height/weight chart to include part of the current Small size block. Further investigation with these specific objectives would help clarify the necessary modifications to the sizing standard.

Recommendations for modifications of sleeve and leg length on the sizing standard were not made because appropriate length should be established based on anthropometric data for the population the garments are intended to fit. Also, both areas need to be designed for the longest measurements determined by the anthropometric data since inadequate length does not provide protection to the wearer and garments made of Tyvek® are easily shortened by simply cutting away excess length.

Defining minimum, optimum, and maximum ease for each size specified by the sizing standard would result in better fitting garments. Current standards identify only minimum dimensions for garments (Appendix A). Therefore, garments that are overly large may pass the standard testing for smaller sizes and qualify for ANSI/ISEA certified labeling. No provision is currently made for controlling maximum dimensions of the garments. Also, a definitive method for measuring body length should be established and adhered to.

It is recommended that minimum and maximum dimensions be specified by the standard. That would allow individual manufacturers a range so they could maintain their specific type of fit yet assure the customer that the garment would not be overly large or small. Additional research on minimum, optimum, and maximum ease in addition to anthropometric data on subjects falling within each size block would help provide more definitive results which could lead to recommended body dimensions for each size.

CHAPTER VII

SUMMARY

Human factors research has two major objectives: enhancing the effectiveness and efficiency with which activities are carried out and retaining certain desirable human values such as improved safety, reduced fatigue and stress, increased comfort, greater user acceptance, increased job satisfaction, and improved quality of life (Sanders & McCormick, 1987). As technology increases, industrial situations sometimes endanger the health or safety of workers. When possible, the best solution is to engineer a change in the operational processes producing the hazard since these changes are generally more reliable than human behavior changes. When hazards cannot be controlled through engineering revisions to the systems or products, then the second choice is administrative control which limits exposure to the hazard. If neither engineering nor administrative controls are possible then the use of protective gear (a behavioral change) is the most common solution. Protective gear is often advisable as a safeguard even if engineering and/or administrative controls are implemented. Of the three types of exposure to environmental hazards--dermal, ingestion, and inhalation--dermal exposure poses the greatest health hazard for many occupations (Wolfe, Durham, & Armstrong, 1967). Protective clothing is the only significant type of dermal barrier available to many people. Limited-use protective coveralls are the type used by many workers due partially to the prohibitive cost and availability of other types of protective gear.

Protective clothing must be acceptable to the consumer for it to be effective. If it is not worn it cannot shield workers from harmful environmental exposure. A frequent complaint of those workers using limited-use protective coveralls is poor fit. The fit of protective garments may adversely affect body mobility and, consequently, productivity. Poor fit can also result in exposed body areas, thereby reducing the amount of environmental protection provided.

Standards for sizing of limited-use protective coveralls are developed by the Industrial Safety Equipment Association (ISEA), adopted and approved by the American National Standards Institute (ANSI), and regulated by the Safety Equipment Institute (SEI). The current ANSI/ISEA 101-1985 standard for size and labeling of limited use coveralls defines five sizes ranging from Small to 2XLarge. A proposed revision of the standard expands the sizes to seven ranging from XSmall to 3XLarge. This revision attempts to improve fit by including a smaller proportion of the user population in each size designation.

The purpose of this research was to evaluate the fit of protective clothing manufactured to the proposed revision ANSI/ISEA 101-1985 sizing standard. Three styles of garments -- a yoke with cut-on sleeve (YSlv), a raglan sleeve (RSlv), and a set-in sleeve (SSlv) -- were tested in each of the seven sizes specified by the proposed sizing standard. The research was supported by three manufacturers of limited-use protective coveralls and the manufacturer of the fabric used for the garments.

Method

The research followed the procedure for anthropometric fit testing set forth by McConville (1986). The garments were prepared for testing by recording the measurements of garment dimensions as specified by the proposed revision to the ANSI/ISEA 101-1985 sizing standard (Appendix A) on 40 percent of the test garments. Mean garment dimensions were calculated based on these measurements. Since each subject tested three garments, the order of testing was randomized by use of counterbalancing (Keppel, 1973).

Anthropometric methods were used to measure the subjects. Each participant donned the protective clothing and carried out a wear test consisting of a series of exercises developed to represent typical work related body movements. The subjects then evaluated both static and dynamic fit of the protective coveralls by completing a questionnaire which asked about garment fit in specific body areas and ability to move in the garment. This procedure was repeated for each of the three garments.

The Sample

Most of the subjects for the research were volunteers attending agricultural conferences sponsored by the Virginia Cooperative Extension Service. By offering the garments as an incentive, the participants tended to be individuals who used or had an interest in protective clothing. Seven of the 166 subjects were recruited because of their size. All sizes specified in the sizing chart based on height and weight were represented in the sample. Reporting home address was optional but of the subjects who did list an address, 104 were from Virginia, 12 stated they were from states other than Virginia, and seven were from countries other that the United States.

Demographic and dimensional data were collected for each subject. In addition to height and weight, body dimensions corresponding to ANSI/ISEA specified coverall dimensions were measured. Biceps and thigh measurements were also taken since they were indicators of muscular development.

Two thirds (66.3%) of the sample were male and one third (33.7%) female. Subjects from five racial groups were represented in the sample (Appendix J, Table J.4) and the subjects' ages ranged from 15 to 75 years with the majority 26 to 50 years old (Appendix J, Table J.3). Just over half of the participants (85) had previously used protective clothing. Responses from users of protective clothing did not differ significantly from those of non-users (Appendix J, Table J.13), therefore the findings were assumed to be representative of users.

The Exercise Protocol

The exercise protocol for the wear test was designed to incorporate typical work postures and movements. The exercise activities were developed from several sources including one developed by DuPont for licensing their garments, one adopted by the American Society for Testing and Materials in their test method for testing the integrity of totally encapsulated chemical protective suits, and through interviews with users of personal protective clothing.

Five repetitions were selected for each of the exercise activities since each subject was required to repeat the exercise series three times (once for each style garment). The subjects were encouraged to complete the exercises at their own speed but as quickly as was comfortable. An instructional video which demonstrated the exercise protocol was viewed while the participants waited to be measured. Charts illustrating the exercises (see Appendix D) were posted on the wall in front of the participants and one of the research assistants also led the subjects through the exercises at the beginning of the procedure.

The Questionnaire

A Likert scale questionnaire was developed that assessed the quality of fit, the ability to move during the various exercises, the ease of donning the coverall, and the participants perception of his/her ability to perform a job wearing the coverall (Appendix F).

Data Analysis

Static Fit. All items were analyzed by size and style. Analysis of variance with repeated measures was used to analyze static fit, which was measured by the length in the sleeves, legs, and body, and the tightness/looseness in the sleeves, legs, chest and hip of the garment. The body length was considered too long for all styles in the XSmall size and too short for the yoke sleeve style in the 3XLarge size. The other sizes and styles were considered to be alright or only a little long or short (see Appendix J, Table J.16 and Fig. J.9). Although perceptions of the leg and sleeve length were included in the analysis (see Appendix J, Tables J.14 & J.15 and Figs. J.7 & J.8), they were not considered in recommendations for modification to the sizing standard because appropriate length should be established based on anthropometric data for the population the garments are intended to fit. Since inadequate length does not provide protection to the wearer and garments made of Tyvek® are easily shortened by simply cutting away excess length, a minimum length should be established.

Results for leg and sleeve tightness indicated that all styles were considered loose in the XSmall size. The leg and sleeve were considered loose on the raglan sleeve style and tight on the yoke sleeve style in the 3XLarge size (see Appendix J, Tables J.17 & J.18 and Figs. J.10 & J.11). Chest and hip tightness were judged to be a little loose for the raglan and set-in sleeve style in size XSmall and for the raglan sleeve style in the 2XLarge size (see Appendix J, Tables J.19 & J.20 and Figs. J.12 & J.13). The other sizes and styles were considered alright.

Dynamic Fit. Factor analysis of the dynamic fit items identified two factors affecting fit ratings. These were renamed upper body factor and lower body factor since the individual items grouped together according to the portion of the body that was evaluated by the individual items. Analysis of variance with repeated measures was used on these two factors as well as on Item 20 which assessed overall fit. Descriptive statistics were used with Item 21 which assessed ability to perform a job wearing the coverall. It should be noted that on the upper body and lower body factors that a non-restrictive rating was not necessarily synonymous with good fit since the garments could be judged as being non-restricting and still be considered too large to have a good fit rating.

There was a significant difference between sizes across styles (Appendix J., Table J.21). Therefore, individual analysis of variance with repeated measures on upper body factors was used on each of the contributing items. These analyses showed that only the yoke sleeve style in size 3XLarge was restricting in upper body movements (see Appendix J, Tables J.22 - J.27 and Figs. J.14 - J.18). The lower body factor analysis did not indicate a significant difference between sizes across styles so no further analyses were conducted on those items (see Appendix J, Table J.28 and Fig. J.20).

Key body measurements affecting fit. Multiple regression for predicting fit from body dimensions was conducted to determine if any body measurements could be considered good predictors of fit. Height was identified as the only body variable predictive of fit (see Appendix J, Table J.33). All other body measurements were highly correlated considering the loose fit of the garment so no single one could be identified as being more predictive of fit than the others (see Appendix J, Fig. J.25).

Ease requirements for satisfactory fit. When ease requirements were analyzed results were conflicting. Some ratings for minimum ease were greater than those for maximum ease. In some sizes, the required dimensions of the garment for good fit was reported to be less than the actual body dimension. One possible reason for these conflicting responses is that the subjects' perception of static fit was influenced by their ability to move in the garments.

Effect of design on fit of protective coveralls. All three styles -- set-in sleeve, yoke with cut-on sleeve and raglan sleeve -- were manufactured to specifications that met the proposed revision to the ANSI/ISEA 101-1985 sizing standard for limited-use protective coveralls. However, meeting the standard requires only that garments meet or exceed stated minimum dimensions. No provision is currently made for controlling a maximum dimension.

General observations of the styles showed the yoke sleeve style to be the best fitting in the smaller sizes and the set-in sleeve style in the larger sizes. Excluding the XSmall size, these two sizes were also the most consistent across all other sizes (see Appendix J, Fig. J.21). The major differences in dimensions for the three styles occurred in the biceps area. The thigh dimensions also differed, but not as much. The body length varied some but the chest dimensions of all three styles were similar (see Appendix J, Figs. J.1 - J.6).

Measurements of the test garments differed in all ANSI/ISEA specified dimensions as well as in sleeve style (see Appendix J, Tables J.36 - J.42). Consequently, it was not possible to evaluate the effect of sleeve style because the other portions of the coveralls were not consistent with one another.

Conclusions and Recommendations

The proposed revision to ANSI/ISEA 101-1985 Men's Limited-Use and Disposable Protective Coveralls - Sizing and Labeling Requirements added two sizes to the current standard, one at each end of the size range. The addition of these two sizes was an attempt to fit larger size males and to make the coveralls fit the female population also. Results of wear tests of the garments made to the proposed revision of the sizing standard indicated that the two added sizes did not fit as well as the previously existing sizes.

Generally, subjects wearing the garments rated all the XSmall sized garments as too large and the yoke sleeve style of the 3XLarge as too small in the shoulder/biceps area. The raglan style sleeve was rated large in the XLarge and 2XLarge sizes. Comparisons of body dimensions and garment dimensions also revealed that the garments in the largest sizes were too short in the body. Ratings on fit were sometimes conflicting with comparisons of body and garment dimensions. This may have been a result of subjects being unable to separate static and dynamic fit after having completed the exercise protocol. If further investigation of static and dynamic fit is conducted, it is recommended that static fit be evaluated before exercising so the ability to move in the garment does not confound the perceptions of static fit. The questionnaire could also be revised so there would be an equitable number of items assessing upper body fit, lower body fit, and overall fit and function.

Since fit was not as satisfactory in the extreme sizes of the sizing standard, it is recommended that either the dimensional specifications for these sizes be adjusted or the size blocks that each size is designed to fit be revised. One recommended revision to the

size blocks would be to expand the XSmall size block on the bi-variate height/weight chart to
include part of the current Small size block. Further investigation with these specific objectives would help clarify the necessary modifications.

The proposed revision to the ANSI/ISEA 101-1985 sizing standard includes a bi-variate height/weight chart to be used for selecting the proper sized coveralls (see Appendix B). Multiple regression analysis on predicting fit from body dimensions across all sizes did not identify any body variables other than height as significant predictors of fit. Therefore, no recommendations can be made for using additional body measurements to select a better fitting garment.

Development of a standard defining minimum, optimum, and maximum ease for satisfactorily fitting garments could lead to better fitting garments. Current standards identify only minimum dimensions for garments (see Appendix A). Therefore, garments that are overly large may pass the standard testing for smaller sizes and qualify for ANSI/ISEA certified labeling. No provision is currently made for controlling maximum dimensions of the garments. It is recommended that minimum and maximum dimensions be specified by the standard. That would allow individual manufacturers a range so they could maintain their specific type of fit yet assure the customer that the garment would not be overly large or small. Additional research on minimum, optimum, and maximum ease in addition to anthropometric data on subjects falling within each size block would help provide more definitive results which could lead to recommended body dimensions for each size.

Analysis of the effect of sleeve style was not possible with the garments obtained for this research project. In order to evaluate the effect of sleeve style on the garment, all other dimensions of the garment would need to be held constant. The test garments for this research were donated by three manufacturers and were made from their own patterns and to each individual companies regular coverall dimensions except for the addition of two sizes. It is recommended that additional research be conducted for the purpose of evaluating the effect of the sleeve style. To control for all body dimensions, it would be ideal to use one master pattern for all three styles and make the necessary modifications to produce each of the sleeve styles. That way, the responses to the questionnaire would be evaluating the effect of the sleeve change and not some other body variable.

Suggestions for Further Research

The findings of this research identified several areas that could be investigated in further studies. The method for determining minimum, optimum, and maximum ease could be explored using garments designed with varying amounts of ease. It was difficult to get definitive results with garments designed to be as loose fitting as those used for this research. Refining the method by testing it with close fitting garments as well could help establish a method for determining the necessary functional ease required by the designated purpose of the garment.

The effect of design on the fit and function of the garment could be further explored by evaluating garments that are constructed exactly to specified dimensions except for the area under investigation. Static and dynamic fit measures could be used to evaluate the design feature in question.

The question of whether dynamic fit is a measure of fit or a measure of restriction could be investigated. Using dynamic fit to evaluate the function of a garment provides useful information, but overly large areas of a garment may not produce adverse ratings pertaining to the function of the garment. Therefore, the method of evaluating dynamic fit may need to be expanded so it is more definitive.

CHAPTER VIII

REFERENCES

Advancing the Art of Employee Safety (1990). Occupational Hazards, 52, (3), 29-31.

Ashdown, S.P. (1989). An Analysis of Task-Related Movement of Asbestos Abatement Crews as a Basis for the Design of Protective Coveralls. Unpublished Masters Thesis, Cornell University.

ASTM. (1988). User's Protective Clothing/Ensemble Questionnaire. Summary of Results presented at meeting of Committee F23.51 on Protective Clothing, Human Factors subcommittee. American Society for Testing and Materials.

Bergeron, D.P., & Carver, M.N. (1988). Student preferences for domestic-made or imported apparel as influenced by shopping habits. Journal of Consumer Studies and Home Economics, 12, (1), 87-94.

Breisch, S.L. (1990). PPE and your company. Safety and Health, 141, (3), 62-65.

Cloud, R.M., Boethel, D.J., & Buco, S.M. (1988). Protective clothing for crop consultants: Field studies in Louisiana. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 597-604.

Clulow, E.E. (1983). Protective clothing and comfort. Proceedings at the Shirley Institute Conference on Protective Clothing.

Coletta, G.C. & Spence, M.W. (1985). Chemical protective clothing: Determining good performance. Occupational Health and Safety, 54, (4), 20,21, 23, 72.

Conforti, J.V. & Grunberg, R.D. (1987). Asbestos Protection: A critical difference. Safety and Health, 136, (3), 70-75.

Crow, R.M. & Dewar, M.M. (1986). Stresses in clothing as related to seam strength. Textile Research Journal, 56, (8), 467-473.

Crown, E.M. & Rigakis, K.B. (1989). Protective clothing research: A systematic holistic approach. Canadian Home Economics Journal, 39, (1), 11-13.

DeJonge, J.O., Easter, E.P., Leonas, K.K., & King, R.M. (1985). Protective apparel research. In R.C. Honeycutt, G. Zweig, & N.N. Ragsdale (Eds.) Dermal exposure related to Pesticide Use. American Chemical Society Symposium Series 273, 403-411.

DeJonge, J.O., Vredevoogd, J., & Henry, M.S. (1983-84). Attitudes, practices, and preferences of pesticide users toward protective apparel. Clothing and Textiles Research Journal, 2, (1), 9-14.

Delk, A.E. & Cassill, N.L. (1989). Jeans sizing: problems & recommendations. Apparel Manufacturer, 1, (2), 18-23.

deMarly, D. (1986). Working Dress. New York: Holmes & Meier Publishers, Inc.

Dillman, D.A. (1978). Mail and Telephone Surveys. New York: John Wiley & Sons.

DuPont Company (1990, January). DuPont BLOCKADE® Asbestos Abatement Garment. Brochure No. H-24827. Wilmington, DE: Dupont Company.

DuPont Company (1990, January). Protective Apparel of DuPont Tyvek : Safety You Can Wear. Brochure No. H-1960. Wilmington, DE: Dupont Company.

Ehntholt, D.J., Almeida, R.F., Beltis, K.J., Cerundolo, D.L., Schwope, A.D., Whelan, R.H., Royer, M.D., & Nielson, A.P. (1988). Test method development and evaluation of protective clothing items used in agricultural pesticide operations. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 727-737.

Eiser, D.N. (1988). Problems in personal protective equipment selection. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 341-346.

Farmer, B.M. & Gotwals, L.M. (1982). Concepts of Fit. New York: MacMillian Publishing Co.

Fenske, R.A. (1988). Use of fluorescent tracers and video imaging to evaluate chemical protective clothing during pesticide

Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 630-639.

Fenski, R.A., Blacker, A.M., Hamburger, S.J., & Simon, G.S. (1990). Worker exposure and protective clothing performance during manual seed treatment with lindane. Archives of Environmental Contamination and Toxicology, 19, (2), 190-196.

Fisher, W. (1989). Increasing human factors effectiveness within the organization. Proceedings of the Human Factors Society 33rd Annual Meeting, 460-461.

Fraser, A.J., & Keeble, V.B. (1988). Factors influencing design of protective clothing for pesticide application. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 565-572.

Fourt, L. & Hollies, N. (1970). Clothing Comfort & Function. New York: Marcel Dekker, Inc.

Fuzek, J.F. (1981). Some factors affecting the comfort assessment of knit T-shirts. Industrial and Engineering Chemistry Product Research and Development, 20, 254-259.

Gabele, P.D. (1989). Protective apparel for agricultural mixers, loaders and applicators. Agricultural Aviation, 16, (7), 20-22.

Gaskill, L.R. (1990). Product development: a case study analysis. Asociation of College Professors of Textiles and Clothing Proceetings, 1-4.

Gohlke, D.J. (1989). GORE-TEX fabrics for chemical protective clothing. Journal of Coated Fabrics, 18, 180-186.

Goldstein, L. (1985). Protective clothing: Limited use garments. Industrial Fabric Review, 61, (10a), 88-89.

Gordon, C.C. (1986). Anthropometric sizing and fit testing of a single battledress uniform for U.S. Army men and women. In R.L. Barker & G.C. Coletta (Eds.) Performance of Protective Clothing, ASTM STP 900, Philadelphia: American Society for Testing and Materials, 581-592.

Heisey, F.L., Brown, P., & Johnson, R.F. (1988). Three-dimensional pattern drafting: A theoretical framework. Clothing and Textiles Research Journal, 6, (3), 1-9.

Henry, M.S. (1980). Users' Perceptions of Attributes of Functional Apparel. Unpublished masters thesis, Michigan State University, East Lansing, Michigan.

Hoffman, M.S. (1989). Advanced product development through market participation. Proceedings of the Human Factors Society 33rd Annual Meeting, 461.

Hogge, V.E., Baer, M., & Kang-Park, J. (1988). Clothing for elderly and non-elderly men: A comparison of preferences, perceived availability and fitting problems. Clothing and Textiles Research Journal, 6, (4), 47-53.

Huck, J. (1988). Protective clothing systems: A technique for evaluating restriction of wearer mobility. Applied Ergonomics, 19, (3), 185-190.

Johnson, J.S. & Stull, J.O. (1988). Measuring the integrity of totally encapsulated chemical protective suits. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 525-534.

Kallal, M.J. (1985). Clothing Construction. New York: MacMillian Publishing Co.

Katzel, J. (1985). Personal protective equipment: A basic selection and application guide. Plant Engineering, 39, (20), 46-58.

Keeble, V.B. (1988, Summer). Clothing to reduce exposure to pesticides. Utah Science, 38-43.

Keeble, V.B., Norton, M.J.T., & Drake, C.R. (1987). Clothing and personal equipment used by fruit growers and workers when handling pesticides. Clothing and Textiles Research Journal, 5, (2), 1-7.

Kelly, S.M. (1989). Garments tailored to match risks. Safety and Health, 139, (3), 60-62.

Keppel, G. (1973). Design and Analysis: A researchers Handbook. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kincaid, D. (1991). Planning for survival. Apparel Inducstry Magazine, 52, (1), 98.

Kincaid, D. & Cassill, N.L. (1989). A closer look at quick response. Apparel Manufacturer, 1, (3), 89-92.

Kirk, W., Jr. & Ibrahim, S.M. (1986, January). Fundamental relationship of fabric extensibility to anthropometric requirements and garment performance. Textile Research Journal, 37-47.

Kroemer, K.H.E. (1989). Engineering anthropometry. Ergonomics, 32, (7), 767-784.

Kroemer, K.H.E., Kroemer, H.J. & Kroemer-Elbert, K.E. (1986). Engineering Physiology: Physiology Bases of Human Factors/Ergonomics. New York: Elsevier Science Publishers.

LaBar, G. (1990). Safeguarding workers: The role of personal protection. Occupational Hazards, 52, (3), 23-26.

LaBat, K.L.L. (1987). Consumer Satisfaction/Dissatisfaction with the Fit of Ready-to-Wear Clothing. (Doctoral dissertation, University of Minnesota, 1987).

Laing, R.M. & Ingham, P.E. (1985). Patterning of objective and subjective responses to heat protective clothing systems, Pat 2: Subjective measurements of comfort. Clothing and Textiles Research Journal, 3, (2), 31-34.

Laughlin, J. (1990). Decontaminating personal protective clothing: historical, scientific, theoretical and applied contexts. Association of College Professors of Textiles and Clothing Proceedings, 1-4.

Litchfield, M.H. (1988). A review of the requirements for protective clothing for agricultural workers in hot climates. In S.Z. Mansdorf, R. Sager, and A.P. Nielson, (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989. Philadelphia: American Society for Testing and Materials, 796-801.

Lloyd, G.A. (1986). Efficiency of protective clothing for pesticide spraying. In R.L. Barker & G.C. Coletta (Eds.) Performance of Protective Clothing, ASTM STP 900, Philadelphia: American Society for Testing and Materials, 121-135.

Martin, T.E. (1987). Limited use protective garments in industrial applications. Developments in the Protective Clothing Industry. Papers presented at the Industrial Fabrics Association International 75th Annual Convention. Las Vegas, NV.

McConville, J.T. (1986). Anthropometric fit testing and evaluation. In R.L. Barker & G.C. Coletta (Eds.) Performance of

Protective Clothing, ASTM STP 900, Philadelphia: American Society for Testing and Materials, 556-568.

Minetos, P. (1988). They're dressed for work. Safety and Health, 138, (4), 30-33.

Minter, S.G. (1987). Chemical protective clothing: Making the right choice. Safety and Health, 49, (2), 39-42.

Moraski, R.V. & Nielsen, A.P. (1985). Protective clothing and its significance to the pesticide user. American Chemical Society Symposium Series, 273, 395-402.

NASA. (1978). Anthropometry. In Webb Associates (Ed.), Anthropometric Source Book, Volume I: Anthropometry for Designers. NASA Reference Publication 1024. Washington D.C.: National Aeronautics and Space Administration.

