OPTIMIZATION OF FIT FOR MASS CUSTOMIZED APPAREL ORDERING USING FIT PREFERENCE AND SELF MEASUREMENT

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Sean Frederick Ahrens

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ABSTRACT

Mass customized apparel production holds great promise for revitalizing garment manufacturing in this country. Improved production processes like flexible manufacturing, Computer Assisted Design (CAD), Computer Assisted Manufacturing (CAM), and single-ply cutting have allowed customized, single garment production runs to become cost effective. In order for firms in the apparel industry to successfully implement this promising new production program, ordering methodologies must be established that provide customized garments with acceptable fit for the consumer. My first hypothesis is that the inclusion of fit preference queries in an apparel ordering model will improve the accuracy of size predictions. My second hypothesis is that these fit preference queries combined with an optimized method of self-measurement have the greatest potential to predict accurate garment sizes. This study is designed to evaluate the effectiveness of such ordering models using men's casual shorts as the primary test garment. I conducted research in two phases with a pilot and primary test. Male, college students within a specified waist size range were recruited and asked to report self-measurements and fit preferences on a mock internet website. These subjects were then scheduled for a fit testing session where they were measured by expert evaluators and tried on a series of test shorts. The first three short sizes presented were predicted using a size prediction model and data from self-measurement, expert measurement, and self-measurement plus reported fit preferences. In order to determine their optimum size, test subjects assessed up to a total of six shorts until they selected a pair with the perceived best fit. Subjects were also presented with a background questionnaire that asked demographic and apparel purchasing questions.

After the completion of all fit testing sessions adjustments were made to the size prediction model to enhance its effectiveness. Since collaborative interaction between the manufacturer and the consumer is essential in the ordering process for customized goods, the inclusion of fit preference queries with guided self-measurement procedures should improve ordering accuracy and selection of the optimum garment size. In the initial size prediction model fit preference adjustments to self-measurements were found to significantly improve optimum short size prediction accuracy. However, evidence to support my second hypothesis that self-measurement plus fit preference was a better predictor than expert measurement alone was not found in this study. Wide variations in reported self-measurements hampered the significance testing of fit preference adjustments and variations in garment positioning limited the predictive ability of the size prediction models. Due to the inaccuracies of short sizes predicted by self and expert measurement with and without fit preference adjustments it is apparent that additional variables may exist in the ordering process that can improve the accuracy of optimized garment size predictions in addition to fit preferences. Identifying and quantifying these variables may improve the optimum size selection for apparel customers and allow mass customization to be an effective alternative to mass production and made-to-measure manufacturing. Fit related variables such as waist height, garment positioning, and the interplay of garment style and fit characteristics with individual fit preferences may be the essential elements missing or miscalculated in this ordering process. Fit preference also requires additional research to determine its effectiveness in improving the accuracy of size predictions for a wider range of body types and mass customized apparel products.

BIOGRAPHICAL SKETCH

Sean Frederick Ahrens graduated from J. J. Pearce High School in Richardson, Texas. He attended the University of Colorado, Colorado Springs and graduated in August 1990 with a Bachelor of Science Degree in Production Management. He was named the Top Production Management student in his graduating class. He received an active duty US Army commission in May 1990 through the Reserve Officer's Training Corps (ROTC). He was designated the Top Cadet in his Regiment at ROTC Advanced Camp.

Captain Ahrens' commissioned military training includes the Combined Logistics Officer Advanced Course - Honor Graduate, the Petroleum Officer Course - Honor Graduate, the Quartermaster Officer Basic Course - Distinguished Honor Graduate, the Combat Developments Course - Honor Graduate, and the US Army Airborne School.

to my loving wife, Amanda and our wonderful son, Christopher

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LIST OF ABBREVIATIONS

AAMA	American Apparel Manufacturers Association
ABC	Activity Based Costing
ANSUR	Anthropometric Survey
CAD	Computer Assisted Design
CAM	Computer Assisted Manufacturing
CIM	Computer Integrated Manufacturing
CIT	Computer Information Technology
CM	Centimeters
CMT	Cut, Make, and Trim
EDI	Electronic Data Interchange
ILO	International Labour Office
IN	Inches
JIT	Just-In-Time
MPS	Modular Production System
NAFTA	North American Free Trade Agreement
PBS	Progressive Bundle System
POS	Point of Sale
QR	Quick Response
ROI	Return on Investment
ROTC	Reserve Officer Training Corps
SQC	Statistical Quality Control
TQC	Total Quality Control
UNITE	Union of Needletrades, Industrial and Textile Employees
UPS	Unit Production System
VMI	Vendor Managed Inventory
WIP	Work in Process