Neilson, A.P. & Moraski, R.V., (1986). Protective clothing and the agricultural worker. In R.L. Barker & G.C. Coletta (Eds.) Performance of Protective Clothing, ASTM STP 900, Philadelphia: American Society for Testing and Materials, 95-102.

Nigg, H.N., Stamper, J.H., Easter, E.P., Mahon, W.D., & DeJonge, J.O. (1990). Protection afforded citrus pesticide applicators by coveralls. Archives of Environmental Contamination and Toxicology, 19, (5), 635-639.

Nigg, H.N., Stamper, J.H., & Queen, R.M. (1986). Dicofol exposure to Florida citrus applicators: Effects of protective clothing. Archives of Environmental Contamination and Toxicology., 15, (1), 121-134.

Norton, M.J.T., Drake, C.R., & Young, R.W. (1988). Protectiveness of Gore-Tex and PVC spray suits in orchard pesticide spraying. Journal of environments science and health, B23, (6), 623-641.

Pederson, E.L. (1989). Clothing: A basic human need? Home Economics Forum, 3, (2), 18-19.

Reinert, J.C. & Severn, D.J. (1985). Dermal exposure to pesticides: The environmental protection agency's viewpoint. In R.C. Honeycutt, G. Zweig, & N.N. Ragsdale (Eds.) Dermal exposure related to Pesticide Use. American Chemical Society Symposium Series 273, 357-368.

Robinette, K.M. (1986). Anthropometric methods for improving protection. In R.L. Barker & G.C. Coletta (Eds.) Performance of Protective Clothing, ASTM STP 900,

Philadelphia: American Society for Testing and Materials, 569-580.

Robinette, K.M., Churchill, T. & McConville, J.T. (1981). Integrated Size Programs for U.S. Army Men and Women. (Report No. Natick/TR-81/032). Natick, Massachusetts: U.S. Army Natick R & D Laboratories.

Robinette, K. M., Churchill, T. & McConville, J.T. (1979). A Comparison of Male and Female Body Sizes and Proportions. (Report No. AMRL-TR-79-69). Wright-Patterson AFB, Ohio: Aerospace Medical Research Laboratory.

Rosenblad-Wallin, E. (1985). User-oriented product development applied to functional clothing design. Applied Ergonomics. 16, (4), 279-287.

Rucker, M., Branson, D., Nelson, C., Olson, W., Slocum, A. & Stone, J. (1988). Farm families' attitudes and practices regarding pesticide application and protective clothing: A five-state comparison. Part 1: applicator data. Clothing and Textile Research Journal, 6, (4), 37-46.

Rucker, M.H., McGee, K.M., & Chordas, T. (1986). California pesticide applicators' attitudes and practices regarding the use and care of protective clothing. In R.L. Barker & G.C. Coletta (Eds.) Performance of Protective Clothing, ASTM STP 900, Philadelphia: American Society for Testing and Materials, 103-113.

Shannon, E. (1987). Apparel's new role of function and comfort. Canadian Home Economics Journal, 37, (1), 12-15.

Shirley Institute. (1982, October). Protective clothing. Papers prersented at Shirley Institute Conference on Protective Clothing (Background), England.

Shishoo, R. (1990). Interaction between fabric properties and garment making, Apparel International, March 1990.

Sieben, W.A. (1988). Consumer Perception of Quality as it Relates to Garment Fit. Paper presented at the 37th Annual Conference of the Textile and Needle Trades Division, American Society for Quality Control, Savannah, GA.

Smith, G.E. (1987). Your symbol of quality in safety equipment. Safety and Health, 135, (3), 54-55.

Smith, W.C. (1989). Protective clothing in the U.S. Textile Asia, 20, (9), 189-194.

Sontag, M.S. (1985). Comfort dimensions of actual and ideal insulative clothing for older women. Clothing and Textiles Research Journal, 4, (1), 9-17.

Srachta, B.J. (1985). Personal protective equipment. National Safety News, 131, (3), 47-52.

van Schoor. (1989). The Design and Evaluation of Disposable Protective Coveralls for Pesticide Applicators in Agriculture. Unpublished master's thesis. University of Alberta, Alberta, Canada.

Veghte, J.H. (1989). The physiologic strain imposed by wearing fully encapsulated chemical protective clothing. In J. Perking and J. Stull (Eds.), Chemical Protective Clothing Performance in Chemical Emergency Response, ASTM STP 1037, Philadelphia: American Society for Testing and Materials, 51-64.

Watkins, S.M. (1977). The design of protective equipment for ice hockey. Home Economics Research Journal, March, 1977, 154-166.

Watkins, S.M. (1984). Clothing: The Portable Environment. Ames, Iowa: Iowa State University Press.

Watkins, S.M. (1989). Workers at risk: The role of home economists in meeting basic needs with protective clothing. Home Economics Forum, 3, (2), 20-23.

Wolfe, H.R., Durham, W.F., & Armstrong, J.F. (1967). Exposure of workers to pesticides. Archives of Environmental Health, 14, 622-633.

American National Standard

for personnel protection – men's limited-use and disposable protective coveralls – size and labeling requirements

Approved September 9, 1985

Secretariat: Industrial Safety Equipment Association

1. Scope, Purpose, and Application

1.1 Scope. This standard establishes minimum size requirements for men's limited-use and disposable protective coveralls. It also establishes minimum labeling and packaging requirements for these garments.

1.2 Purpose. This standard is intended to provide minimum requirements for finished garment dimensions, labeling, and packaging of men's limited-use and disposable protective coveralls. Garments that meet the requirements of this standard will provide the user assurance of the minimum level of fit. In addition, the information provided by the labeling and packaging requirements will provide the user with information important to worker safety.

1.3 Application. It is specifically intended that utilization of only a portion or part of this standard is prohibited.

2. Definitions

coverall. A protective garment designed to be worn over other clothing. (See Figure 1 for an example.)

disposable. A product that is intended to be disposed of rather than refurbished or cleaned.

fabric identification. The name of the fiber or the registered trade name of the fabric.

finished dimensions. Measurements of the completed garment.

limited use. A product that is intended to be worn for one or several wearings prior to disposal.

shall. The word "shall" denotes a mandatory requirement.

should. The word "should" denotes a recommendation.

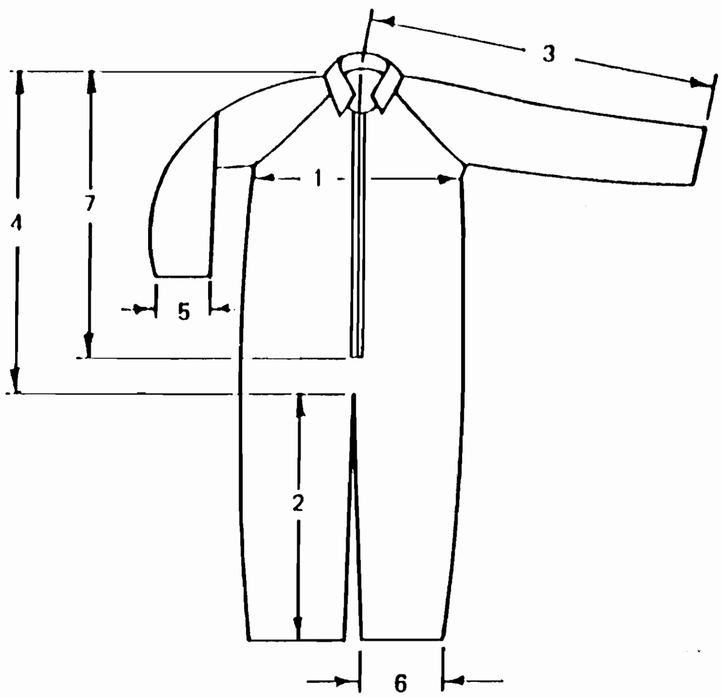


Figure 1
Measurement Locations for Coveralls

Table 1
Minimum Finished Dimensions of
Limited-Use and Disposable Protective Coveralls

Size	(1) Chest	(2) Leg Inseam	(3) Sleeve Outseam from Center Back	(4) Body Length	(5) Sleeve Opening	(6) Leg Opening	(7) Finished Front Opening Length
Small (S)	21-1/2 (54.6)	27-1/2 (69.9)	31-1/2 (80.0)	35 (88.9)	6-1/2 (16.5)	9-1/2 (24.1)	29-1/2 (74.9)
Medium (M)	23-1/2 (59.7)	28 (71.1)	32-1/2 (82.6)	36 (91.4)	7 (17.8)	10 (25.4)	29-1/2 (74.9)
Large (L)	25-1/2 (64.8)	29 (73.7)	33-1/2 (85.1)	37 (94.0)	7 (17.8)	10 (25.4)	30 (76.2)
X large (XL)	27-1/2 (69.9)	29-1/2 (74.9)	35 (88.9)	38-1/2 (97.8)	7 (17.8)	10 (25.4)	30-1/2 (77.5)
XX large (XXL)	29-1/2 (74.9)	30 (76.2)	36-1/2 (92.7)	39 (99.1)	7 (17.8)	10 (25.4)	31 (78.7)

NOTE: All dimensions without parentheses are in inches. All dimensions within parentheses are in centimeters.

3. Minimum Size Requirements

3.1 **Measurements.** Finished garments shall be measured in the seven locations described in this subsection and illustrated in Figure 1. All measurements (in either inches or centimeters) shall be taken with the garment lying flat on a hard horizontal surface. To establish center back point, locate the center back seam (if any) at the top of the neckline or fold the garment so that the sleeve ends meet. The center back point is at the junction of the fold and the top of the neckline.

NOTE: The following numbers correspond to the numbers used in Figure 1 and Table 1.

(1) *Chest.* Measure from 1 inch below the base of the armhole, across the chest from folded edge to folded edge.

(2) *Leg Inseam.* Measure from the center of the crotch seam, down the leg inseam, to the leg bottom.

(3) *Sleeve Outseam Length from Center Back Point.* Measure from the center back point to the top edge of the sleeve end.

(4) *Body Length.* Measure from the top of the neckline at the center back point to the crotch seam with the coveralls flat and front side up.

(5) *Sleeve Opening.* Flatten the sleeve and measure from one folded edge to the other folded edge at the sleeve end.

(6) *Leg Opening.* Flatten the leg and measure from one folded edge to the other folded edge at the leg end.

(7) *Finished Front-Opening Length.* Measure from the center back point to the bottom of the front opening with the coverall flat and front side up.

3.2 **Minimum Dimension Requirements.** Each of the seven measurements shall equal or exceed the dimensions listed for the appropriate size in Table 1.

4. Minimum Labeling Requirements

4.1 Each garment shall be marked legibly and in a conspicuous position using a sewn-in label, contact label, stamp, or other equivalent method.

4.2 For each garment, the following information shall be provided:

(1) Name of manufacturer or other means of identification of the manufacturer
(2) Size
(3) Statement of compliance with this standard
(4) Fabric identification

5. Minimum Packaging Requirements

5.1 Each package shall be marked legibly.

5.2 The following information shall be provided on the package:

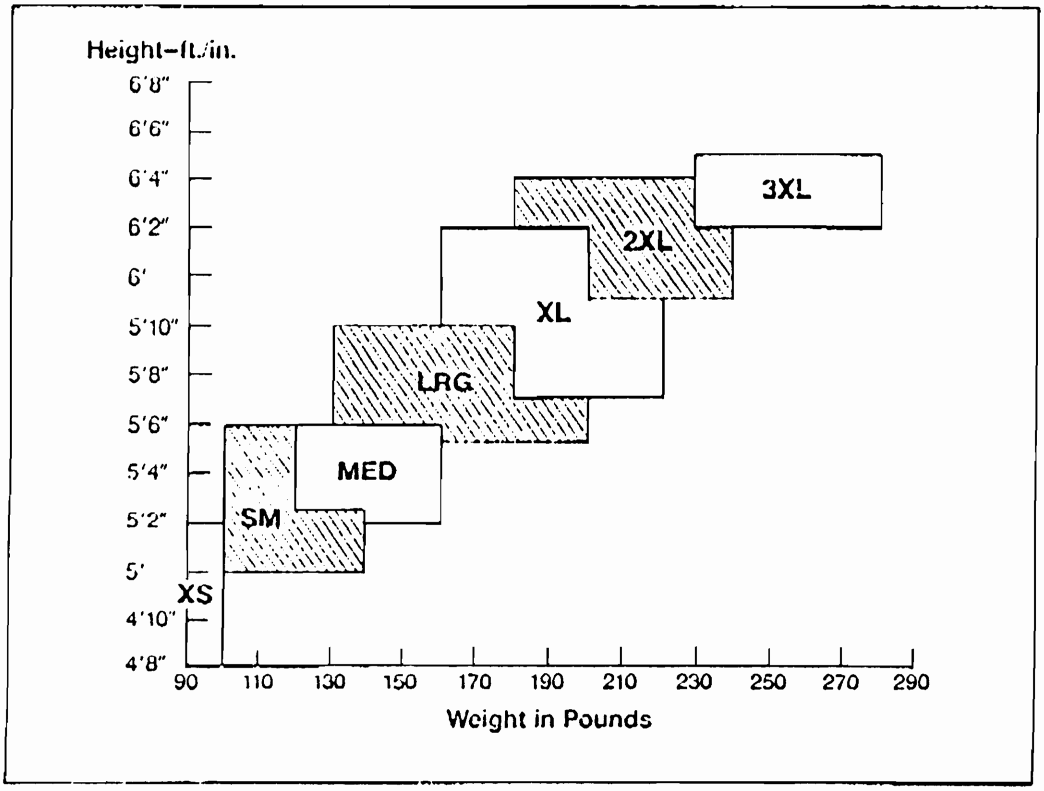
(1) Name of manufacturer or other means of identification of the manufacturer
(2) Number of garments in the package
(3) Size
(4) Statement of compliance with this standard
(5) Fabric identification

Changes to ANSI/ISEA 101-1985 for Proposed Standard

Table 1
Minimum Finished Dimensions of
Limited-Use and Disposable Protective Coveralls

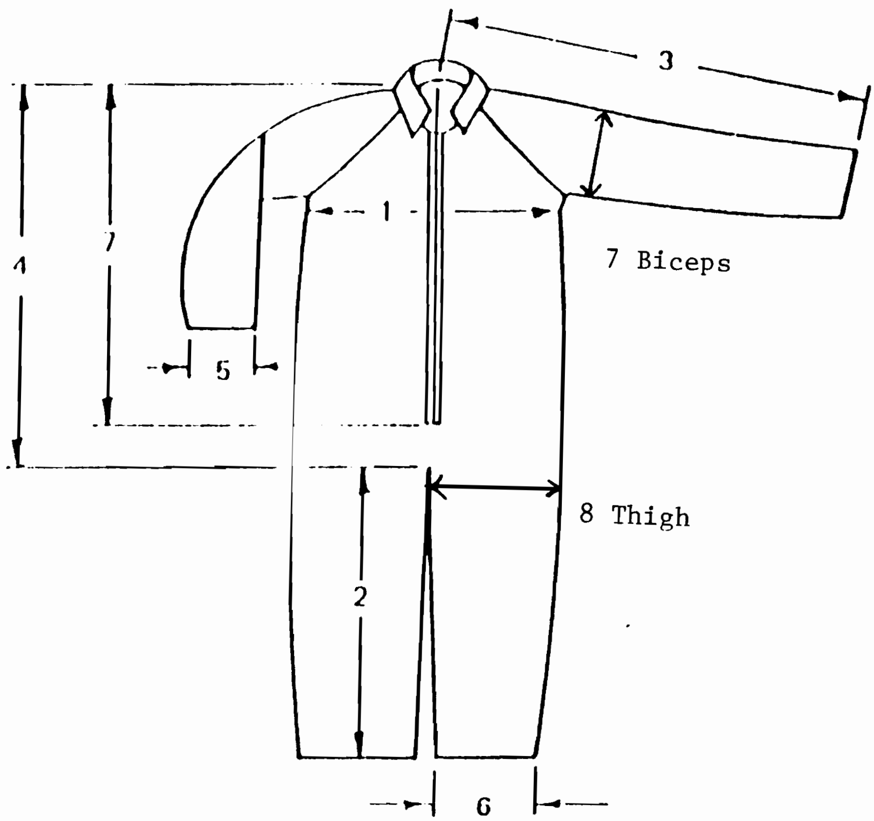
Size	(1) Chest	(2) Leg Inseam	(3) Sleeve Outseam from Center Back	(4) Body Length	(5) Sleeve Opening	(6) Leg Opening	(7) Finished Front Opening Length
X-Small (XS)	19½ (49.5)	27 (68.6)	30½ (77.5)	34 (86.4)	6½ (16.5)	9½ (24.1)	29 (73.7)
Small (S)	21-1/2 (54.6)	27-1/2 (69.9)	31-1/2 (80.0)	35 (88.9)	6-1/2 (16.5)	9-1/2 (24.1)	29-1/2 (74.9)
Medium (M)	23-1/2 (59.7)	28 (71.1)	32-1/2 (82.6)	36 (91.4)	7 (17.8)	10 (25.4)	29-1/2 (74.9)
Large (L)	25-1/2 (64.8)	29 (73.7)	33-1/2 (85.1)	37 (94.0)	7 (17.8)	10 (25.4)	30 (76.2)
X-large (XL)	27-1/2 (69.9)	29-1/2 (74.9)	35 (88.9)	38-1/2 (97.8)	7 (17.8)	10 (25.4)	30-1/2 (77.5)
XX-large (XXL)	29-1/2 (74.9)	30 (76.2)	36-1/2 (92.7)	39 (99.1)	7 (17.8)	10 (25.4)	31 (78.7)
XXX Large (XXXL)	31½ (80)	31 (78.7)	37½ (95.3)	40 (101.6)	7½ (19.1)	10½ (26.7)	31½ (80)

Sizing Chart for Limited Use and Disposable Protective Coveralls



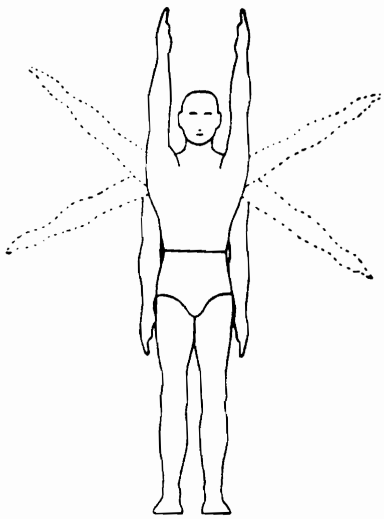
Please Note: This chart is a guide for garment selection, but proper fit varies with individual body shape and under clothing. Test for proper fit before use. Garment performance depends on selecting appropriate size.

APPENDIX C

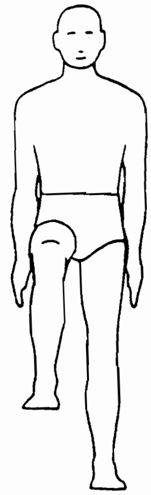


Measurement Locations for Coveralls

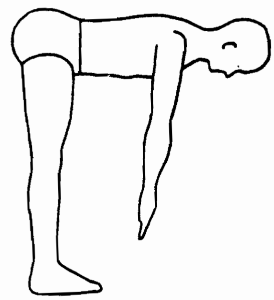
APPENDIX D



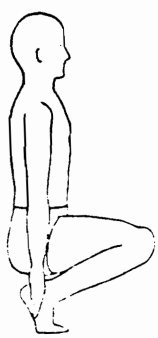
RAISING ARMS OVERHEAD



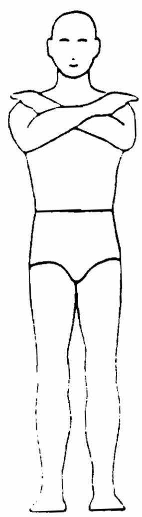
WALKING IN PLACE



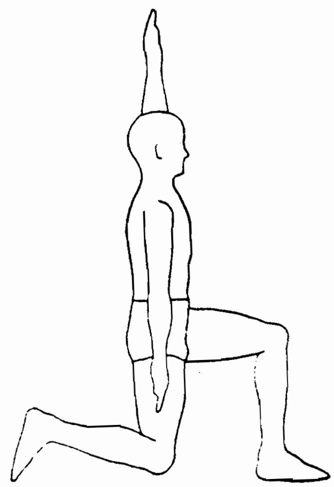
REACHING TOWARDS TOES



DEEP KNEE BENDS



REACHING OPPOSITE SHOULDERS



KNEELING & REACHING OVERHEAD

APPENDIX E

SIZE_____ PACKET NO.____ SUBJECT NO.____

1. Age______
2. Sex ____M ____F
3. Height______
4. Weight______
5. Shoulder Circumference______
6. Chest______
7. Waist______
8. Hip______
9. Sleeve Length______
10. Bicep______
11. Thigh______
12. Girth______
13. Inseam______

Type of clothing worn:

14. ____Knit shirt
____Woven shirt
____Other

15. ____Dress pants
____Blue jeans
____Other

16. Race/Nationality ____Caucasian
____Hispanic
____American Indian
____Black
____Oriental
____Other________

17. Do you ever use protective coveralls? ____Yes ____No

18. If yes, how often? ____Two or three times a year
____Once a month
____Two or three times a month
____Two or three times a week
____Every day

17. In what capacity?____________________________________

Do you object to being videotaped? ____Yes ____No

(The tapes will be used for further evaluation of the coveralls. They may also be used in a classroom setting to describe fit problems.)

Home County ________________ State______________________

Mailing address (Optional)

____
Address City State Zip

APPENDIX F

FIT EVALUATION

Subject No______

Style R S Y

Please circle the number which corresponds
with your assessment of the fit

	Too Short to Function	A Little Too Short	Just Right	A Little Too Long	Too Long to Function	.	Too Tight to Function	A Little Too Tight	Just Right	A Little Too Loose	Too Loose to Function
1. The sleeves were:	1	2	3	4	5	.	1	2	3	4	5
3. The legs were:	1	2	3	4	5	.	1	2	3	4	5
5. The body length was:	1	2	3	4	5	.	1	2	3	4	5
7. The chest area was:	1	2	3	4	5	.	1	2	3	4	5
9. The hip area was:	1	2	3	4	5	.	1	2	3	4	5

The coverall:	Strongly agree	Agree	Tend to agree	Tend to disagree	Disagree	Strongly disagree
10. was difficult to put on	1	2	3	4	5	6
11. was binding across the shoulders	1	2	3	4	5	6
12. was binding in the body area	1	2	3	4	5	6
13. restricted arm movement	1	2	3	4	5	6
14. restricted overhead reach	1	2	3	4	5	6
15. restricted forward reach	1	2	3	4	5	6
16. restricted bending from the waist	1	2	3	4	5	6
17. restricted leg movement	1	2	3	4	5	6
18. restricted kneeling	1	2	3	4	5	6
19. restricted combined kneeling & bending	1	2	3	4	5	6
20. fits well	1	2	3	4	5	6

21. I could easily perform my job wearing this coverall _____Yes _____No

22. If not, I felt the coverall was _____Too Large _____Too Small

Additional comments:

APPENDIX G

INFORMED CONSENT FORM

The Evaluation of Fit of Limited Use Protective Clothing
Manufactured to a Proposed ANSI/ISEA Sizing Standard

Principal Investigator (PI): Dr. Vera B. Keeble

Environmental conditions often require workers to come in contact with hazardous materials. Protective clothing shields the workers from these environmental risks. The fit of these garments may adversely affect body mobility and consequently the ability to perform the job. The purpose of this research project is to evaluate the fit of protective clothing manufactured to a proposed revision of ANSI/ISEA 101, 1985 Sizing Standard. Three companies have supplied their standard Tyvek coverall with zippered front, regular collar and no elastic at wrists or ankles for testing.

Subjects will be selected on the basis of height and weight as specified by the proposed revision to the sizing standard. At least ten subjects per size will wear each style suit while performing tests to evaluate static (stationary body stance) and dynamic (moving body) fit. Measurements to be taken are: height, weight, inseam length, arm length, shoulder girth, vertical trunk circumference, and chest, hip, waist, thigh and upper arm circumference. The garment size will be selected for each individual based on their height and weight. An instructional video that explains the project and the exercise protocol will be viewed by subjects. Then they will don the protective coveralls over their street clothes and perform the exercise routine. The exercise wear test is a series of body movements designed to incorporate typical work postures and movements. Some subjects will be video taped while performing the exercise routine. Faces will be covered for subjects who wish to preserve their anonymity. Subjects will complete a form which identifies how the garments fit.

Subjects will be assigned a code for identification and will not be identified individually at any time. Only group data will be used for publication and presentations based on this study.

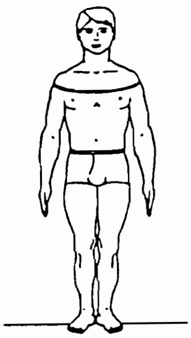
The entire process will take approximately 30 min. Participation is voluntary and subjects may withdraw consent and terminate the test at any time.

Participants may keep all three protective coveralls they test. The use of these garments is not recommended in high heat and humidity. If you experience discomfort under these conditions you should remove the suit.

Any inquiries concerning the project will be answered by Vera B. Keeble.
You may also contact DR. E. R. Stout, Chairman of the Institutional Review Board at Virginia Tech. He oversees the rights of participants in research studies. His number is (703) 231-5281.

Participant, Signature and Date   PI, Signature and Date

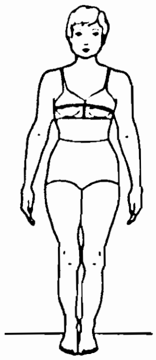
APPENDIX H*



SHOULDER CIRCUMFERENCE

Definition: The horizontal circumference of the body over the deltoid muscles. The subject stands erect, looking straight ahead, arms relaxed at the sides, heels together, and weight distributed equally on both feet.

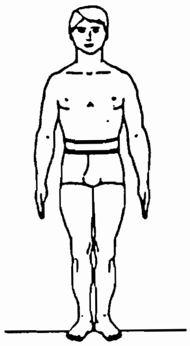
Application: General body description;
Sizing of clothing and personal protective equipment;
Workspace layout.



CHEST CIRCUMFERENCE

Definition: The horizontal circumference of the chest at the level of the nipples. The subject stands erect, looking straight ahead, heels together, and weight distributed equally on both feet.

Application: General body description;
Sizing of clothing and personal protective equipment;
Workspace layout;
Equipment design: upper torso restraint systems and rigging.

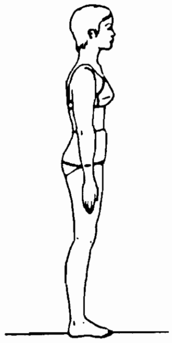


WAIST CIRCUMFERENCE

Definition: The horizontal circumference of the trunk at the level of the waist landmarks. Subject stands erect, looking straight ahead, heels together and weight distributed equally on both feet.

Application: General body description;
Sizing of clothing and personal protective equipment.

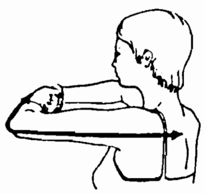
*Reprinted from NASA Anthropometric Source Book, Volume I: Anthropometry for Designers.



BUTTOCK CIRCUMFERENCE

Definition: The circumference of the hips at the level of the maximum posterior protrusion of the buttocks. The subject stands erect, looking straight ahead, heels together, and weight distributed equally on both feet.

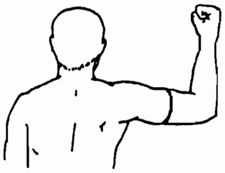
Application: General body description; Sizing of clothing and personal protective equipment.



SPINE-TO-WRIST LENGTH (SLEEVE LENGTH)

Definition: The surface distance from the spine to the wrist landmark. The subject stands, arms horizontal, elbows flexed about 60 degrees, fists clenched and touching, and shoulders relaxed.

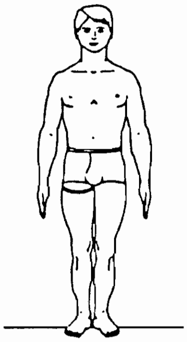
Application: Sizing of clothing and personal protective equipment.



BICEPS CIRCUMFERENCE, FLEXED

Definition: The circumference of the arm at the level of the biceps landmark. The subject stands with his elbow bent at 90 degrees and the biceps maximally flexed.

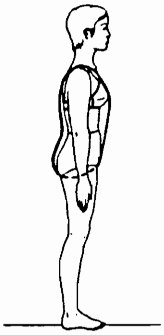
Application: General body description; Sizing of clothing and personal protective equipment.



THIGH CIRCUMFERENCE

Definition: The circumference of the thigh at the level of the gluteal furrow. The subject stands erect, heels approximately 10 cm. apart, and weight distributed equally on both sides.

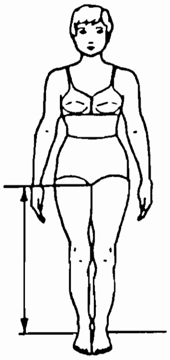
Application: General body description;
Sizing of clothing and personal protective equipment.



VERTICAL TRUNK CIRCUMFERENCE

Definition: The circumference of the trunk measured by passing a tape between the legs, over the protrusion of the right buttock, and up the back to lie over the midshoulder landmark. The other end of the tape is brought up over the right nipple to the midshoulder landmark. The subject stands with the legs slightly apart.

Application: Sizing of clothing and personal protective equipment;
Equipment design: length of straps and webbing for restraint systems and rigging.



CROTCH HEIGHT

Definition: The vertical distance from the standing surface up into the crotch until light contact is made. The subject stands erect, heels approximately 10 cm. apart, and weight distributed equally on both feet.

Application: Sizing of clothing and personal protective equipment.

APPENDIX I

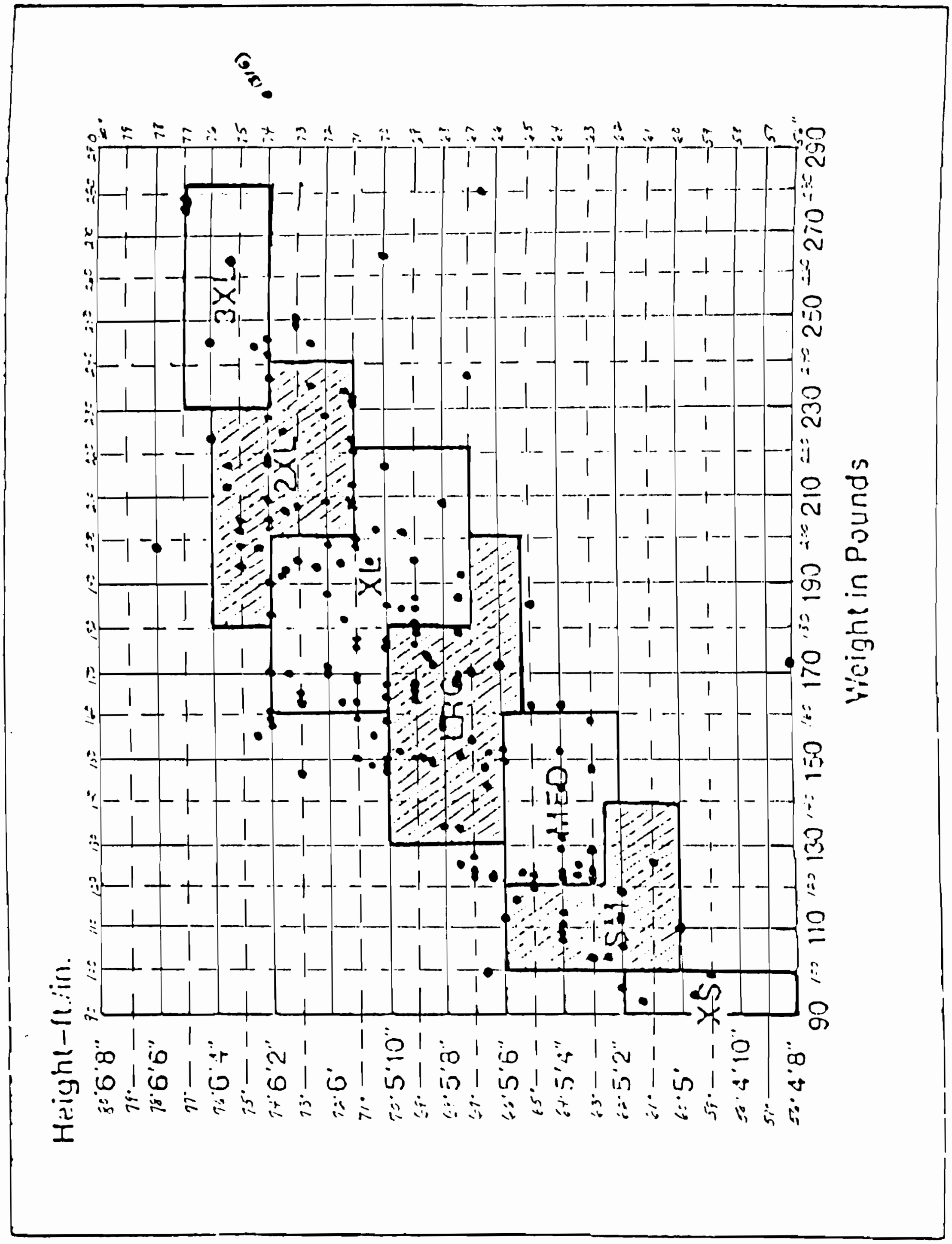


FIGURE I.1. Size Distribution for Entire Sample

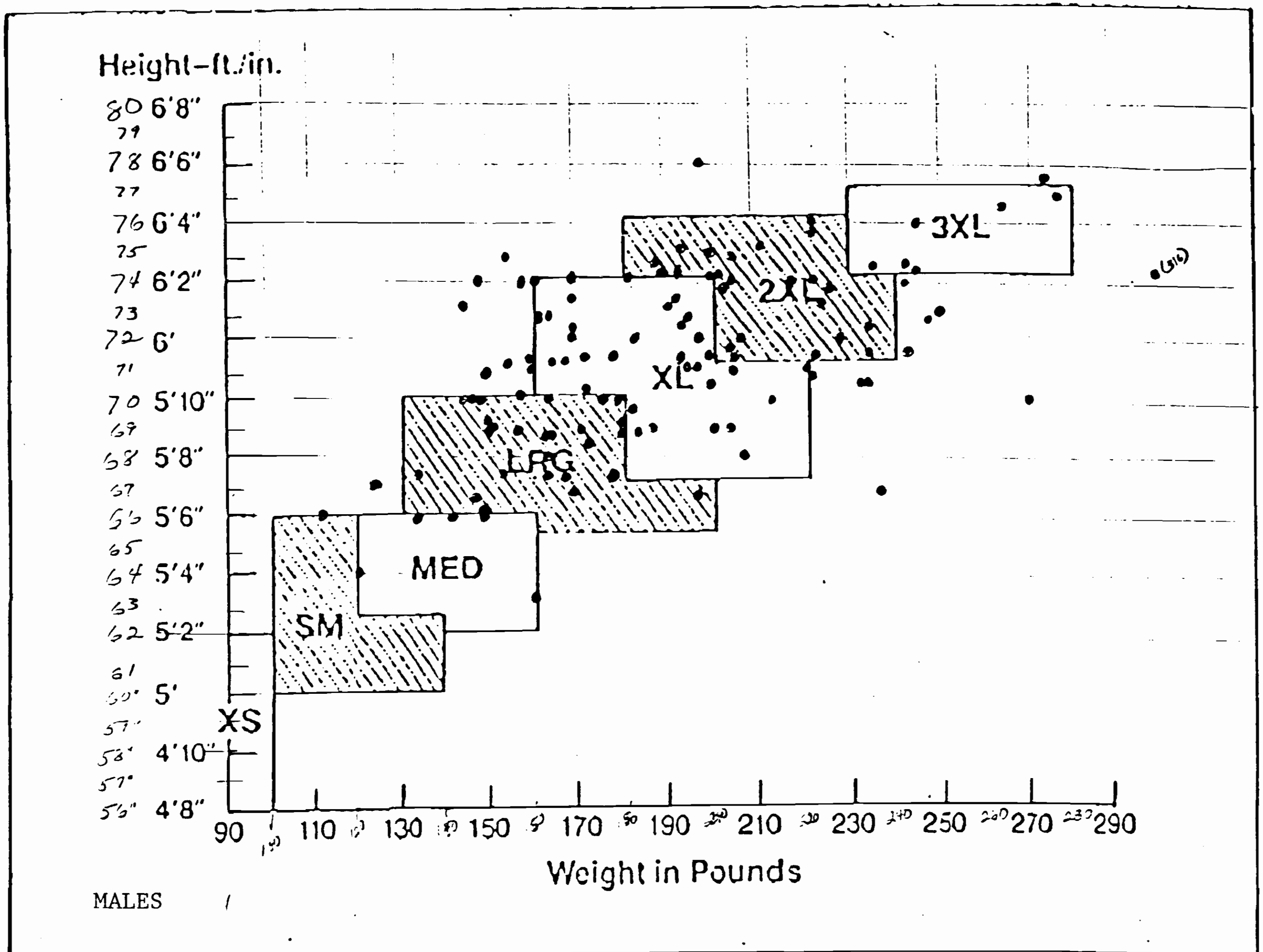


FIGURE I.2. Size Distribution for Males

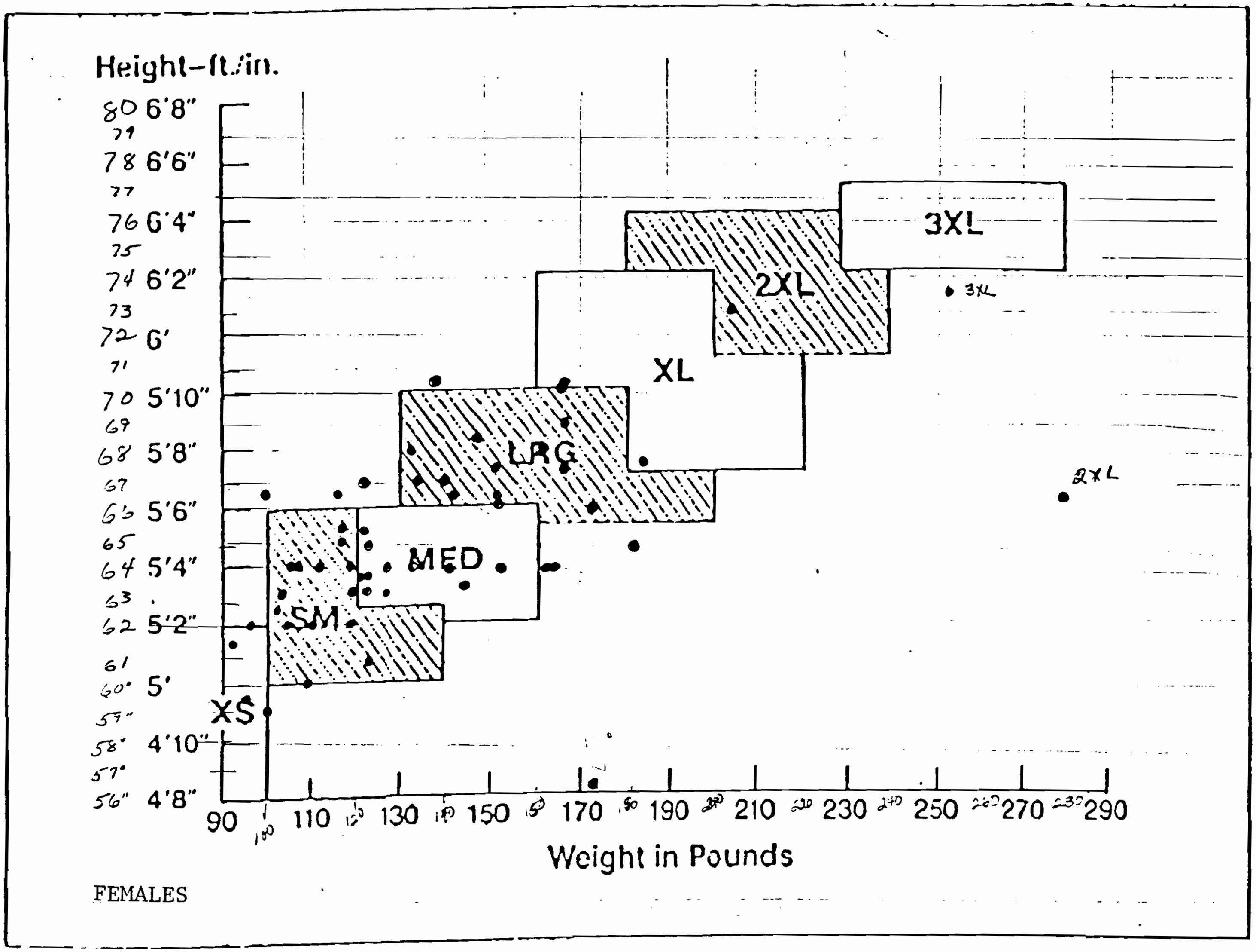


FIGURE I.3. Size Distribution for Females

APPENDIX J

TABLE J.1

Demographics of Sample

Size	Total Number	Males	Females	Age Range	Racial Groups
XS	4	0	4	20-29	4
S	21	2	19	15-64	3
M	22	5	17	25-68	2
L	35	24	11	21-65	2
XL	37	35	2	15-75	3
2XL	33	31	2	19-69	2
3XL	14	13	1	19-67	2
TOTAL	166	110	56	15-75	

TABLE J.2

Demographics of Sample by Gender and Size

Size	Total Number	Percent of Sample	Males	Percent of Size	Percent of Sample	Females	Percent of Size	Percent of Sample
XSmall	4	2.4	0	0	0	4	100	2.4
Small	21	12.6	2	9.5	1.2	19	90.5	11.4
Medium	22	13.3	5	22.7	3.0	17	79.3	10.3
Large	35	21.1	24	68.6	14.5	11	31.4	6.6
XLarge	37	22.3	35	94.6	21.1	2	5.4	1.2
2XLarge	33	19.9	31	93.9	18.7	2	6.1	1.2
3XLarge	14	8.4	13	92.9	9.8	1	7.1	0.6
TOTAL	166	100	110	---	66.3	56	--	88.6

TABLE J.3

Demographics of Sample by Size & Age

Age	XSmall	Small	Medium	Large	XLarge	2XLarge	3XLarge	Total
18 or less	2	0	1	0	0	0	3	3
19-25	2	0	1	3	8	4	3	27
26-35	0	4	7	8	10	8	3	40
36-50	0	5	9	14	12	14	5	59
51 and Over	0	4	4	6	3	7	3	27
Totals	4	19	22	31	33	33	14	156*

*10 Subjects did not report their ages.

TABLE J.4

Racial Mix of Sample

Racial Group	Total Number
Caucasian	130
Hispanic	1
Black	25
Oriental	6
Other	1
No Response	3

TABLE J.5

Frequencies for Entire Sample

166 Subjects 3 Garments each	Total No.	 %	Yoke with Sleeve No.	 %	Raglan Sleeve No.	 %	Set-in Sleeve No.	 %
The garment fits well								
Agree	255	51.2	88	53.0	75	45.2	92	55.4
Disagree	243	48.8	78	47.0	91	54.9	74	44.6
Total	498	100.0	166	100.0	166	100.0	166	100.0
I could easily perform my job wearing this coverall								
Yes	302	60.9	103	62.4	86	51.8	113	68.5
No	194	39.1	62	37.6	80	48.2	52	31.5
Total	496	100.0	165	100.0	166	100.0	165	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	147	29.5	22	13.3	78	47.0	47	28.3
Too small	72	14.5	49	29.5	7	4.2	16	9.6
Total	219	44.0	71	42.8	85	51.2	63	37.9

TABLE J.6

Frequencies for Size XSmall

4 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	1	8.3	1	25.0	0	0.0	0	0.0
Disagree	11	91.7	3	75.0	4	100.0	4	100.0
Total	12	100.0	4	100.0	4	100.0	4	100.0
I could easily perform my job wearing this coverall								
Yes	3	25.0	1	25.0	4	100.0	1	25.0
No	9	75.0	3	75.0	0	0.0	3	75.0
Total	12	100.0	4	100.0	4	100.0	4	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	10	83.5	3	75.0	4	100.0	3	75.0
Too small	0	000	0	0.0	0	0.0	0	0.0
Total	10	83.0	3	75.0	4	100.0	3	75.0

TABLE J.7

Frequencies for Size Small

21 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	25	39.7	11	52.4	9	42.9	5	23.8
Disagree	38	60.3	10	47.6	12	57.2	16	76.2
Total	63	100.0	21	100.0	21	100.0	21	100.0
I could easily perform my job wearing this coverall								
Yes	32	50.8	13	61.9	10	47.6	9	42.9
No	31	49.2	8	38.1	11	52.4	12	57.1
Total	63	100.0	21	100.0	21	100.0	21	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	30	47.6	9	42.9	8	38.1	13	61.9
Too small	3	4.8	1	4.8	2	9.5	0	0.0
Total	33	52.4	10	47.7	10	47.2	13	61.9

TABLE J.8 <u>Frequencies for Size Medium</u>

22 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	39	49.9	11	49.9	13	59.1	15	68.2
Disagree	27	50.0	11	50.0	9	40.9	7	31.7
Total	66	100.0	22	99.9	22	100.0	22	99.9
I could easily perform my job wearing this coverall								
Yes	41	63.1	13	61.9	11	50.0	17	77.3
No	24	36.9	8	38.1	11	50.0	5	22.7
Total	65	100.0	21	100.0	21	100.0	22	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	16	24.2	2	9.1	8	38.4	6	27.3
Too small	9	13.6	5	22.7	3	13.6	1	4.5
Total	25	37.8	7	31.8	11	50.0	7	31.8

TABLE J.9 Frequencies for Size Large

35 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	69	65.7	21	60.0	23	65.7	25	71.5
Disagree	36	34.1	14	40.0	12	34.9	10	28.5
Total	105	100.0	35	100.0	35	10030	35	99.9
I could easily perform my job wearing this coverall								
Yes	74	70.5	25	71.4	23	65.7	26	74.3
No	31	29.5	10	28.6	12	34.3	9	25.7
Total	105	100.0	35	100.0	35	100.0	35	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	24	22.9	3	8.6	11	31.4	10	28.6
Too small	14	13.3	9	25.7	2	5.7	3	8.6
Total	38	36.2	12	34.3	13	37.1	13	37.2

TABLE J.10 Frequencies for Size XLarge

37 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	61	55.0	21	56.7	16	43.2	24	64.8
Disagree	50	45.0	16	43.2	21	56.7	13	35.1
Total	111	100.0	37	100.0	37	100.0	37	100.0
I could easily perform my job wearing this coverall								
Yes	73	65.8	24	64.9	19	61.4	30	81.1
No	38	34.2	13	35.1	18	48.6	7	18.9
Total	111	100.0	37	100.0	37	100.0	37	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	30	27.0	4	10.8	21	56.8	5	13.5
Too small	16	14.4	12	32.4	0	0.0	4	10.8
Total	46	41.4	16	43.2	21	56.8	9	24.3

TABLE J.11 Frequencies for Size 2XLarge

33 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	45	45.5	19	57.6	8	24.3	18	54.6
Disagree	54	54.5	14	42.4	25	75.8	15	45.4
Total	99	100.0	33	100.0	33	100.1	33	100.0
I could easily perform my job wearing this coverall								
Yes	55	55.6	22	66.7	11	33.3	22	66.7
No	44	44.4	11	33.3	22	66.7	11	33.3
Total	99	100.0	33	100.0	33	100.0	33	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	31	31.3	1	3.0	23	69.7	7	21.2
Too small	16	16.2	11	33.3	0	0.0	5	15.2
Total	47	44.5	12	36.3	23	69.7	12	36.4

TABLE J.12

Frequencies for Size 3XLarge

14 Subjects	Total No.	Total %	Yoke with Sleeve No.	Yoke with Sleeve %	Raglan Sleeve No.	Raglan Sleeve %	Set-in Sleeve No.	Set-in Sleeve %
The garment fits well								
Agree	15	35.6	4	28.6	6	42.8	5	35.7
Disagree	27	64.3	10	71.4	8	57.1	9	64.3
Total	42	100.0	14	100.0	14	99.9	14	100.0
I could easily perform my job wearing this coverall								
Yes	24	58.6	5	35.7	11	78.6	8	61.5
No	17	41.4	9	64.3	3	21.4	5	38.5
Total	41	100.0	14	100.0	14	100.0	13	100.0
If I couldn't perform my job it was because the coverall was								
Too Large	6	14.3	0	0.0	3	21.4	3	21.4
Too small	14	33.3	11	78.6	0	0.0	3	21.4
Total	20	47.6	11	78.6	3	21.4	6	42.8