CHAPTER ONE
INTRODUCTION

1.1 Overview

Clothing mass produced in standard sizes appears to provide a poor fit for a large percentage of retail customers. Fifty percent of men and 62% of women recently reported that their body shapes do not fit well into mass produced sizes (Kurt Salmon Associates, 1999). In addition, standard sizing is not consistent for apparel manufacturers. Most manufacturers develop base pattern sizes independently utilizing fit models that represent the target body type the firm wants to attract. Additional garment sizes are then proportionally graded from the base size. If a consumer does not match body type intended by a particular manufacturer then they may be forced to try on a variety of garments from other manufacturers until an acceptable fit can be achieved. Often this quest ends in failure or the lowering of fit-related expectations for the consumer. The emergence of mass customization gives apparel manufacturers the abilities to mass produce garments individualized for fit that can meet the needs and preferences of a much larger percentage of apparel customers.

This shift from traditional mass production techniques to mass customization requires a collaborative interaction between the consumer and the manufacturer. The information exchanged between these groups becomes the basis for ease and sizing determination in the manufacturing process and may ultimately determine customer satisfaction. Consumers must accurately communicate their sizing and preference requirements and the manufacturer must provide garment-related fit characteristics and style features in the ordering process. If any of these components is missing an unacceptable or poor fitting garment may result. Due to the average consumer's unfamiliarity with proper fit, retail shoppers may have difficulty providing accurate information in the ordering process. Inaccurate body measurements taken by the consumer or retail sales associates also pose potential problems for mass customization.

Several recent apparel industry initiatives like whole-body scanning, computer assisted design (CAD), and computer assisted manufacturing (CAM) may supply the tools needed to help resolve some of these issues. However, these initiatives do not address the importance of fit preference and the perceived interaction of garment fit characteristics with the body. The absence of objective measurement and fit preference data from consumers means the accuracy and importance of these factors requires closer examination. If tendencies exist for consumers to over or under estimate self-measurements or fit preference responses, then these anomalies must be quantified and used by manufacturers to interpret customer order requirements. An examination of variations in disproportionate garment grading may also provide important information for manufacturers.

1.2 Background

Historically, garment production has always been highly dependent on labor-intensive manufacturing steps. It was not until 1849 and the introduction of the sewing machine that major productivity increases were first realized in apparel manufacturing. These production rate increases were accelerated by efficiencies required to meet the uniform demands of the Civil War in the 1860s. By the start of First World War, the apparel industry in the United States included 12,735 factories and 460,000 workers (ILO, Report 1, 1964). The majority of these workers came from the pools of immigrant labor that arrived daily in New York City and other major metropolitan areas.

Constantly changing materials, garment styles, and clothing sizes as well as material handling problems and a diverse product mix make it extremely difficult to automate individual tasks in manufacturing processes. Additionally, the availability of cheap, plentiful labor has limited the return on investment that individual firms can realize funding technological improvements and automating production operations. For these reasons apparel manufacturing may remain a labor-intensive industry.

Just as apparel production was an attractive growth industry for the United States in its early years, third-world countries now look to apparel manufacturing as a way to gain competitive advantages in the global economy. With its low start-up costs, limited technology, and labor intensive production system, apparel manufacturing offers a practicable solution to the employment problems of countries seeking to develop an industrial base with large, unskilled labor pools. The recent increase in apparel production from these low-wage countries has made off-shore sourcing and production alliances a necessity for most US manufacturers and apparel retailers (Dickenson, 1995). The American apparel manufacturing base continues to erode under the competitive pressures generated by these countries.

Through the use of contracting and out-sourcing, many domestic firms have transferred their labor-intensive production tasks overseas. After peaking in the mid-1970s with just over 1.2 million workers, the number of apparel production workers in the United States has dramatically declined to a level of 695,000 workers in 1996 (AAMA, Report 1, 1997). This marks the lowest levels of employment in apparel production since the end of the Second World War. While there is still a large number of apparel manufacturing factories in the United States, the overall decline in the number of workers and plants is projected to continue.

The primary reasons for this deterioration in manufacturing infrastructure include the easing of trade restrictions, inability of firms to compete with cheap labor rates in developing countries, lack of experienced workers available in the labor pool, and significant decreases in the wholesale price index for clothing (Gereffi & Blair, 1998). The wholesale price index reflects the price paid for the apparel industry's output by retailers.