TABLE J.13

Responses of Users Versus Non-Users

	(85 Subjects - 3 Garments) Users Only		(Subjects 3-Garments) Non-Users	
Garment Fit Well	Number	Percent	Number	Percent
Agree	139	54.5	113	47.7
Disagree	116	45.5	124	52.3
Total	255		237	
I could easily perform my job wearing this coverall				
Agree	166	65.1	133	56.2
Disagree	88	34.5	103	43.8
Total	254		236	
If I couldn't perform my job it was because the coverall was				
Too Large	75	29.4	72	30.3
Too Small	35	13.7	37	15.6
Total	110		109	

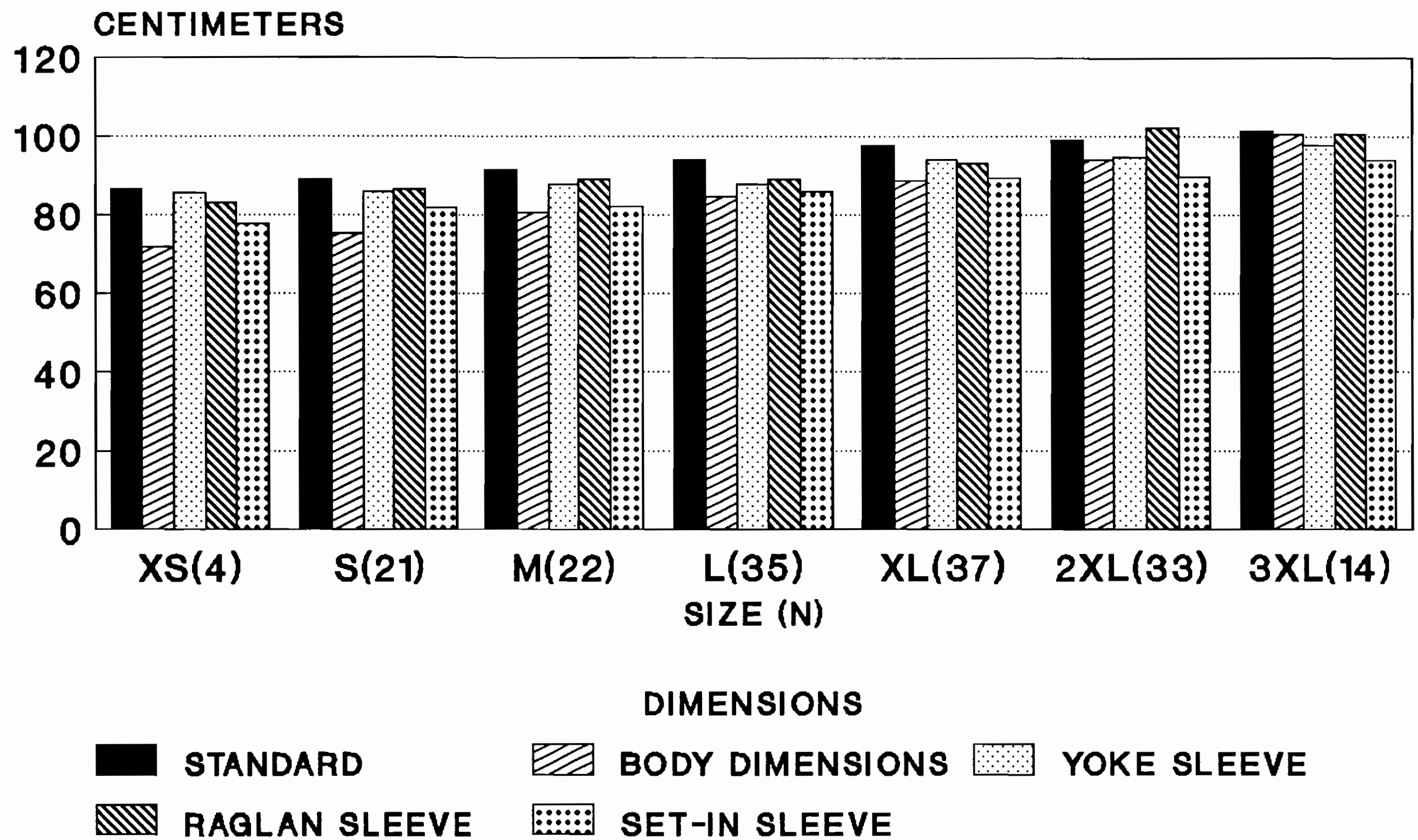


Figure J.1. Body Length Dimensions

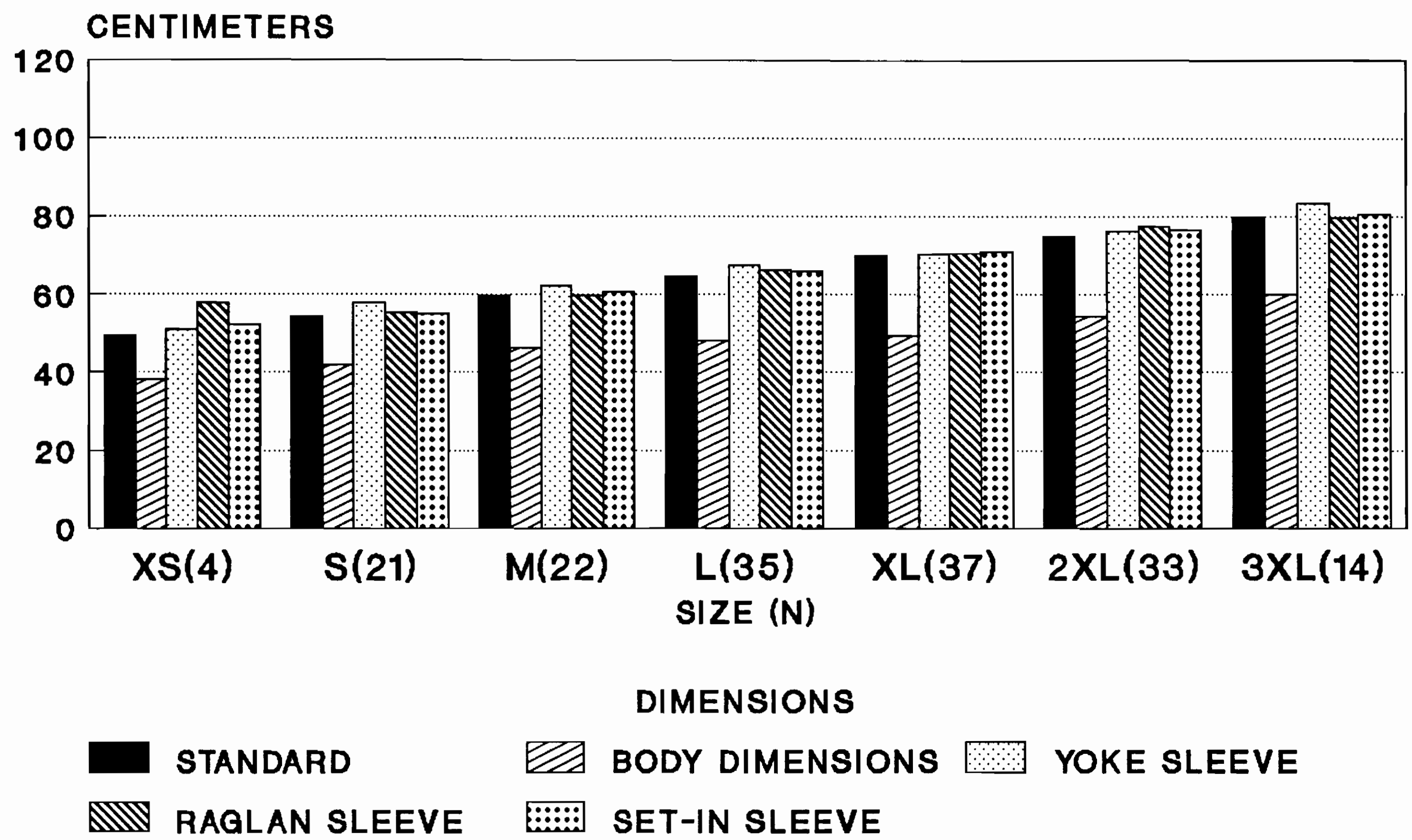


Figure J.2. Chest Dimensions

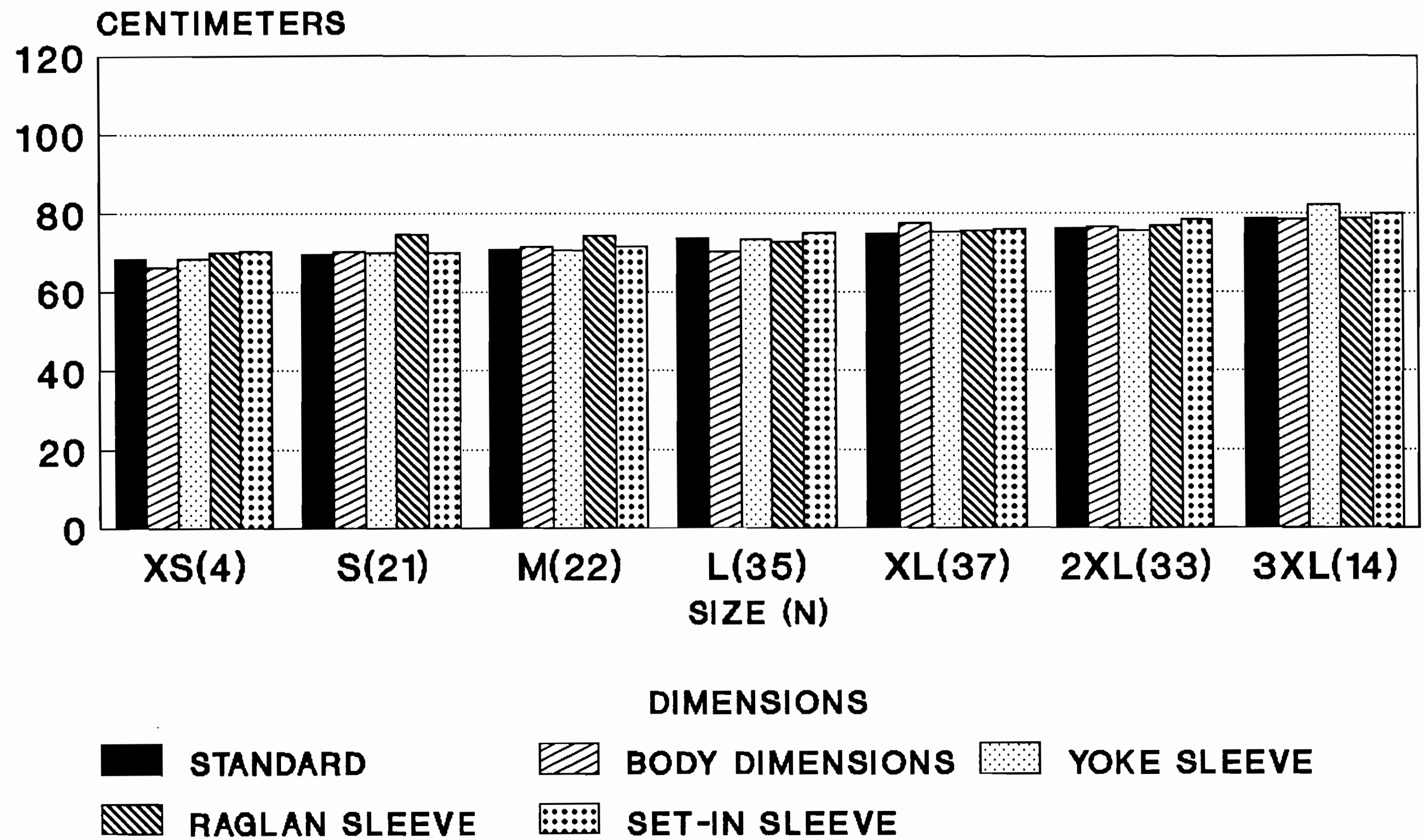


Figure J.3. Leg Inseam Dimensions

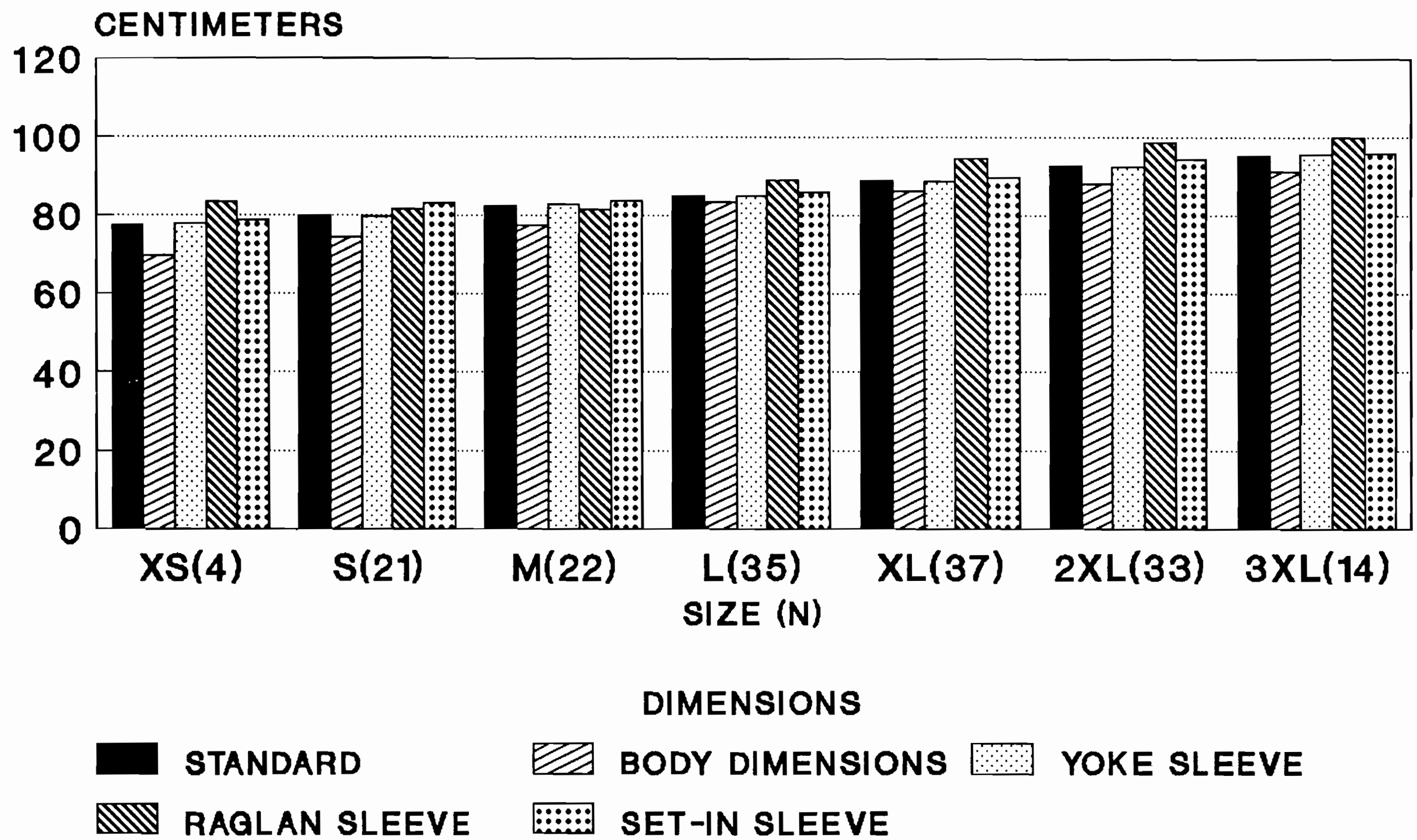


Figure J.4. Sleeve Outseam Dimensions

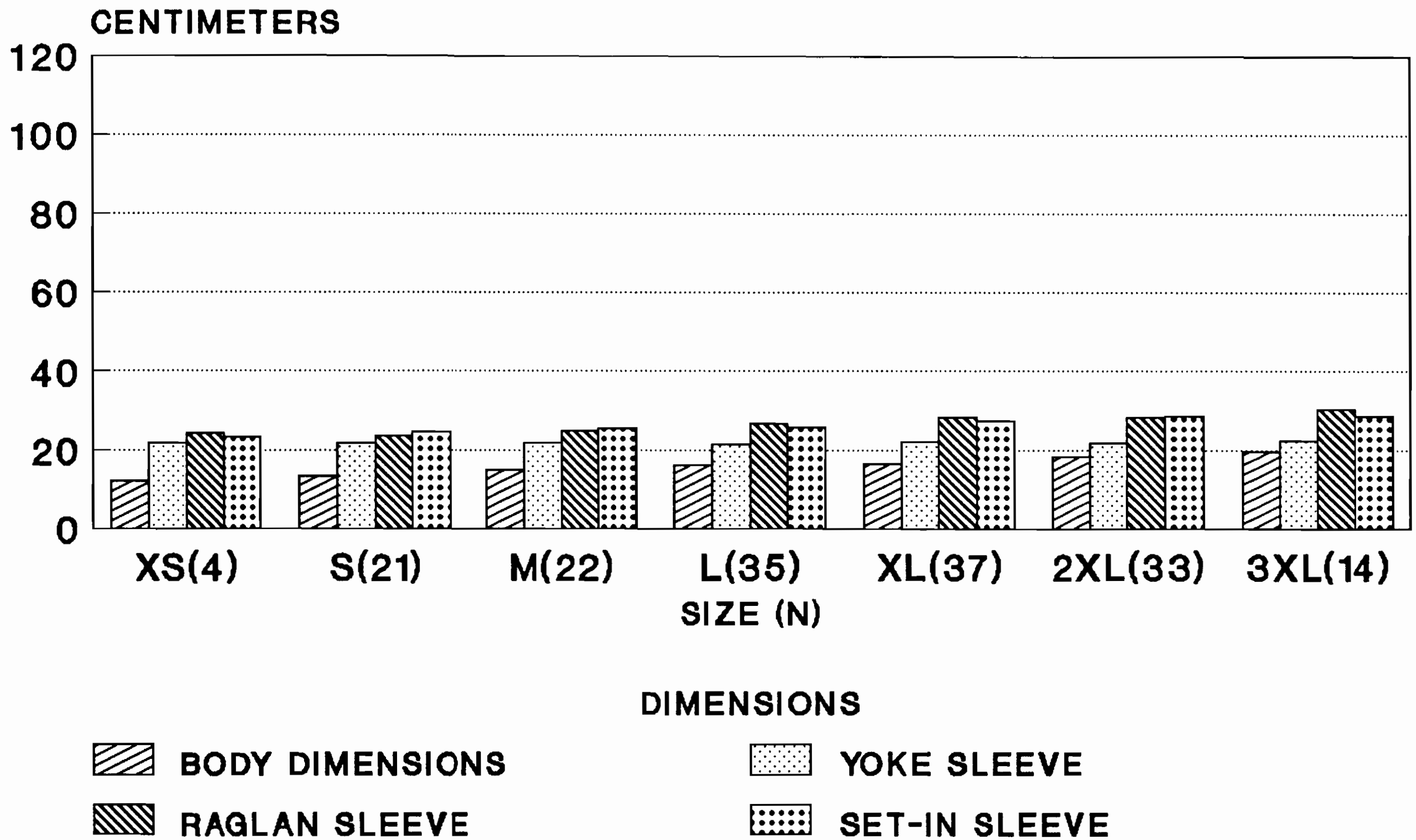


Figure J. 5. Biceps Dimensions

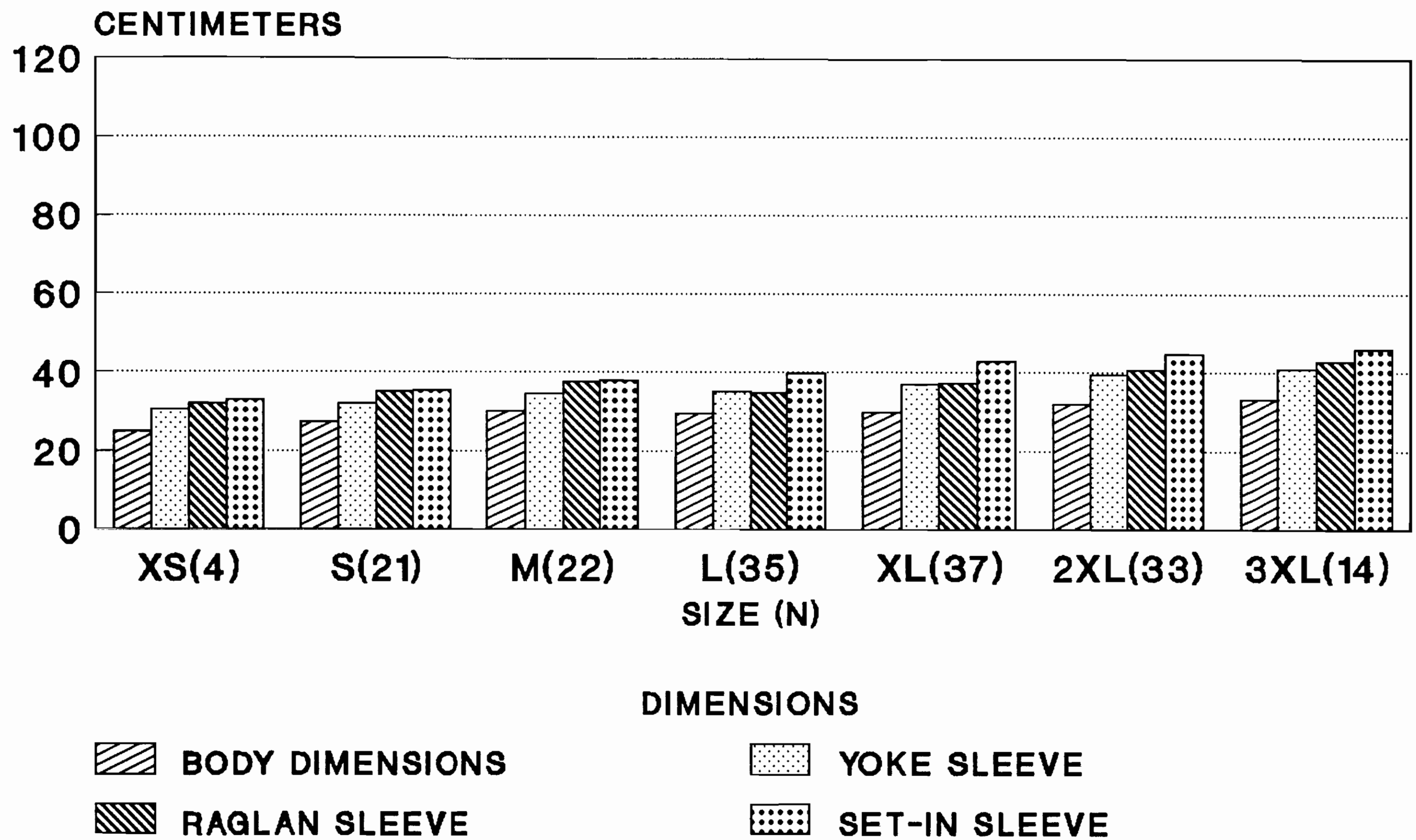


Figure J.6. Thigh Dimensions

TABLE J.14

Means, Standard Deviations and Analysis of Variance for Sleeve Length Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.25	3.95	3.09	3.05	2.70	2.81	2.86
(SD)	(0.96)	(0.74)	(0.92)	(0.59)	(0.74)	(0.82)	(0.82)
Raglan Sleeve							
Mean	4.50	3.90	3.45	3.74	4.16	4.34	3.57
(SD)	(0.58)	(0.70)	(0.67)	(0.78)	(0.69)	(0.74)	(0.85)
Set-in Sleeve							
Mean	4.50	4.04	3.50	3.43	3.32	3.42	3.21
(SD)	(0.58)	(1.02)	(0.86)	(0.88)	(0.58)	(0.87)	(0.70)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	36.02	6.00	6.05	0.0001
Error-between	159	157.71	0.99		
Within Ss					
Styles (B)	2	29.90	14.95	38.08	0.0001
A X B	12	20.27	2.44	6.21	0.0001
Error-within	318	124.84	0.39		

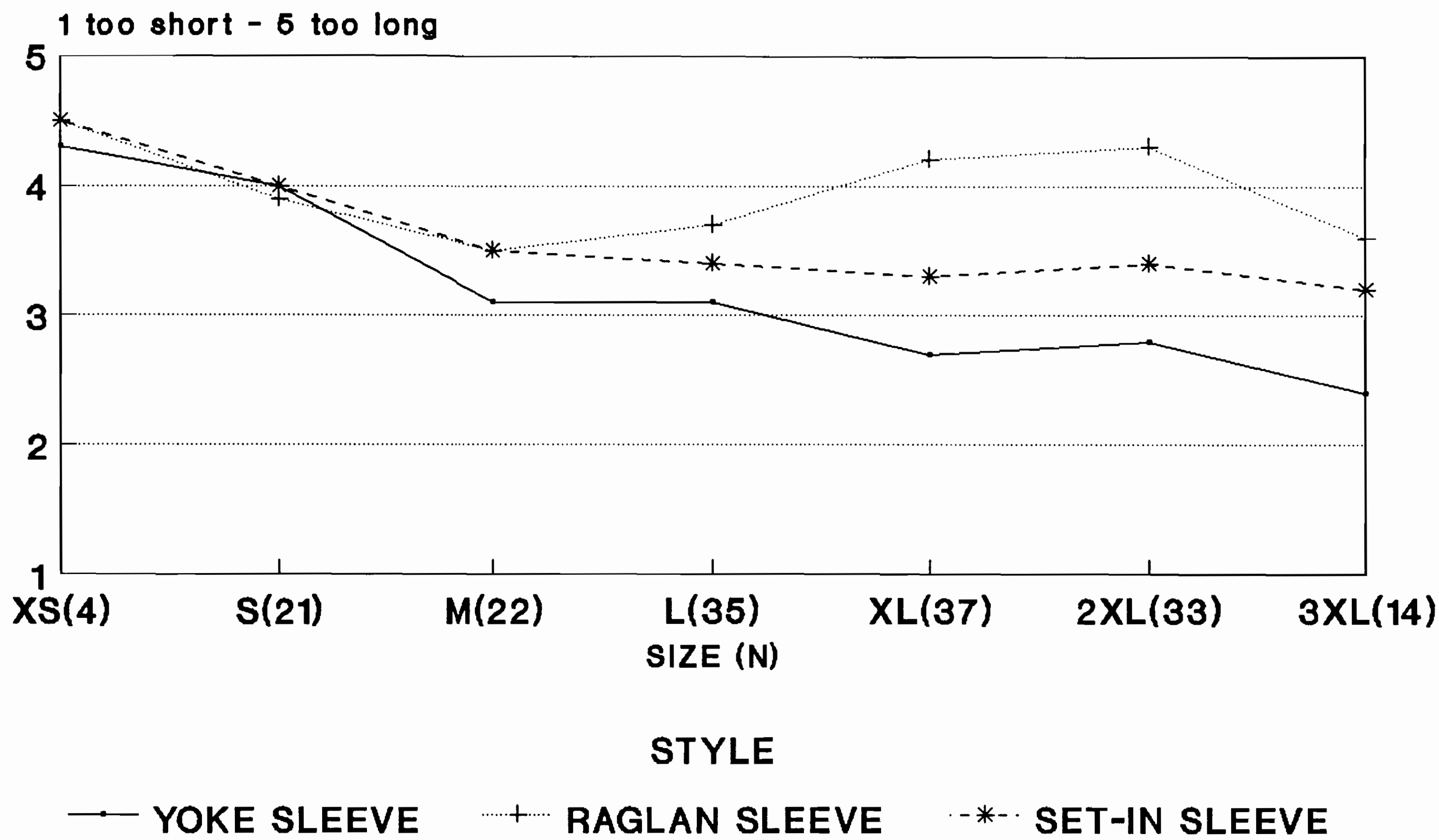


Figure J.7 Static Sleeve Length

TABLE J.15

Means, Standard Deviations and Analysis of Variance for Leg Length Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.50	4.00	3.23	3.08	2.82	2.65	2.43
(SD)	(1.00)	(0.77)	(0.82)	(0.83)	(0.58)	(0.83)	(0.85)
Raglan Sleeve							
Mean	5.00	3.95	3.77	3.69	3.67	4.28	3.57
(SD)	(0.00)	(0.80)	(0.87)	(0.63)	(0.91)	(0.73)	(0.76)
Set-in Sleeve							
Mean	4.75	4.14	3.50	3.37	3.08	3.03	2.65
(SD)	(0.50)	(0.57)	(0.80)	(0.91)	(0.64)	(0.82)	(0.84)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	63.98	10.66	9.36	0.0001
Error-between	159	181.15	1.14		
Within Ss					
Styles (B)	2	27.75	13.88	43.00	0.0001
A X B	12	25.17	2.10	6.50	0.0001
Error-within	318	102.62	0.32		

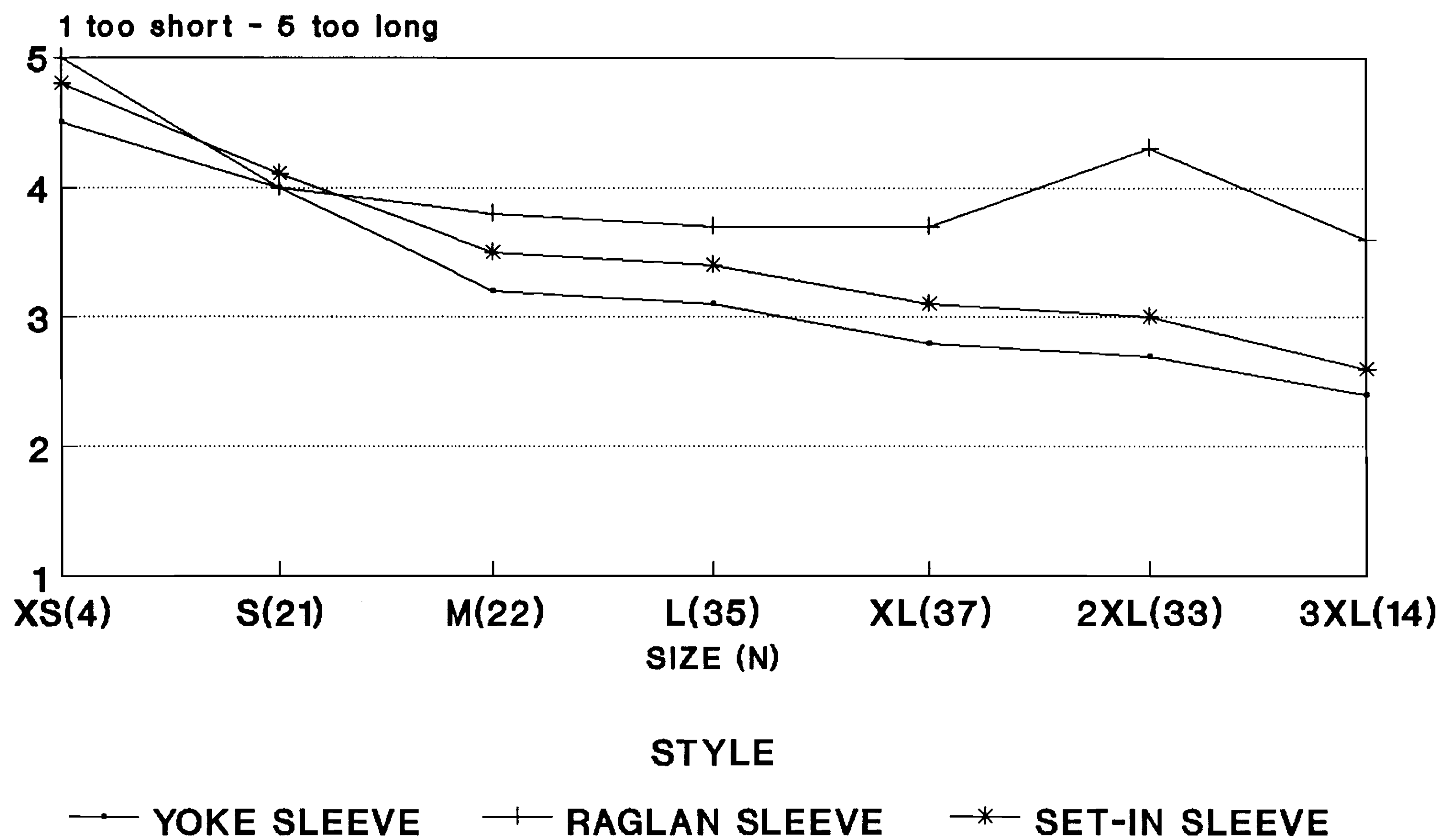


Figure J.8. Static Leg Length

TABLE J.16

Means, Standard Deviations and Analysis of Variance for Body Length Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.25	3.90	2.95	2.66	2.56	2.28	1.92
(SD)	(0.50)	(0.89)	(0.90)	(0.80)	(0.65)	(0.73)	(0.76)
Raglan Sleeve							
Mean	4.50	3.57	3.32	3.02	3.56	3.68	3.57
(SD)	(0.58)	(0.87)	(0.78)	(0.79)	(0.61)	(1.00)	(0.85)
Set-in Sleeve							
Mean	4.50	4.05	3.23	2.91	2.97	2.79	2.71
(SD)	(0.58)	(0.74)	(0.81)	(0.66)	(0.65)	(0.89)	(0.73)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	70.05	11.67	9.95	0.0001
Error-between	159	186.52	1.17		
Within Ss					
Styles (B)	2	20.86	10.43	32.94	0.0001
A X B	12	31.38	2.62	8.26	0.0001
Error-within	318	100.67	0.32		

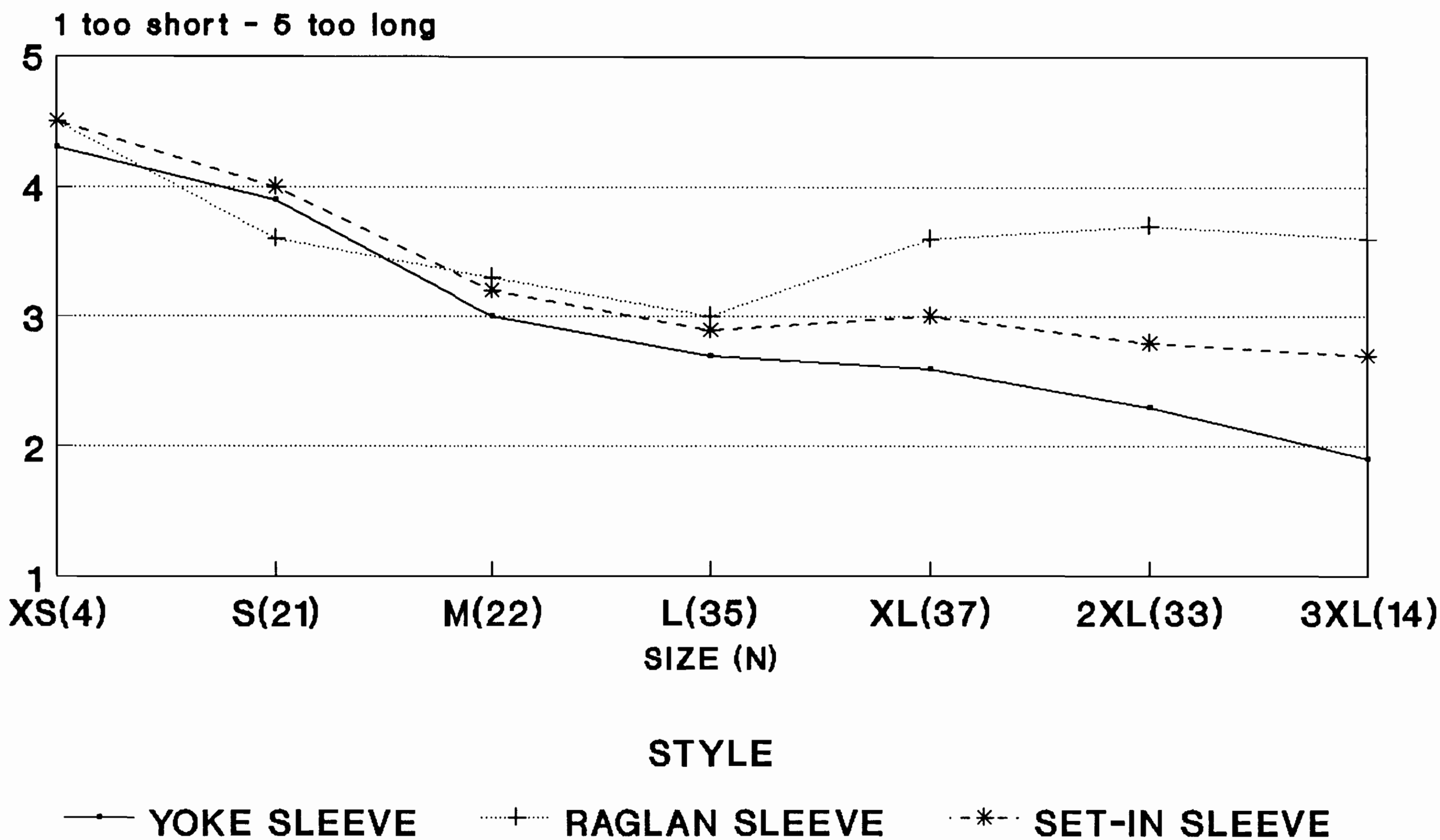


Figure J.9. Static Body Length

TABLE J.17

Means, Standard Deviations and Analysis of Variance for Sleeve Tightness Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	3.50	3.23	2.77	2.88	2.81	2.86	2.10
(SD)	(0.58)	(0.54)	(0.61)	(0.60)	(0.68)	(0.69)	(0.88)
Raglan Sleeve							
Mean	4.00	3.14	3.45	3.50	3.71	4.13	3.73
(SD)	(0.82)	(0.79)	(0.67)	(0.62)	(0.72)	(0.76)	(1.01)
Set-in Sleeve							
Mean	4.25	3.57	3.18	3.38	3.29	3.28	2.65
(SD)	(0.50)	(0.75)	(0.66)	(0.55)	(0.46)	(0.75)	(0.92)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	12.65	2.11	2.70	0.0159
Error-between	159	124.00	0.78		
Within Ss					
Styles (B)	2	27.41	14.20	53.06	0.0001
A X B	12	21.05	1.75	6.55	0.0001
Error-within	318	85.12	0.27		

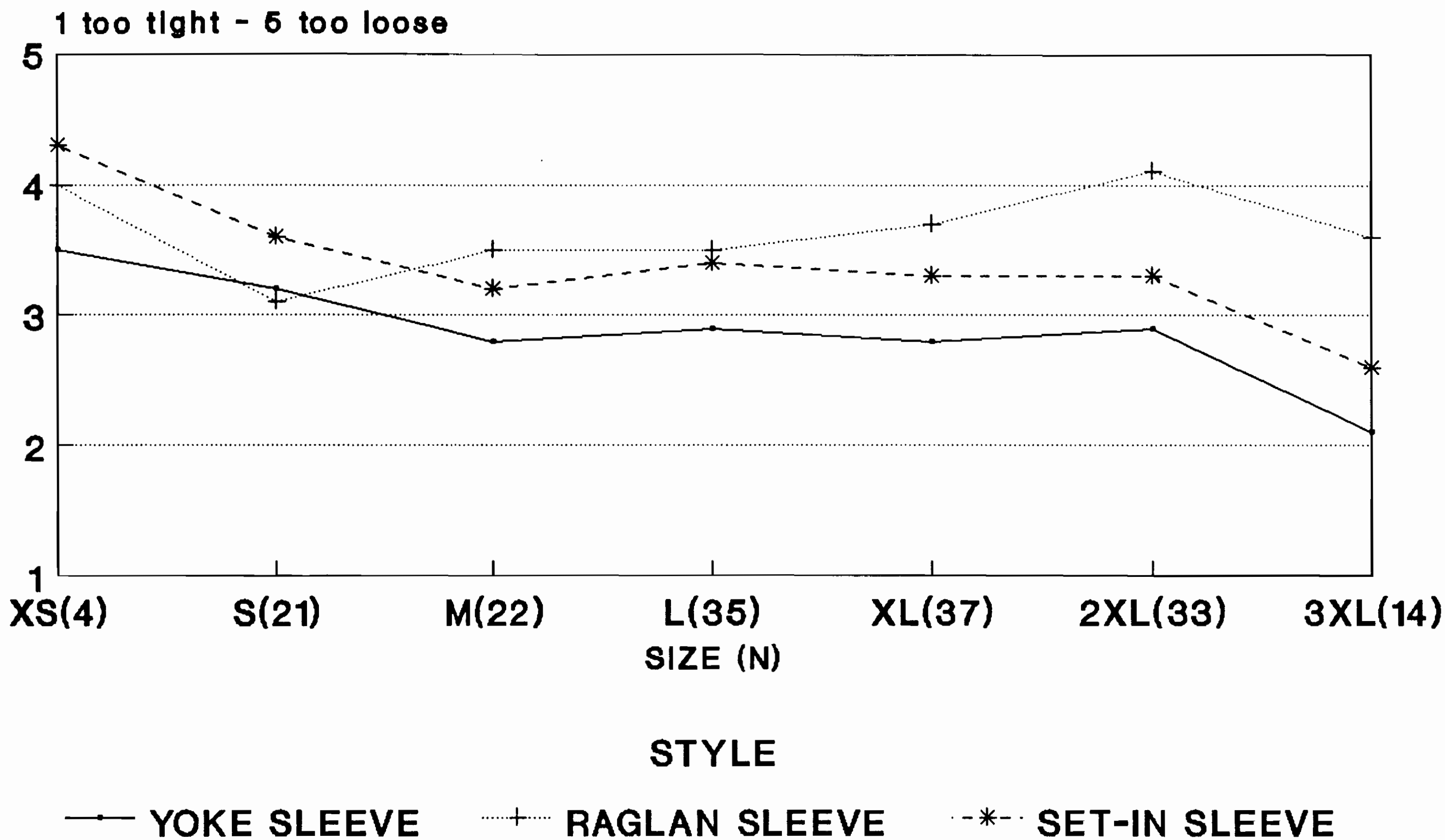


Figure J.10. Static Sleeve Tightness

TABLE J.18

Means, Standard Deviations and Analysis of Variance for Leg Tightness Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.00	3.38	3.09	2.97	3.00	2.83	2.10
(SD)	(0.82)	(0.50)	(0.53)	(0.74)	(0.62)	(0.75)	(0.74)
Raglan Sleeve							
Mean	4.00	3.14	3.32	3.25	3.64	4.16	3.72
(SD)	(0.00)	(0.57)	(0.72)	(0.62)	(0.65)	(0.73)	(0.79)
Set-in Sleeve							
Mean	4.25	3.43	3.19	3.21	3.18	3.14	2.91
(SD)	(0.50)	(0.68)	(0.66)	(0.65)	(0.53)	(0.74)	(0.70)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	13.27	2.21	3.28	0.0045
Error-between	159	107.08	0.67		
Within Ss					
Styles (B)	2	14.05	7.03	25.40	0.0001
A X B	12	27.69	2.31	8.34	0.0001
Error-within	318	87.95	0.28		

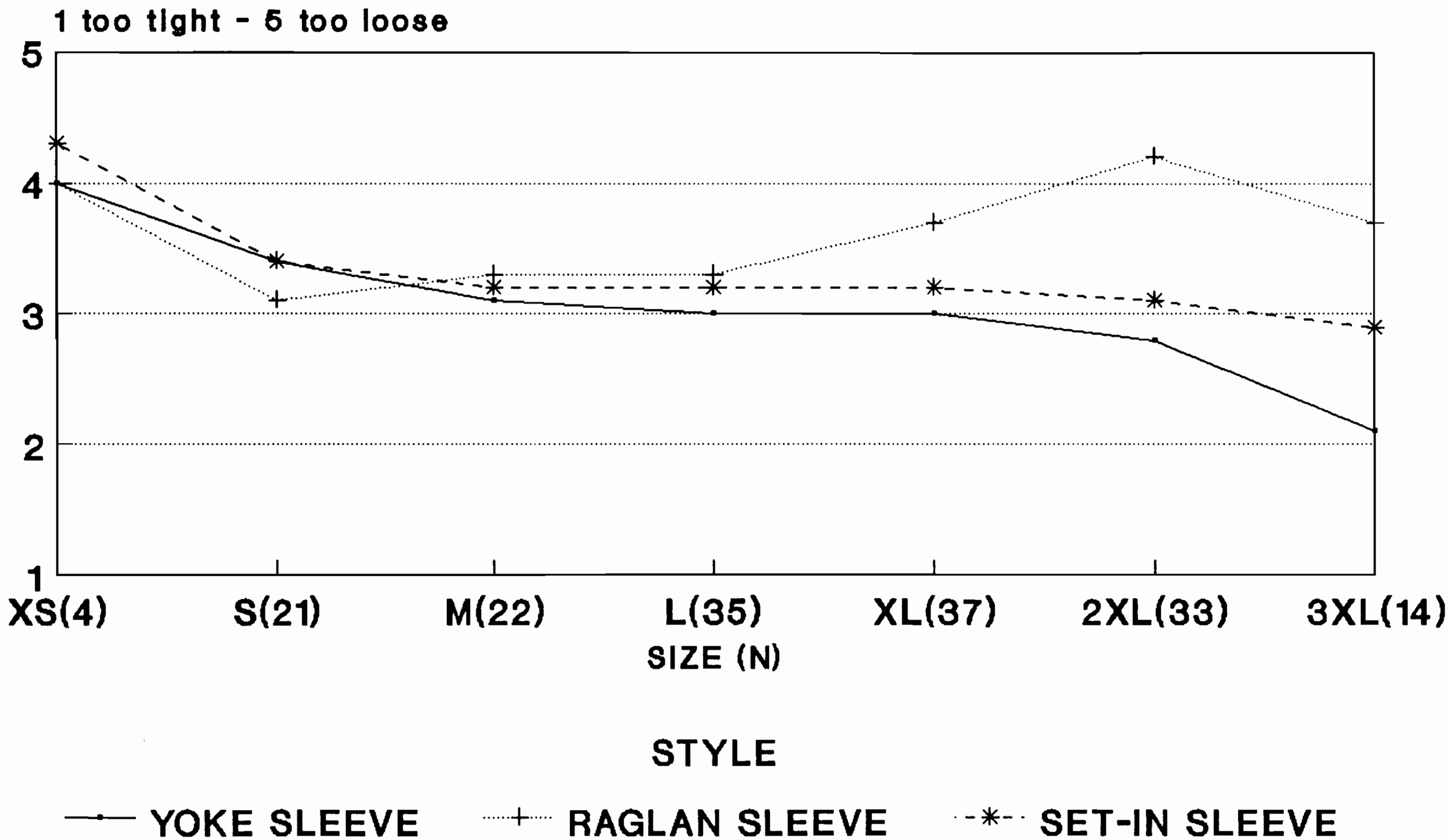


Figure J.II. Static Leg Tightness

TABLE J.19

Means, Standard Deviations and Analysis of Variance for Chest Tightness Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	3.50	3.00	2.95	2.97	2.91	2.94	2.50
(SD)	(0.58)	(0.45)	(0.38)	(0.53)	(0.53)	(0.73)	(0.67)
Raglan Sleeve							
Mean	4.00	3.09	3.32	3.15	3.53	4.00	3.54
(SD)	(0.82)	(0.44)	(0.48)	(0.63)	(0.74)	(0.79)	(0.93)
Set-in Sleeve							
Mean	5.50	3.24	3.23	3.27	3.19	3.26	3.23
(SD)	(0.82)	(0.62)	(0.61)	(0.62)	(0.57)	(0.68)	(0.83)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	13.27	2.21	3.28	0.0045
Error-between	159	107.08	0.67		
Within Ss					
Styles (B)	2	14.05	7.03	25.40	0.0001
A X B	12	27.69	2.31	8.34	0.0001
Error-within	318	87.95	0.28		