The implementation of trade agreements like the North American Free Trade Agreement (NAFTA) has spurred the migration of garment production into Mexico while a 48% decrease in the wholesale price index for apparel products from 1950 to 1981 has forced the closure of many firms (Canning & Tarling, 1985). Multi-national, intra-company agreements have allowed manufacturers to shift production to different countries according to changes in comparative advantages, marketing demands, and other considerations. Comparative advantages may include such factors as the availability of raw materials, labor costs, labor availability, government restrictions, and other production related concerns.

The continued concentration of economic power in a small number of large retail establishments has driven down wholesale apparel prices (Singh, 1991). Retailers like Wal-Mart and K-Mart have used competitive bidding practices that force manufacturers to contract production operations with lowest cost sub-contractors (Gereffi & Blair, 1998). These sub-contractors may use illegal compensation practices and sub-standard working conditions to reduce their overhead costs. The decentralization of clothing manufacturers and the vast number of small economically powerless production firms has enhanced this process (Singh, 1991). Of the total number of apparel manufacturers in 1984, over 78% employed less than 50 workers (ILO, Report 2, 1987). Without large scale, economically powerful manufacturers, large retailers will continue to set prices paid for wholesale garments. The inflexibility of raw material costs such as fabric and findings further complicate this situation. These set costs and fixed profit margins for most firms mean that wage and compensation packages will continue to suffer in order to make the firms competitive.

1.3 Apparel Industry Initiatives

During the early 1980s there was a strong movement to automate assembly tasks using robotics technology (Dickenson, 1995). However, a lack unified industry-wide support, cost benefits, and problems manipulating a diverse range of limp fabrics soon doomed the effort. Since then, the apparel industry has moved toward automating and refining selected manufacturing processes. In recent years, the introduction of new manufacturing technologies like CAD, CAM, and computer integrated manufacturing (CIM) has allowed substantial improvements in both quality and flexibility for production and pre-production operations.

Recent applications of quick response (QR) strategies have also provided promise for a resurgence in American apparel manufacturing. King and Hunter (1997) contend that domestic QR methodologies result in better overall retail performance than importing apparel produced overseas. QR allows the retailer to stock only the sizes and styles demanded by the consumer and dramatically decreases inventory holding costs, stock-outs, and end-of-season mark-downs.

Other manufacturing improvement efforts involve the application of technological advances and quality control. Technological advances like single-ply cutting, computerized work stations, and the modularization of assembly operations have helped change the basic framework of the apparel industry. These advances have allowed manufacturers to minimize waste, improve flexibility, and regain some competitive advantages. Quality is another area in which US manufacturers have gained a competitive edge in apparel production. First-run, production quality must continuously improve if apparel firms wish to remain competitive. King and Hunter (1997) posit that flexibility in getting competitively priced garments to market will result in better overall retail performance for American manufacturers than importing. With team-based production, total quality control (TQC), QR, and new technologies, quality and flexibility have certainly become critical factors in apparel manufacturing (Mazziotti, 1993).

Retail developments like Internet ordering, factory owned outlets, and electronic data interchange (EDI) have changed the business practices of many apparel production firms. Manufacturers are now entering the retail arena in increasing numbers. While this may provide significant advantages in branding and availability of product for consumers, it can also have disadvantages. Retail sales is a highly competitive business sector that may increase overhead and operating costs for manufacturers. However, if this type of vertical integration can be managed properly manufacturers may realize significant gains in profitability and brand awareness. A retail presence also allows manufacturers to interact directly with consumers in the purchasing process. This lays some of the fundamental groundwork needed for the successful implementation of mass customization.

1.4 Mass Customization

Mass customization embodies many of the tenets of QR, increased quality, and flexible manufacturing processes and expands on these concepts. In recent years, apparel mass customization has emerged as a viable alternative to mass production. Mass customization can provide low cost, custom-made clothing in an expedient, efficient, and effective manner that maximizes customer satisfaction. As a result, mass customization holds great promise for revitalizing garment production in this country. Along with the application of improved production practices and technologies, mass customization offers beleaguered American manufacturing firms a strong competitive advantage over sub-standard wage paying plants in developing countries that utilize mass production techniques.

Mass customization strategies have the ability to counter the pricing pressures of large retailers and the lower wage rates in developing countries by allowing garment manufacturers to compete in areas other than price. Total quality, individualized products, and expedited delivery processes have become the hallmarks of mass customization. Levi Strauss & Co.'s "Original Spin" program is one example of the successful application of mass customization strategies (Cuneo, 1998). Levi's has been able to provide custom fit jeans to customers through its own retail sales outlets. Customers make style and fabric selections at retail outlets. Customer service representatives or a three-dimensional body scanner then measures customers. Data from measuring procedures are then used to select a size of jeans to try. If necessary multiple try-ons are used to find the customer's optimum size. Final orders based on optimum size selections are sent to the factory electronically. At the factory automated systems are used to adjust the garment pattern, prepare the marker, and guide the production process. Customized jeans arrive in just a matter of weeks but Levi's is working to reduce this time as well (Wirtz & Adams, 1997).