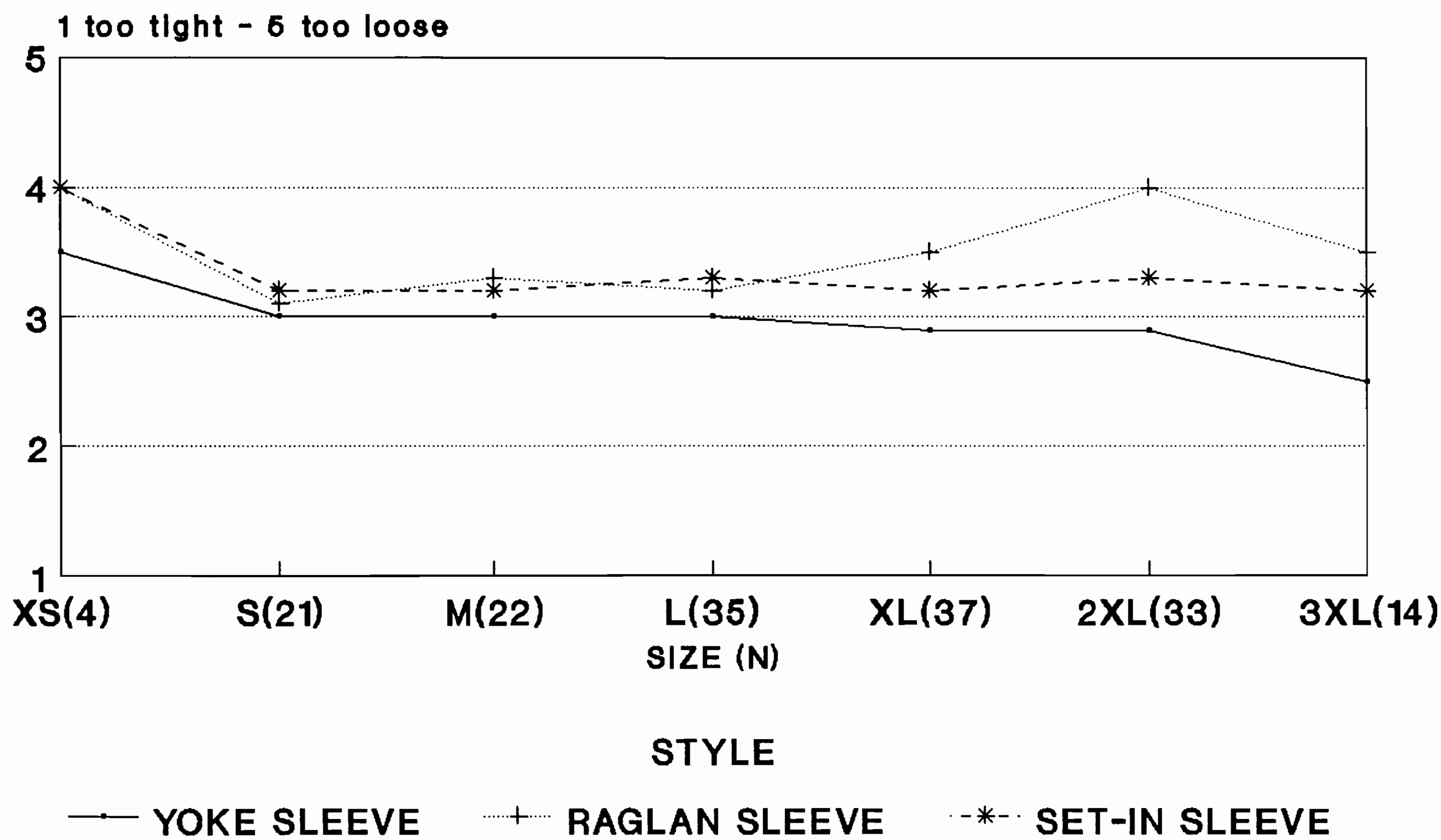


Figure J.12. Static Chest Tightness

TABLE J.20

Means, Standard Deviations and Analysis of Variance for Hip Tightness Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	3.50	3.05	2.91	2.97	2.97	2.74	2.25
(SD)	(0.58)	(0.59)	(0.53)	(0.53)	(0.53)	(0.73)	(0.75)
Raglan Sleeve							
Mean	4.25	3.00	3.18	3.28	3.58	3.87	3.54
(SD)	(0.50)	(0.71)	(0.59)	(0.85)	(0.70)	(0.91)	(0.82)
Set-in Sleeve							
Mean	4.00	3.14	3.18	3.18	3.26	3.35	2.92
(SD)	(0.82)	(0.65)	(0.59)	(0.68)	(0.61)	(0.71)	(0.76)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	13.64	2.27	2.91	0.0101
Error-between	159	124.10	0.78		
Within Ss					
Styles (B)	2	16.23	8.12	28.57	0.0001
A X B	12	12.93	1.08	3.79	0.0001
Error-within	318	90.35	0.28		

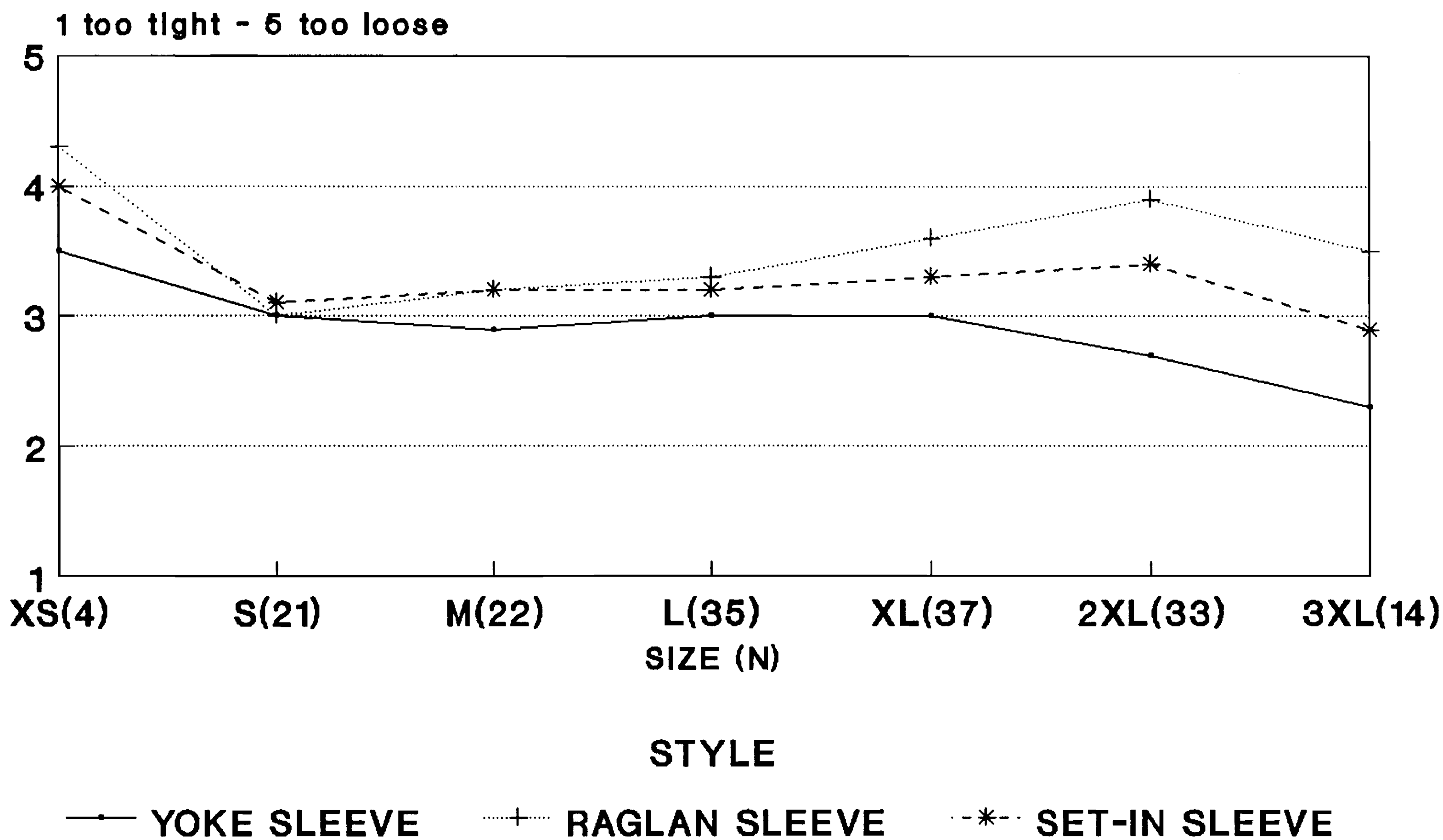


Figure J.13. Static Hip Tightness

TABLE J.21

Means, Standard Deviations and Analysis of Variance for Upper Body Dynamic FIT Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	25.87	23.80	20.88	19.42	17.69	17.99	12.98
(SD)	(1.29)	(3.41)	(4.52)	(3.79)	(3.66)	(6.27)	(6.86)
Raglan Sleeve							
Mean	23.59	21.40	21.88	21.24	21.29	23.39	20.68
(SD)	(1.99)	(5.03)	(3.69)	(2.76)	(3.09)	(2.79)	(5.14)
Set-in Sleeve							
Mean	22.30	20.89	20.98	19.20	18.84	18.44	15.65
(SD)	(1.57)	(3.63)	(1.93)	(2.99)	(2.66)	(3.97)	(4.86)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	58.64	9.77	6.69	0.0001
Error-between	159	232.42	1.46		
Within Ss					
Styles (B)	2	21.23	10.62	24.62	0.0001
A X B	12	35.02	2.92	6.81	0.0001
Error-within	318	136.35	0.43		

TABLE J.22

Means, Standard Deviations and Analysis of Variance for Donning Garment Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.75	4.90	4.95	4.48	4.11	3.76	3.07
(SD)	(1.50)	(0.83)	(0.95)	(0.95)	(1.29)	(1.44)	(1.86)
Raglan Sleeve							
Mean	5.25	4.62	4.90	4.80	4.84	5.00	4.93
(SD)	(1.50)	(1.32)	(1.02)	(0.80)	(1.04)	(0.97)	(1.19)
Set-in Sleeve							
Mean	5.25	4.90	5.27	4.83	4.67	4.39	4.14
(SD)	(1.50)	(1.09)	(0.55)	(0.82)	(0.94)	(1.30)	(1.30)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	37.52	6.25	2.86	0.0113
Error-between	159	347.56	2.19		
Within Ss					
Styles (B)	2	20.77	10.38	14.61	0.0001
A X B	12	33.47	2.79	3.93	0.0001
Error-within	318	225.92	0.71		

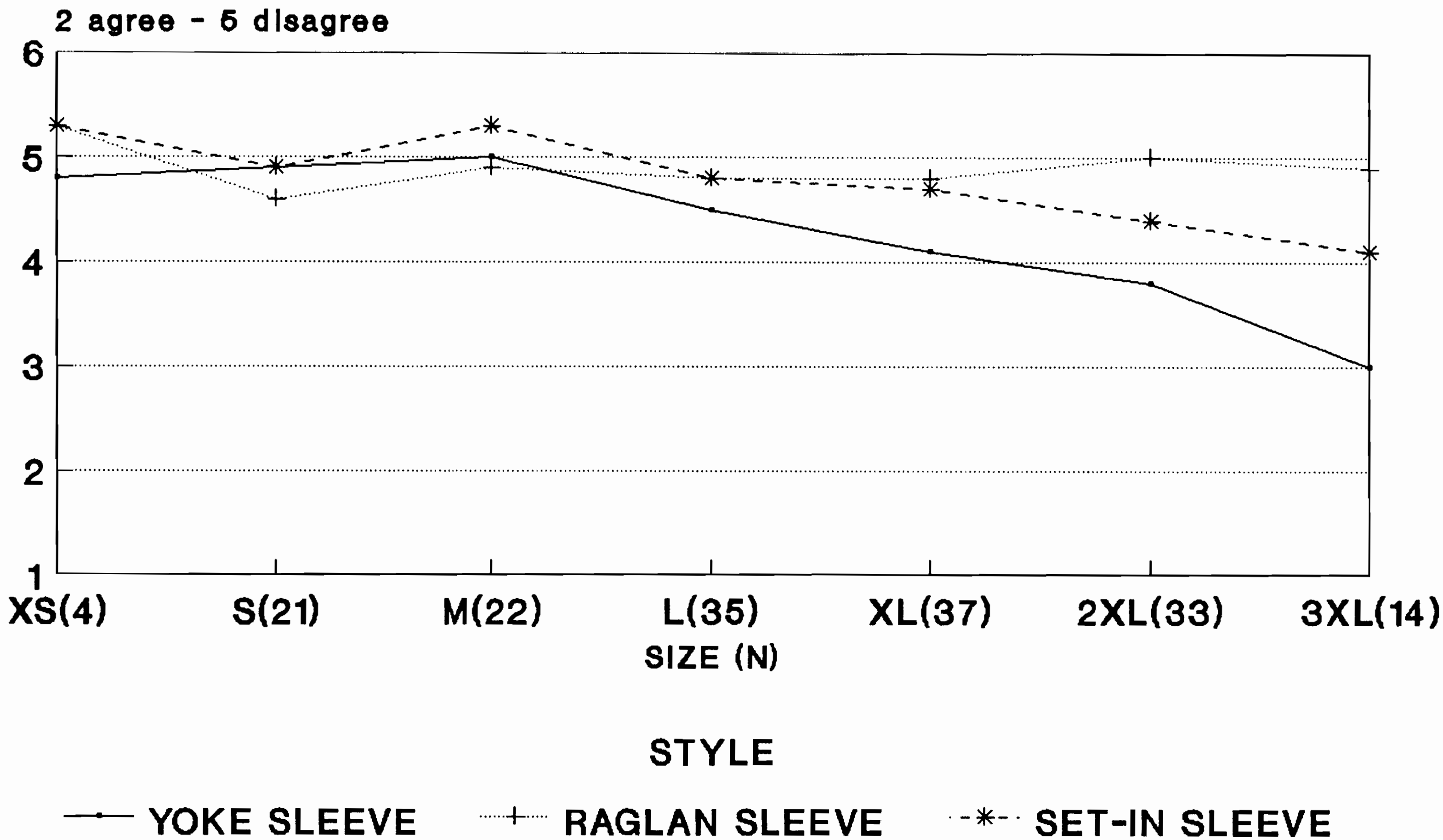


Figure J.14. Garment Difficult to Don

TABLE J.23

Means, Standard Deviations and Analysis of Variance for Binding Across Shoulders Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	6.00	5.24	4.68	4.31	3.73	4.03	2.57
(SD)	(0.00)	(0.83)	(1.21)	(1.16)	(1.50)	(1.47)	(1.35)
Raglan Sleeve							
Mean	5.75	4.62	5.09	5.03	4.86	5.48	4.57
(SD)	(0.50)	(1.04)	(0.92)	(0.66)	(0.95)	(0.62)	(1.40)
Set-in Sleeve							
Mean	5.75	5.24	5.23	4.77	4.57	4.48	3.71
(SD)	(0.50)	(1.304	(0.53)	(0.77)	(1.02)	(1.30)	(1.54)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	86.68	14.45	6.62	0.0001
Error-between	159	347.03	2.18		
Within Ss					
Styles (B)	2	24.23	12.11	15.53	0.0001
A X B	12	49.65	4.14	5.30	0.0001
Error-within	318	248.05	0.78		

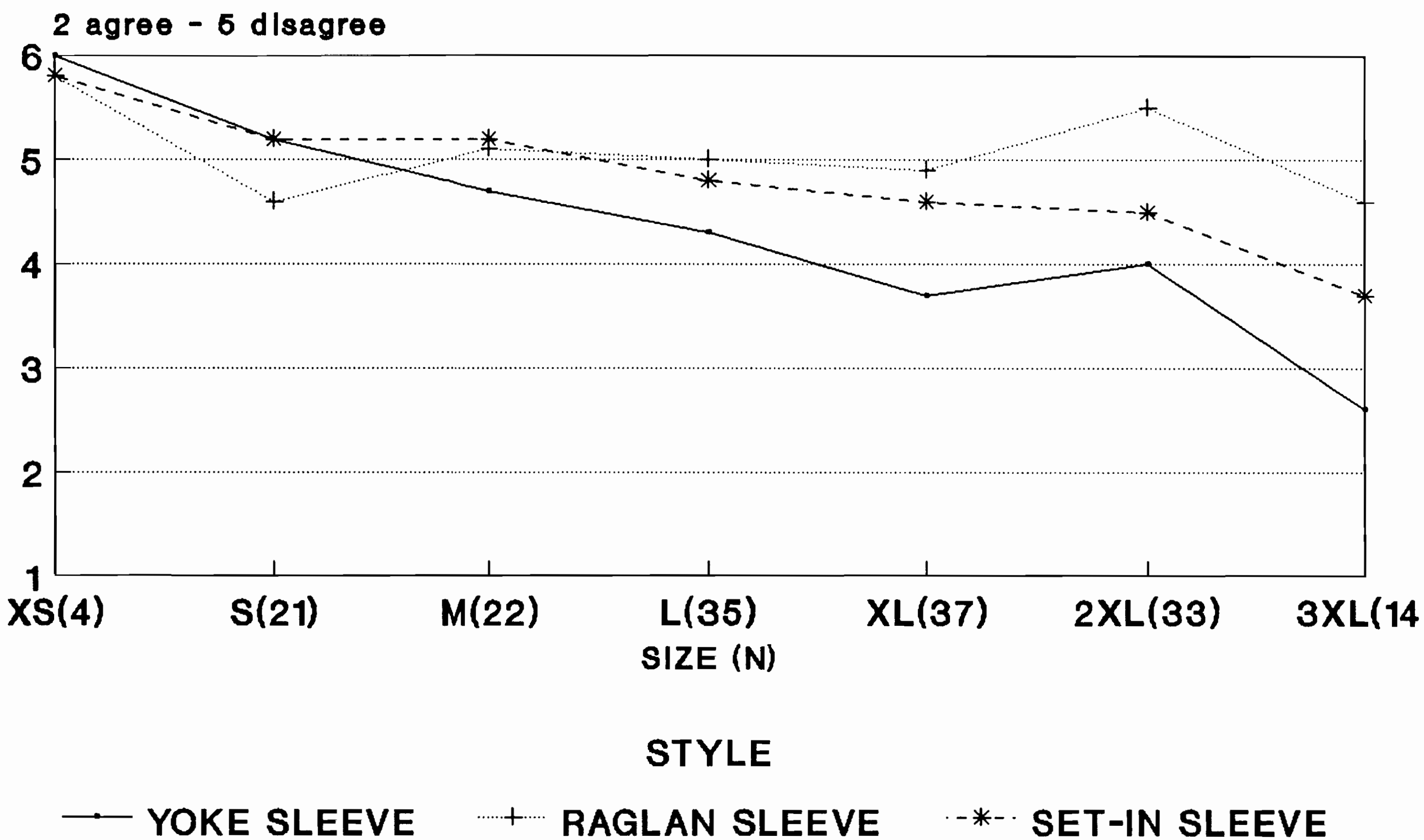


Figure J.15. Binding Across Shoulders

TABLE J.24

Means, Standard Deviations and Analysis of Variance for Binding in Body Area Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	5.75	4.95	4.64	4.17	3.81	3.78	2.43
(SD)	(0.50)	(1.43)	(1.21)	(1.18)	(1.15)	(1.62)	(1.45)
Raglan Sleeve							
Mean	5.75	4.86	4.82	4.69	4.84	5.42	4.57
(SD)	(0.50)	(1.35)	(1.14)	(0.96)	(1.01)	(0.71)	(1.40)
Set-in Sleeve							
Mean	5.75	5.00	5.09	4.31	4.62	4.72	3.86
(SD)	(0.50)	(1.04)	(0.68)	(1.30)	(0.86)	(1.21)	(1.51)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	74.34	12.39	5.25	0.0001
Error-between	159	375.10	2.36		
Within Ss					
Styles (B)	2	30.89	15.44	18.12	0.0001
A X B	12	43.54	3.63	4.26	0.0001
Error-within	318	271.01	0.85		

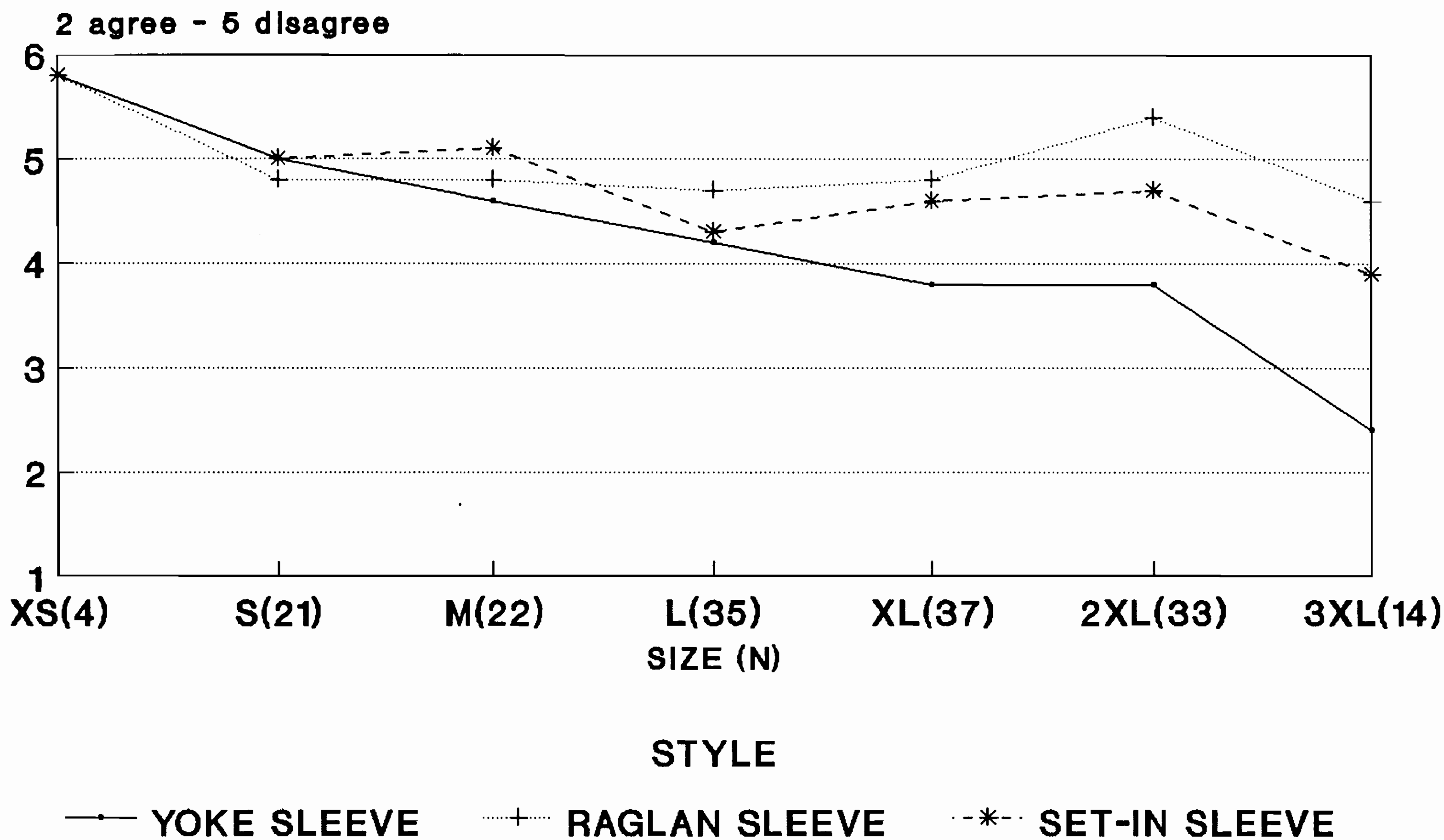


Figure J.16. Binding in the Body

TABLE J.25

Means, Standard Deviations and Analysis of Variance for Restricted Arm Movement Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	5.75	5.33	4.27	4.14	3.89	3.94	3.07
(SD)	(0.50)	(0.86)	(1.64)	(1.12)	(1.04)	(1.56)	(1.69)
Raglan Sleeve							
Mean	5.50	4.81	5.00	4.74	4.81	5.24	4.50
(SD)	(0.58)	(1.47)	(1.20)	(0.95)	(0.70)	(0.90)	(1.51)
Set-in Sleeve							
Mean	5.00	5.24	5.04	4.85	4.65	4.52	3.57
(SD)	(1.41)	(0.89)	(0.95)	(0.84)	(1.01)	(1.46)	(1.60)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	63.01	10.50	4.72	0.0002
Error-between	159	353.43	2.22		
Within Ss					
Styles (B)	2	17.84	8.92	9.57	0.0001
A X B	12	35.23	2.94	3.15	0.0003
Error-within	318	296.33	0.93		

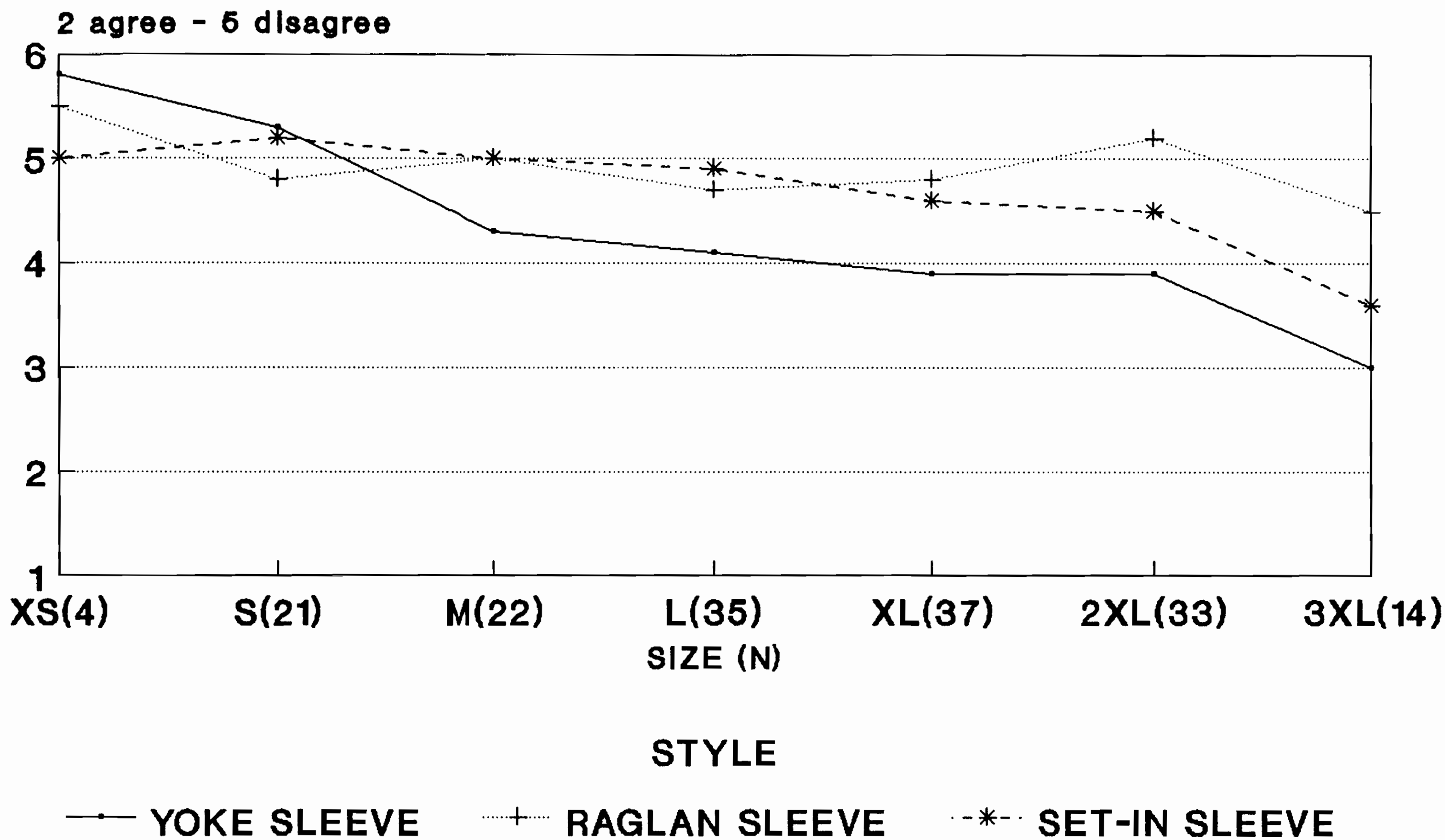


Figure J.17. Restricted Arm Movement

TABLE J.26

Means, Standard Deviations and Analysis of Variance for Restricted Overhead Reach Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	5.75	5.19	4.14	3.83	3.50	3.82	2.71
(SD)	(0.50)	(0.87)	(1.39)	(1.34)	(1.12)	(1.53)	(1.59)
Raglan Sleeve							
Mean	5.00	5.04	4.77	4.66	4.76	5.24	4.64
(SD)	(0.82)	(1.12)	(1.15)	(1.03)	(0.83)	(0.83)	(1.28)
Set-in Sleeve							
Mean	5.00	5.10	4.86	4.60	4.41	4.30	3.50
(SD)	(1.41)	(1.18)	(1.28)	(1.06)	(1.09)	(1.38)	(1.65)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	72.68	12.11	5.40	0.0001
Error-between	159	356.69	2.24		
Within Ss					
Styles (B)	2	27.34	13.67	13.64	0.0001
A X B	12	40.04	3.34	3.33	0.0001
Error-within	318	318.79	1.00		

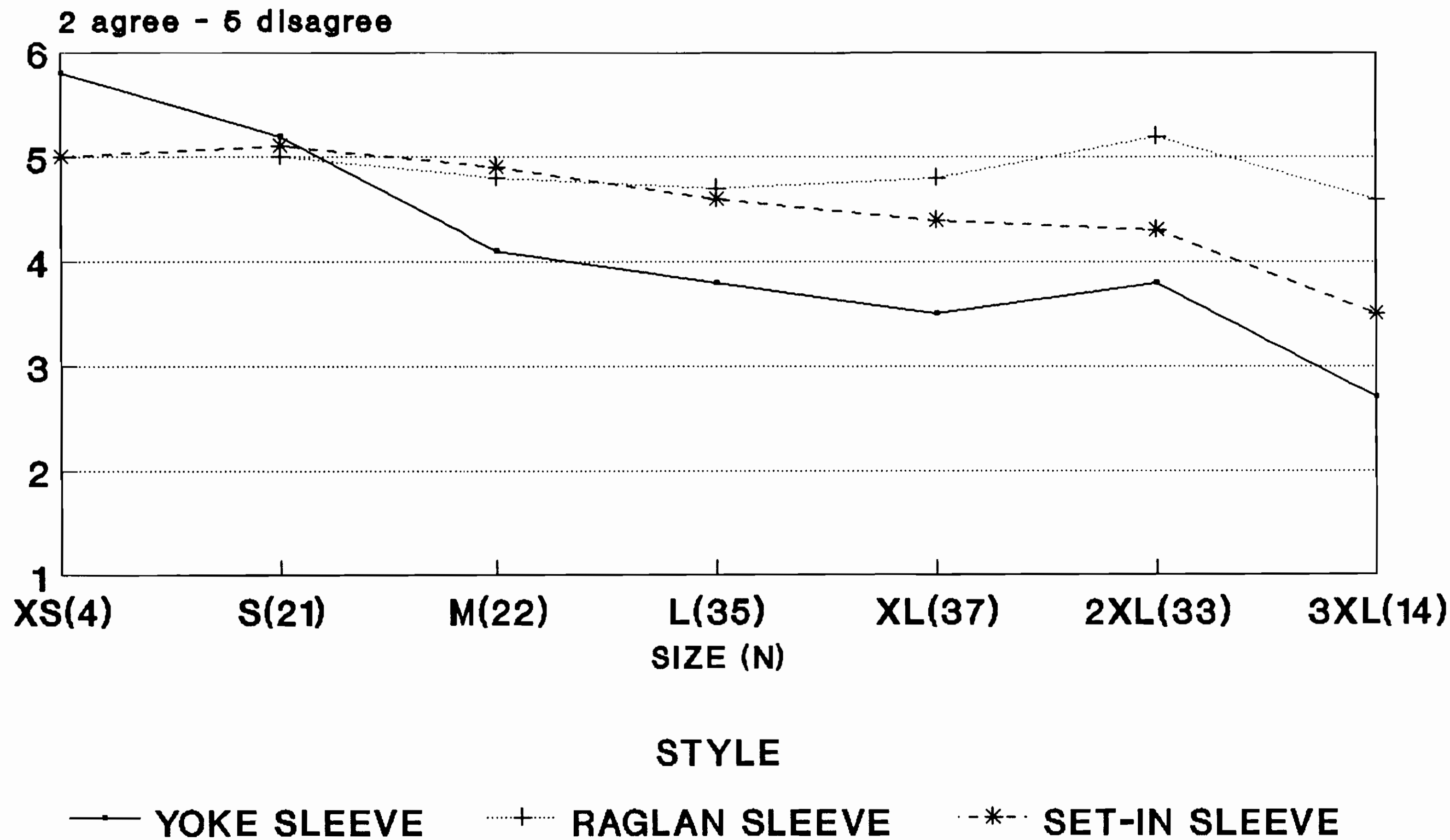


Figure J.18. Restricted Overhead Reach

TABLE J.27

Means, Standard Deviations and Analysis of Variance for Restricted Forward Reach Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	5.75	5.43	4.73	4.49	4.03	4.21	3.07
(SD)	(0.50)	(0.68)	(0.98)	(0.95)	(0.96)	(1.45)	(1.69)
Raglan Sleeve							
Mean	4.75	5.10	5.04	4.86	4.86	5.33	4.86
(SD)	(1.26)	(1.30)	(0.95)	(0.69)	(0.71)	(0.78)	(1.03)
Set-in Sleeve							
Mean	5.75	5.19	5.18	4.80	4.70	4.60	4.07
(SD)	(0.50)	(1.08)	(0.85)	(0.93)	(0.70)	(1.24)	(1.33)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	53.00	8.83	5.27	0.0001
Error-between	159	266.48	1.68		
Within Ss					
Styles (B)	2	11.08	5.54	8.21	0.0003
A X B	12	35.00	2.92	4.32	0.0001
Error-within	318	214.51	0.67		

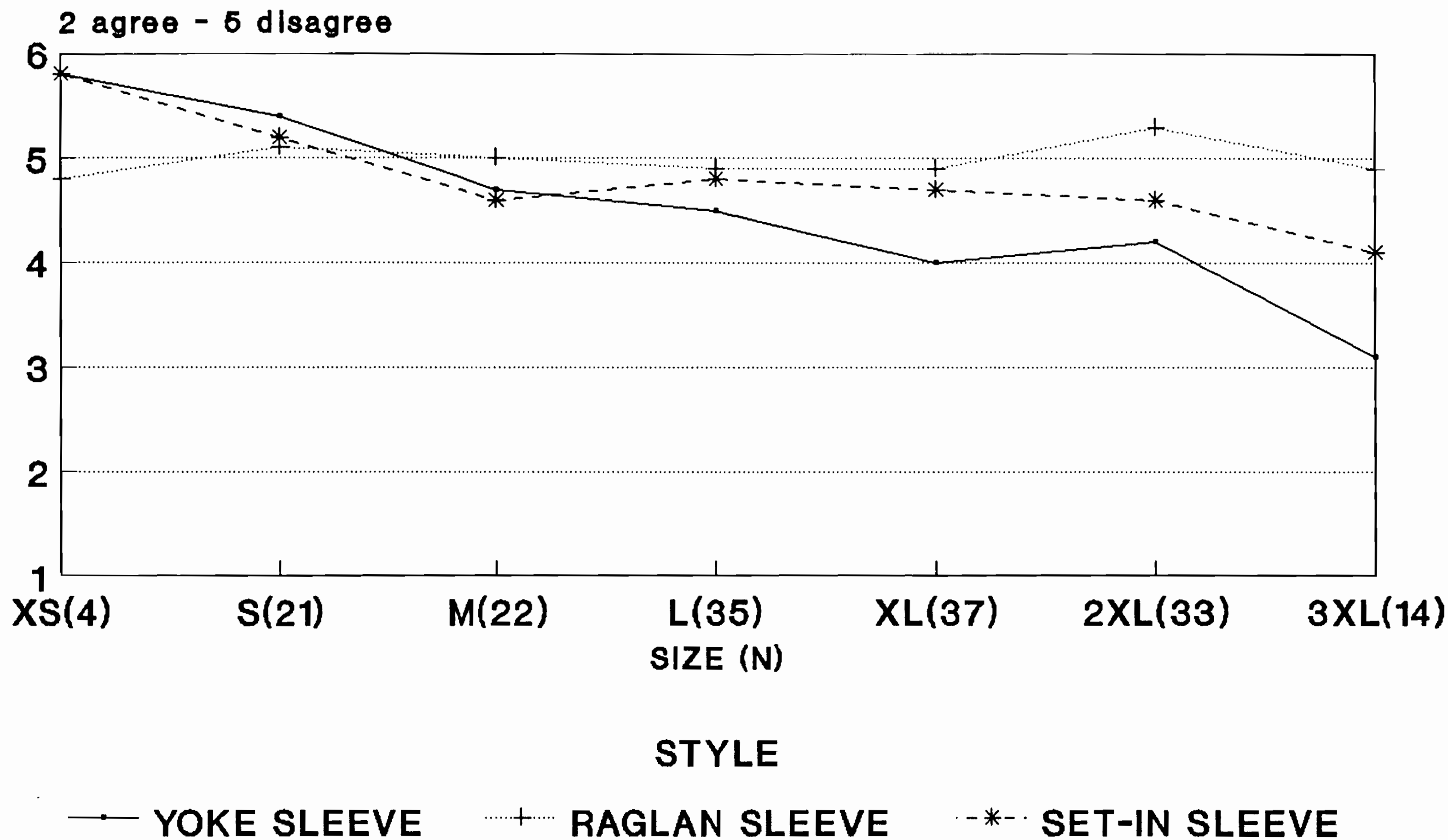


Figure J.19. Restricted Forward Reach

TABLE J.28

Means, Standard Deviations and Analysis of Variance for Lower Body Factors Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.73	4.29	3.88	4.04	3.71	3.70	2.86
(SD)	(1.59)	(1.04)	(1.14)	(1.05)	(1.07)	(1.39)	(1.68)
Raglan Sleeve							
Mean	3.98	4.29	4.53	4.40	4.53	4.93	4.56
(SD)	(1.56)	(0.99)	(1.27)	(0.91)	(0.87)	(1.18)	(1.25)
Set-in Sleeve							
Mean	4.30	4.27	4.42	4.60	4.42	4.07	3.69
(SD)	(1.74)	(1.11)	(1.02)	(0.82)	(0.85)	(1.35)	(1.53)

Source	df	ss	ms	f	Prob
Between Sx	165				
Sizes (A)	6	13.58	2.26	0.87	0.5159
Error-between	159	411.92	2.59		
Within Ss					
Styles (B)	2	16.43	8.22	13.61	0.0001
A X B	12	29.44	2.45	4.07	0.0001
Error-within	318	191.92	0.60		

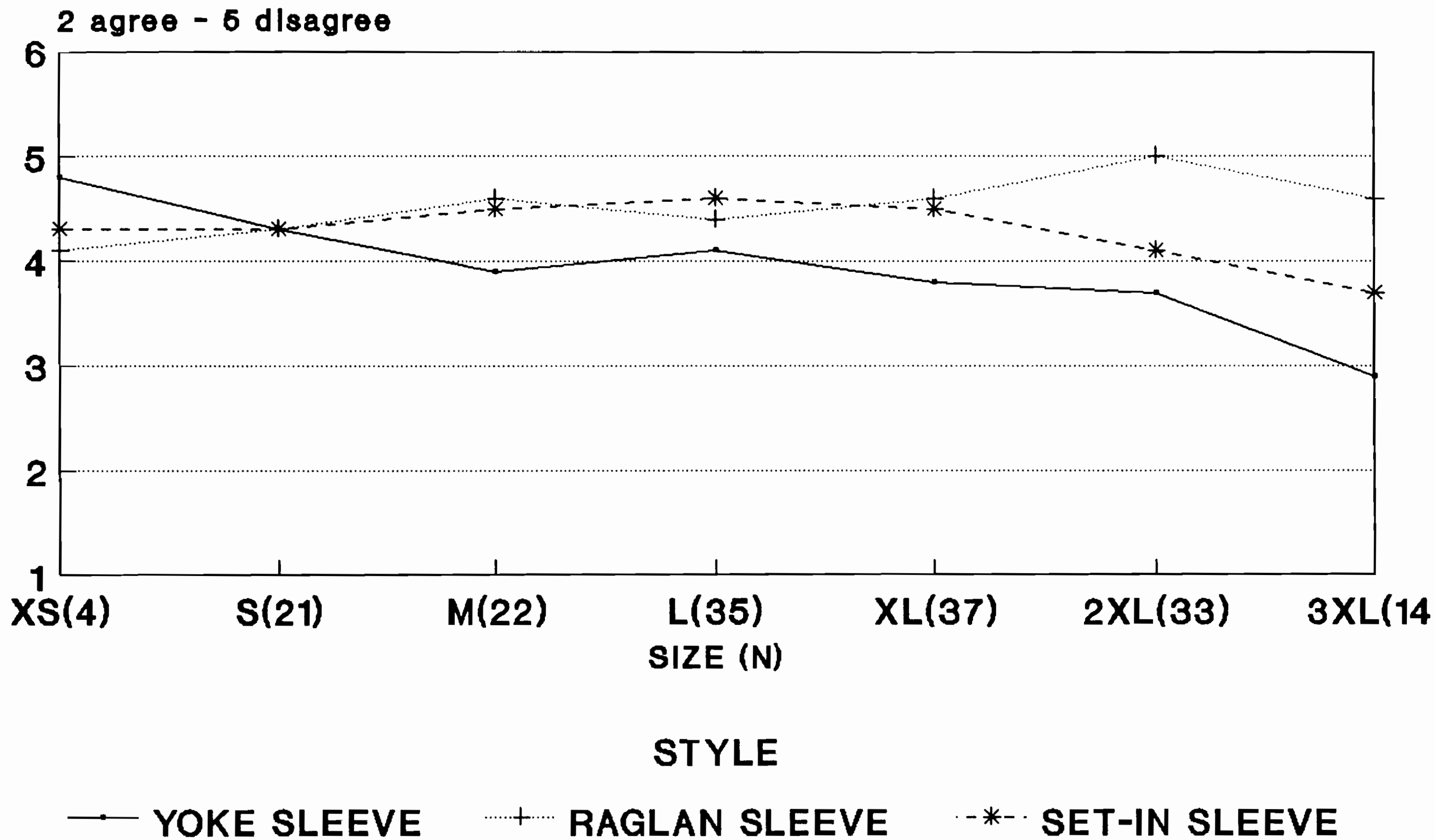


Figure J.20. Restricted Lower Body

TABLE J.29

Means, Standard Deviations and Analysis of Variance for Fit Between Sizes Across Styles

Style	Size						
	XS	S	M	L	XL	2XL	3XL
Yoke Sleeve							
Mean	4.50	3.67	3.45	3.20	3.51	3.30	4.21
(SD)	(2.38)	(1.39)	(1.30)	(1.34)	(1.04)	(1.38)	(1.72)
Raglan Sleeve							
Mean	5.50	3.76	3.36	3.06	4.00	4.58	3.93
(SD)	(0.58)	(1.44)	(1.36)	(1.33)	(1.45)	(1.58)	(1.38)
Set-in Sleeve							
Mean	5.50	4.19	3.09	3.11	3.14	3.33	3.86
(SD)	(1.00)	(1.36)	(1.54)	(0.99)	(1.36)	(1.19)	(1.29)

Source	df	ss	ms	f	Prob
Between Ss	165				
Sizes (A)	6	72.49	12.08	4.89	0.0001
Error-between	159	392.63	2.47		
Within Ss					
Styles (B)	2	6.30	3.15	2.09	0.1251
A X B	12	41.56	3.46	2.30	0.0080
Error-within	318	478.41	1.50		

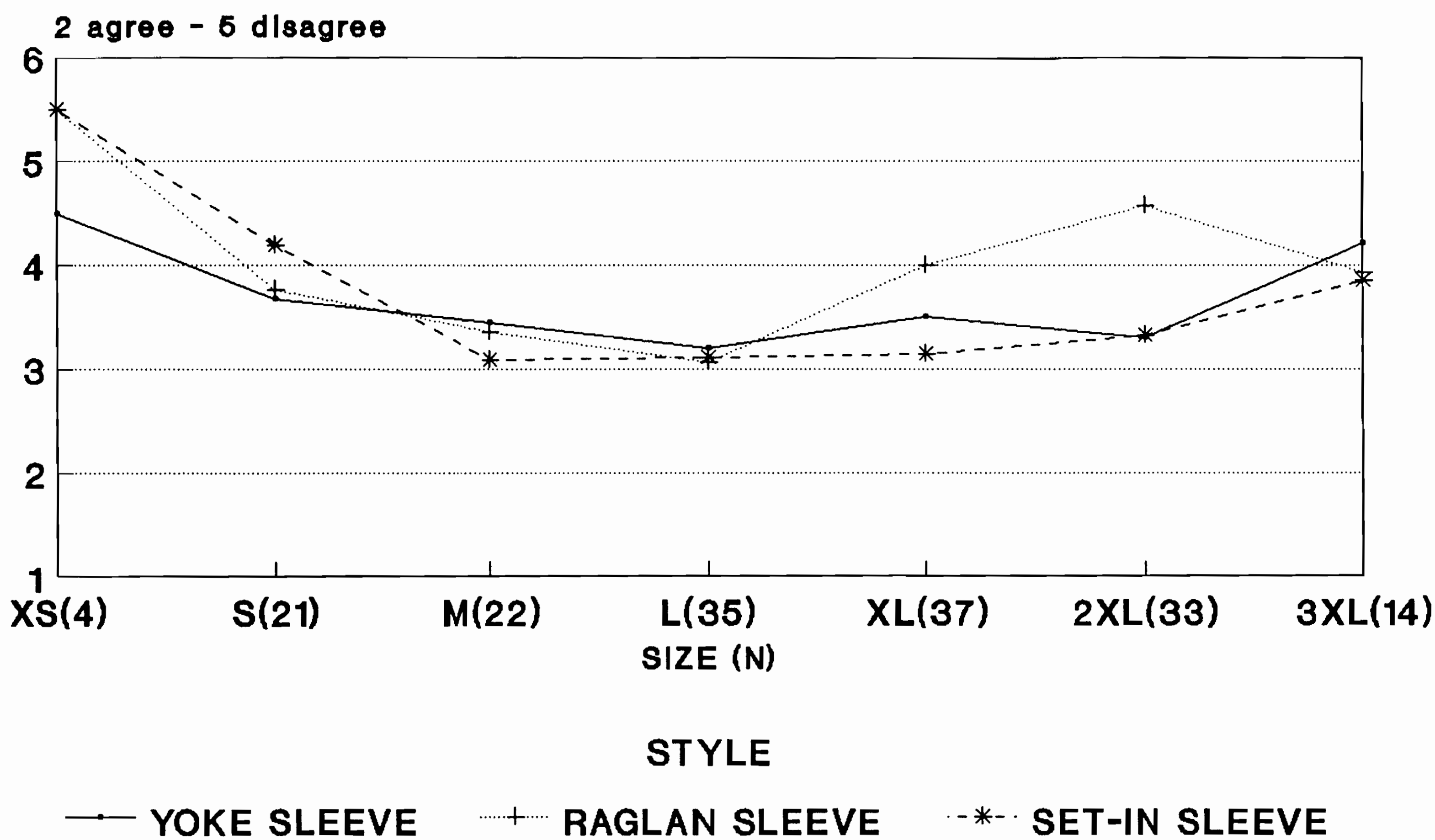


Figure J.21. Garments Fit Well

TABLE J.30

Means, Standard Deviations and Analysis of Variance for Fit For Sizes XL and 2XL Across Styles

Style	Size	
	XL	2XL
Yoke Sleeve		
Mean	3.51	3.30
(SD)	(1.04)	(1.38)
Raglan Sleeve		
Mean	4.00	4.58
(SD)	(1.45)	(1.58)
Set-in Sleeve		
Mean	3.14	3.33
(SD)	(1.36)	(1.19)

Source	df	ss	ms	f	Prob
Between Sx	69				
Sizes (A)	1	1.85	1.85	0.93	0.3389
Error-between	68	135.32	1.99		
Within Ss					
Styles (B)	2	44.52	22.26	13.01	0.0001
A X B	2	5.39	2.70	1.58	0.2104
Error-within	136	232.62	1.71		

TABLE J.31

Multiple Regression for Job Performance by Static & Dynamic Fit Across Styles

STYLE - YOKE SLEEVE						
Static Fit	COEFF	BETA	F-RATIO	R_2	PROB	STD. ERROR
Sleeve Tightness	-0.21	-0.29	14.47	0.08	0.0002	0.05
Dynamic Fit						
Leg Movement	-0.09	-0.25	12.24	0.35	0.0006	0.03
Ease of Donning	-0.16	-0.46	41.42	0.39	<0.0001	0.02
STYLE - RAGLAN SLEEVE						
Static Fit						
Leg Length	0.15	0.23	8.42	0.26	0.0042	0.05
Body Length	0.16	0.27	10.88	0.33	0.0042	0.05
Sleeve Length	0.15	0.24	11.95	0.36	0.0007	0.04
Dynamic Fit						
Leg Movement	0.10	0.20	5.22	0.04	0.0237	0.04
Reaching Upward	-0.11	-0.30	12.00	0.07	0.0007	0.03
STYLE - SET-IN SLEEVE						
Static Fit						
Sleeve Length	0.16	0.25	9.40	0.11	0.0025	0.05
Body Length	0.09	0.17	4.35	0.13	0.0386	0.04
Dynamic Fit	-0.15	-0.40	31.77	0.16	<0.0001	0.03
Leg Movement						

TABLE J.32

Multiple Regression of Fit by Body Dimensions Controlling for Size

STYLE	COEFF.	BETA	R-RATIO	R_2	PROB	STD. ERROR
Yoke Sleeve	0.01	0.08	0.30	<0.01	0.586	0.02
Raglan Sleeve	-0.03	-0.20	1.87	0.02	0.174	0.02
Set-in Sleeve	-0.02	-0.17	4.78	0.03	0.030	0.01

TABLE J.33

Correlation Body Measures/All Subjects

Height(1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Weight(2)	0.715									
Shoulder(3)	0.688	0.926								
Chest(4)	0.578	0.926	0.913							
Waist(5)	0.627	0.930	0.909	0.945						
Hip(6)	0.450	0.830	0.757	0.824	0.799					
Arm(7)	0.812	0.744	0.744	0.653	0.688	0.505				
Biceps(8)	0.590	0.875	0.894	0.872	0.871	0.797	0.680			
Thigh(9)	0.305	0.699	0.629	0.687	0.626	0.859	0.375	0.677		
Girth(10)	0.769	0.914	0.883	0.861	0.891	0.735	0.737	0.834	0.562	
Inseam(11)	0.765	0.359	0.297	0.237	0.213	0.191	0.596	0.222	0.054	0.365

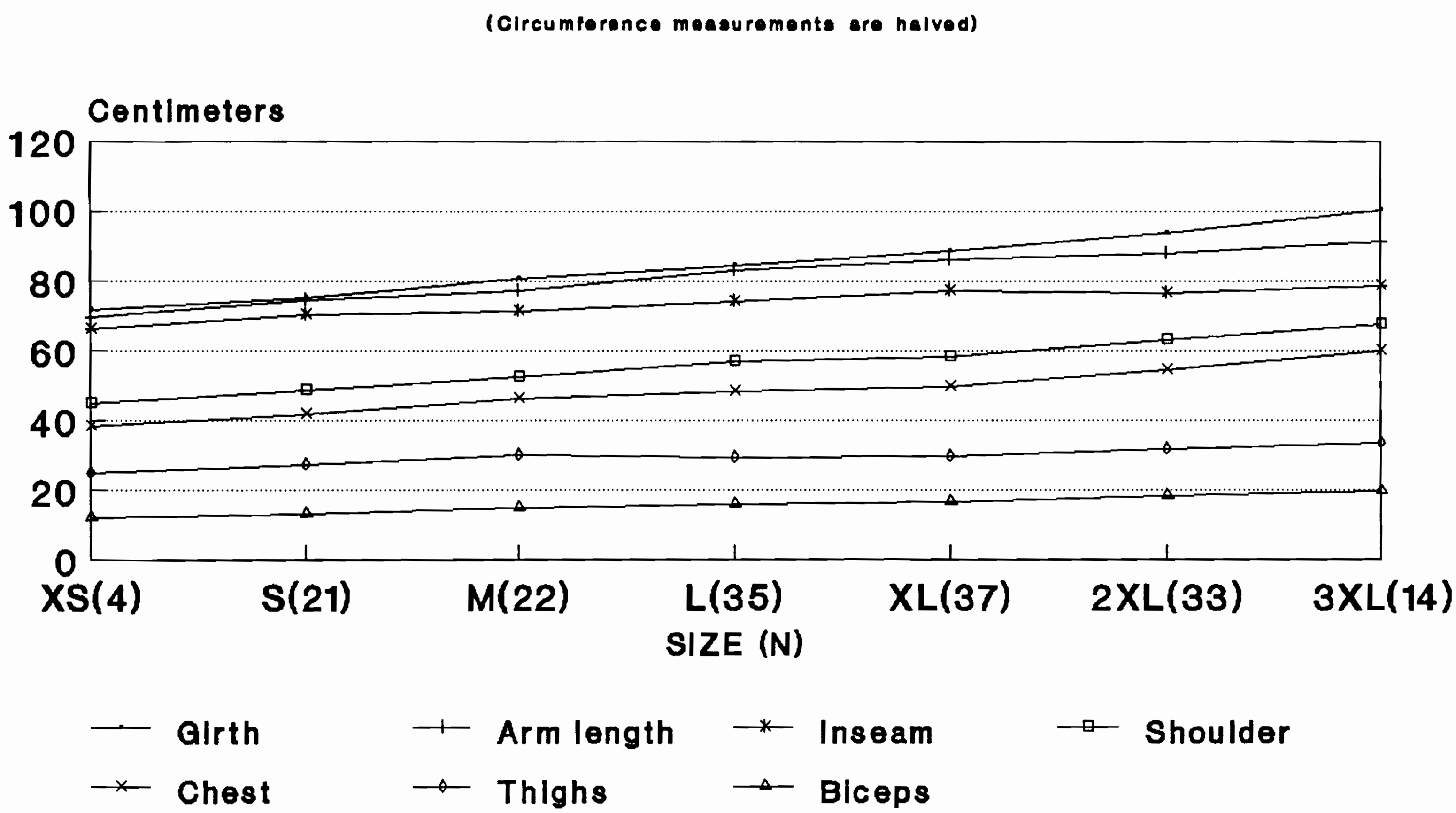


Figure J.22. Mean Body Dimensions

TABLE J.34

Multiple Regression of Fit By Body Dimensions Controlling for Height

Size-Style	COEFF.	BETA	F-RATIO	R_2	PROB.	STD. ERROR
Small-Set-in Sleeve						
Standardized weight	4.06	0.44	5.81	0.22	0.0268	1.6850
Standardized hip meas.	-13.53	- 0.46	6.39	0.41	0.0210	5.3522
Small-Raglan Sleeve						
Standardized weight	6.82	0.69	16.07	0.22	0.0009	1.6999
Standardized chest meas.	20.95	0.58	10.50	0.16	0.0048	6.4656
Standardized arm length	-14.21	-0.45	6.78	0.18	0.0185	5.4565
XLarge - Set-in Sleeve						
Standardized Thigh meas.	14.19	0.42	7.29	0.17	0.0106	5.2568

TABLE J.35

Subjects Who Felt Garment Fit Well (Responses 1 & 2)

Size	Total Possible Males	Males Selecting 1 or 2	Percent of Male Responese	Total Possible Females	Females Selecting 1 or 2	Percent of Female Responses	Total Possible Respones	Total Percent of Responses For SRE
XSmall	0	0	--	12	1	8.3	12	8.3
Small	6	4	66.7	57	8	14.0	63	19.0
Medium	15	6	40.0	57	18	35.3	66	36.4
Large	72	25	34.7	33	9	27.3	105	33.4
XLarge	105	27	25.7	6	0	0.0	111	24.3
2XLarge	93	23	24.7	6	0	0.0	99	23.2
3XLarge	39	5	12.8	3	1	33.3	42	14.3

TABLE J.36

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
XSMALL									
(1) Chest	49.5	38.3	1.55	51.0	0.4	58.0	2.1	52.3	1.6
(2) Leg Inseam	68.6	66.2	2.2	68.9	0.7	70.1	0.3	70.4	0.3
(3) Sleeve Outseam	77.5	69.7	2.6	77.9	0.2	83.3	1.6	78.8	0.5
(4) Body Length	86.4	71.5	1.2	85.5	1.1	83.2	0.4	77.9	0.5
(5) Sleeve Opening	16.5	--	--	19.0	0.2	17.7	0.6	18.6	0.2
(6) Leg Opening	24.1	--	--	24.8	0.7	26.3	0.22	25.8	0.3
(7) Front Opening	73.7	--	--	71.3	0.6	69.1	0.8	74.3	0.6
(8) Bicep	--	12.0	0.6	21.7	0.2	24.3	0.5	23.2	0.2
(9) Thigh	--	24.9	1.5	30.6	0.2	31.9	0.2	33.1	0.2

TABLE J.37

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
SMALL									
(1) Chest	54.6	41.9	2.2	57.8	0.9	55.5	0.6	55.2	0.3
(2) Leg Inseam	69.6	70.5	3.9	70.1	1.0	74.6	0.7	69.9	0.3
(3) Sleeve Outseam	80.0	74.5	2.8	79.7	0.3	81.6	0.7	83.1	0.5
(4) Body Length	88.9	75.2	2.3	85.9	0.3	86.5	0.7	82.0	0.6
(5) Sleeve Opening	16.5	--	--	19.4	0.3	16.7	0.4	18.6	0.3
(6) Leg Opening	24.1	--	--	26.0	0.4	25.3	0.2	25.4	0.3
(7) Front Opening	74.9	--	--	71.2	1.0	73.8	1.0	71.6	0.7
(8) Bicep	--	13.2	1.0	21.8	0.3	23.7	0.6	24.4	0.2
(9) Thigh	--	27.2	2.3	32.0	0.4	35.2	0.3	35.6	0.2

TABLE J.38

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
MEDIUM									
(1) Chest	59.7	46.4	3.2	62.1	0.4	55.9	0.8	60.6	0.4
(2) Leg Inseam	71.1	71.6	3.8	70.6	0.5	74.3	0.8	71.6	0.7
(3) Sleeve Outseam	82.6	77.3	3.2	82.7	0.5	81.7	0.8	83.9	0.7
(4) Body Length	91.4	80.6	3.9	87.8	0.6	89.0	0.9	82.3	1.3
(5) Sleeve Opening	17.8	--	--	19.3	0.2	18.1	0.8	18.6	0.7
(6) Leg Opening	25.4	--	--	26.7	0.1	26.0	0.2	26.5	0.2
(7) Front Opening	74.9	--	--	74.0	0.5	74.5	0.9	75.5	1.0
(8) Bicep	--	14.8	1.1	21.8	0.3	24.9	0.5	25.5	0.5
(9) Thigh	--	30.0	2.4	34.5	0.3	37.7	0.9	38.0	0.3

TABLE J.39

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
LARGE									
(1) Chest	64.8	48.2	3.0	67.6	0.8	66.2	0.4	66.1	0.7
(2) Leg Inseam	73.7	74.2	4.7	73.6	0.3	72.9	0.8	75.1	1.4
(3) Sleeve Outseam	85.1	83.3	3.7	84.9	1.1	89.0	0.8	85.9	1.0
(4) Body Length	94.0	86.2	3.6	87.9	1.5	88.9	1.3	85.9	1.0
(5) Sleeve Opening	17.8	--	--	18.3	0.1	19.8	0.5	18.4	0.4
(6) Leg Opening	25.4	--	--	26.7	0.1	27.5	0.5	26.6	0.4
(7) Front Opening	76.2	--	--	71.3	1.4	68.4	0.9	77.2	1.0
(8) Bicep	--	16.0	1.4	21.5	0.8	26.7	0.5	25.8	0.3
(9) Thigh	--	29.5	2.5	35.3	0.6	34.8	0.5	39.7	0.6

TABLE J.40

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
XLARGE									
(1) Chest	69.9	49.6	3.5	70.2	0.9	70.7	0.8	70.9	0.6
(2) Leg Inseam	74.9	77.4	4.9	75.3	0.7	75.6	1.3	76.1	0.7
(3) Sleeve Outseam	88.9	86.3	3.3	88.8	0.3	94.8	0.7	89.8	0.7
(4) Body Length	97.8	87.9	4.0	94.0	0.7	93.0	1.5	89.5	0.8
(5) Sleeve Opening	17.8	--	--	19.0	0.4	19.9	0.6	18.3	0.3
(6) Leg Opening	25.4	--	--	26.9	0.3	27.5	0.4	26.2	0.6
(7) Front Opening	77.5	--	--	81.8	0.9	78.2	0.9	77.2	1.0
(8) Bicep	--	16.5	1.5	22.0	0.4	28.3	0.4	27.3	0.4
(9) Thigh	--	29.8	2.3	36.9	0.3	37.3	0.9	42.8	0.5

TABLE J.41

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
2XLARGE									
(1) Chest	74.9	54.6	3.1	76.3	0.8	77.4	0.4	76.7	1.7
(2) Leg Inseam	76.2	76.5	3.9	75.6	1.5	76.8	0.7	78.3	1.6
(3) Sleeve Outseam	92.7	88.0	6.0	92.4	0.3	98.8	0.7	94.2	1.3
(4) Body Length	99.1	94.0	3.4	94.7	1.6	102.0	1.3	89.7	1.3
(5) Sleeve Opening	17.8	--	--	18.7	0.3	21.4	0.4	19.3	0.9
(6) Leg Opening	25.4	--	--	27.1	0.2	29.8	0.5	26.6	0.5
(7) Front Opening	78.7	--	--	84.1	4.5	79.8	0.8	76.7	1.0
(8) Bicep	--	18.3	1.1	21.6	0.6	28.3	0.4	28.7	0.7
(9) Thigh	--	31.9	2.0	39.6	0.3	40.8	0.5	44.8	0.9

TABLE J.42

Mean & Standard Dev. of Body and Garment Dimensions

SIZE Dimension Location	Proposed Minimum Standard	Body Means		Yoke Sleeve		Raglan		Set-In	
		M	SD	M	SD	M	SD	M	SD
3XLARGE									
(1) Chest	80.0	60.2	5.3	83.5	0.5	79.8	1.5	80.7	0.4
(2) Leg Inseam	78.7	78.6	5.0	82.2	1.0	78.9	1.5	80.1	0.8
(3) Sleeve Outseam	95.3	91.3	3.6	95.6	0.4	100.0	3.1	95.9	0.6
(4) Body Length	101.6	102.0	5.7	97.7	1.0	100.6	1.6	93.9	1.5
(5) Sleeve Opening	19.1	--	--	20.0	0.3	21.8	1.4	18.4	0.1
(6) Leg Opening	26.7	--	--	27.6	0.7	31.2	1.0	27.8	0.4
(7) Front Opening	80.0	--	--	91.9	1.1	79.4	3.4	78.2	1.2
(8) Bicep	--	19.7	2.3	22.5	0.3	30.5	3.2	28.7	0.4
(9) Thigh	--	33.4	3.0	41.0	0.5	42.8	1.7	45.9	0.4

TABLE J.43

Minimu, Maximum, Optimum East for Chest

SIZE	MAXIMUM		OPTIMUM		MINIMUM	
	N	AVG (cm)	N	AVG (cm)	N	AVG (cm)
XSmall	6	29.0	4	31.5	0	0.0
Small	9	29.1	49	28.9	4	24.7
Medium	12	29.0	50	20.5	3	27.9
Large	19	36.2	74	37.3	10	36.5
XLarge	22	44.5	75	41.5	9	38.7
2XLarge	24	45.3	56	44.6	2	40.1
3XLarge	6	49.0	25	41.3	7	38.8
TOTAL	98	39.1	333	36.0	35	35.6

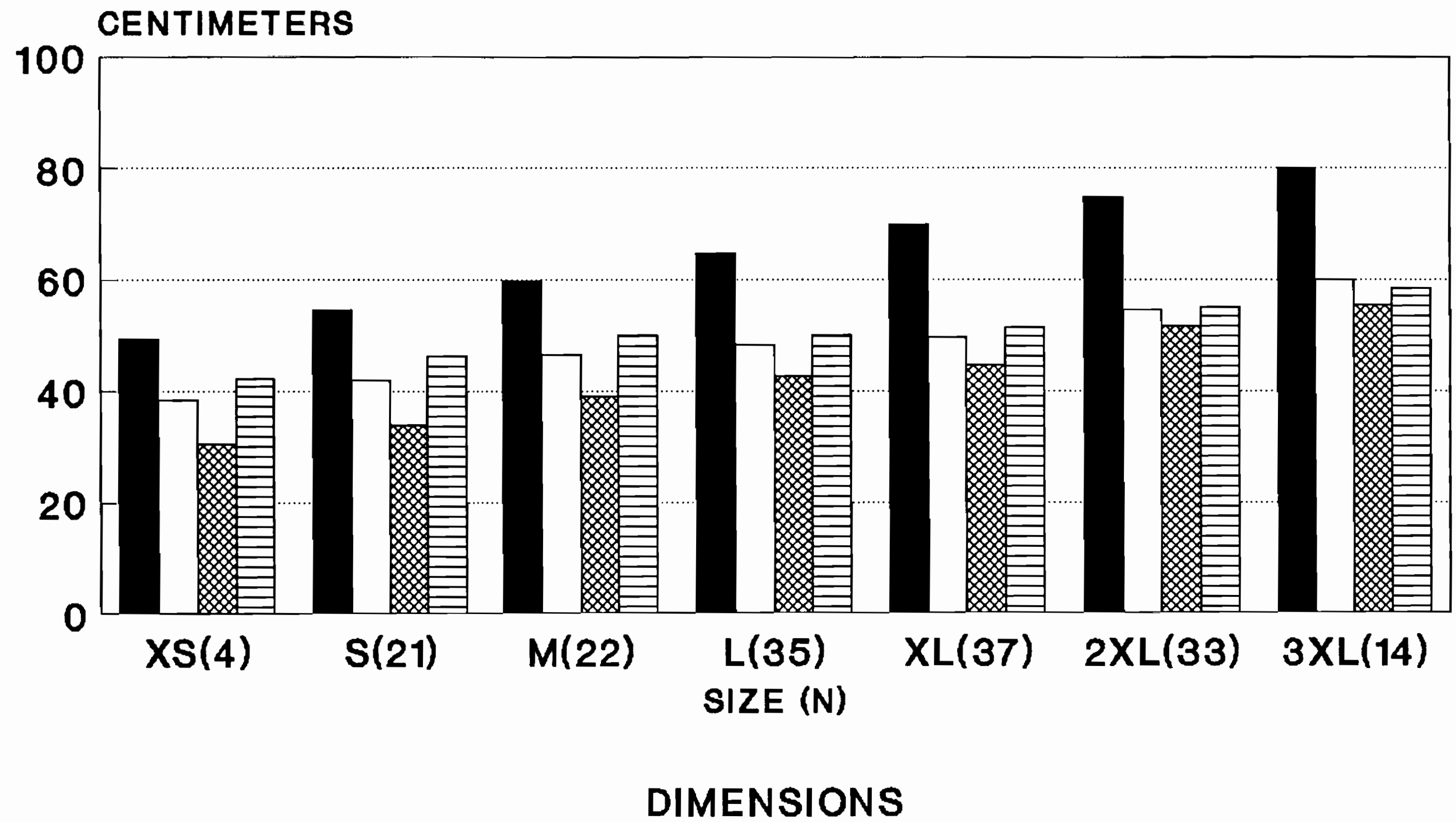


Figure J.23. Chest, Waist, and Hip

TABLE J.44

Minimum, Maximum, Optimum Ease for Hip

SIZE	MAXIMUM		OPTIMUM		MINIMUM	
	N	AVG (cm)	N	AVG (cm)	N	AVG (cm)
XSmall	7	24.5	3	22.2	0	0.0
Small	11	22.9	43	19.6	7	17.4
Medium	11	24.2	47	21.7	7	16.0
Large	17	34.9	72	32.5	12	32.5
XLarge	25	39.6	74	38.1	7	33.7
2XLarge	25	43.4	48	43.1	14	44.2
3XLarge	8	44.3	21	45.0	2	41.2
TOTAL	104	35.0	308	32.8	49	30.2

TABLE J.45

Minimum, Maximum, Optimum Ease for Body Length

SIZE	MAXIMUM		OPTIMUM		MINIMUM	
	N	AVG (cm)	N	AVG (cm)	N	AVG (cm)
XSmall	5	22.1	0	0.0	0	0.0
Small	3	24.9	19	18.8	18	17.5
Medium	6	11.6	37	9.9	12	10.6
Large	6	13.1	55	6.4	32	3.1
XLarge	7	13.2	57	9.8	26	7.4
2XLarge	8	- 5.1	35	10.4	35	- 3.8
3XLarge	2	- 4.0	12	- 4.2	14	- 8.9
TOTAL	22*	14.3*	168*	9.7*	88*	8.5*

*Sizes S, M, L. and XL

TABLE J.46

Minimum, Maximum, Optimum Ease for Biceps

SIZE	MAXIMUM		OPTIMUM		MINIMUM	
	N	AVG (cm)	N	AVG (cm)	N	AVG (cm)
XSmall	7	23.0	3	20.5	0	0.0
Small	19	21.1	37	19.5	3	20.2
Medium	15	19.7	39	13.5	10	15.9
Large	31	18.9	65	17.1	6	6.8
XLarge	34	23.0	63	17.4	9	11.0
2XLarge	26	19.6	50	13.9	9	12.0
3XLarge	8	21.3	19	14.2	8	14.4
TOTAL	140	20.7	276	16.2	45	13.5

TABLE J.47

Minimum, Maximum, Optimum Ease for Thigh

SIZE	MAXIMUM		OPTIMUM		MINIMUM	
	N	AVG (cm)	N	AVG (cm)	N	AVG (cm)
XSmall	4	13.9	1	10.2	0	0.0
Small	21	15.5	38	13.3	3	12.3
Medium	15	12.9	43	13.6	6	12.3
Large	29	16.6	62	13.6	12	14.0
XLarge	33	19.6	67	16.9	8	15.9
2XLarge	26	18.3	45	10.9	15	20.3
3XLarge	9	19.2	21	20.9	8	20.5
TOTAL	142	17.0	237	16.9	52	16.8

TABLE J.48

Demographics of Video Taped Subjects

Gender/ Size	XS	S	M	L	XL	2XL	3XL	Total
Male	0	0	0	2	2	5	1	10
Female	0	1	2	4	0	0	0	7
Total	0	1	2	6	2	5	1	17

VITA

Name: Margaret Brown Prevatt

Permanent Address: 111 University Dr., Suite 201, College Station, TX

Date of Birth: July 12, 1942

Place of Birth: Springfield, Ohio

Husband: Bruce C. Prevatt   Children: Juliana S. Prevatt
Ross C. Prevatt
Robert B. Prevatt

Major: Clothing and Textiles
Degree and Date to be Conferred: Doctor of Philosophy, May 1991

Educational Institutions Attended:	Dates:	Degree and Date:
Greeneview High School Jamestown, Ohio	9/56 5/60	HS Diploma, 1960
The Ohio State University Columbus, Ohio	9/60-5/63 3/64-5/64	
University of Georgia Athens, Georgia	9/63 12/63	
Western Kentucky University Bowling Green, Kentucky	5/81 5/82	B.S., May 1982
Virginia Tech Blacksburg, Virginia	9/82 12/84	M.S., June 1984
Virginia Tech Blacksburg, Virginia	8/88 5/91	PhD., May 1991

Positions Held: Graduate Teaching Assistant, Department of Clothing and Textiles, Virginia Tech. 1983-1984, 1988-1990.

Designer/CAD Specialist/Supervisor, Wolff-Fording, & Co., Richmond, VA. 1985-1988.

Instructor, Department of Clothing and Textiles, Virginia Tech. 1990-1991.

Margaret B. Prevatt