As seen in the Levi's example, mass customization strategies and new technologies allow cost-effective, single garment production runs that can greatly improve the flexibility and responsiveness of manufacturers. However, mass customization is more than just a manufacturing strategy. Its implementation requires the total commitment of all functional areas in a firm. From product design and development to marketing and retailing functions, every department must focus on end-user requirements. Consequently, accurate communication with customers becomes an important concern. In order for firms to successfully implement mass customization, ordering methodologies must be established that provide accurate customer information and relate this data to production and pattern making procedures for the manufacturer. Required information can include body measurements, style and color selections, fit preferences, fabric and finding choices, and other data relating to customizable features in the garment ordered.

1.5 Garment Sizing

Since the introduction of ready-made apparel in the middle of the 19th century, the majority of men's clothing has been based on a very simple incremental and proportional sizing system. The fundamental idea behind this sizing system is that girth and height is correlated. Through the middle of this century, retail stores generally maintained a large stockage of men's garments in a set of basic sizes. They had in-house alteration departments alter garments for each customer. As the current system of sizing men's clothing in relation to specific body measurements was introduced, the importance of custom fit clothing rapidly declined. Even with this newer sizing system based on body measurements, girth and height are still perceived as correlated and garment sizes are proportionally graded from a base pattern. There is a significant percentage of men outside these proportional tolerances that remain unable to purchase ready-to-wear clothing that fits well. Some combinations of waist and inseam measurements are not available in mass produced clothing sizes.

Since the determination of intended garment fit characteristics has historically remained in the hands of apparel designers, pattern makers, and graders, consumers have had little or no input in the determination of comfort ease, styling ease, or pattern grading rules for manufactured clothing. Garments are generally produced based on a narrow range of body types in relatively homogenous proportions. This means manufacturers use specific fit models based on intended target audiences to design and size clothing. Consumers that do not proportionately match these sizing factors may not be satisfied with the resulting garment fit. Most consumers are often forced to try a wide range of garments from a variety of manufacturers to achieve an acceptable fit. With mass customization many of these sizing and fit issues can be resolved. Whole-body scanners or accurate body measurements along with individual fit preferences can provide manufacturers with the information needed to produce customized garments that fit.

1.6 Research Objectives

The overall goal of this study is to evaluate self-measurement and fit preference and their connection with optimum size prediction. In order to accomplish this goal testing procedures were developed to examine the optimum garment size selection process. Significant efforts were made to reduce the impact of fashion, styling, and fabric characteristics on optimum size selection by test participants. The intent of this effort was to focus the attention of test subjects exclusively on the fit characteristics of test garments. Due to their limited styling features and conservative fashion, men's shorts were chosen as the primary test garments for this study. Waist and crotch lengths in these shorts were varied incrementally to provide an increased range of choices in fit. Using test shorts it was possible to determine the impact of fit preference, individual perception of fit, and body measurement procedures in the final short selection process.

Several social variables also have the potential to influence optimum size selection. The impacts of age, socioeconomic status, and gender variables were significantly reduced or eliminated in testing by the selection of a sample from a relatively homogenous subject pool of male college students. However, differences in race, ethnicity, religion, and fashion choices still have the potential to impact findings. The experience level of test subjects in retail apparel shopping may also impact findings. Background questionnaires were given to all test subjects to help identify and isolate these factors and determine their impact on optimum size selection.

It is imperative that manufacturers effectively communicate garment fit characteristics, functionality, and design features to the consumer. Consequently a detailed Internet website was developed for testing. Without an accurate understanding of garment styling characteristics consumers can easily misinterpret the impact of elective sizing adjustments and fit preference responses. If a base style or pattern is designed with a significant amount of functional or comfort ease, the consumer must be aware of this fact in order to accurately refine and adjust their own preference statements while ordering. Without accurate communication, manufacturers will be unable to produce garments that meet the requirements of individual customers.

Expert measurement procedures were conducted to assist in identifying errors in self-measurement and validate self-measurement findings. Self-measurement errors have the potential to include individual biases and inaccuracies related to self-image and improper measurement execution.

There is a strong potential for consumers to unintentionally misrepresent body measurements due to misconceptions about the accuracy of ready-to-wear garment sizes that they typically wear. These tendencies must be identified and error rates quantified in order to develop accurate mass customization ordering models. The overall objectives and research hypotheses of this study include the following.

Primary Objectives

1. Evaluate self-measurement and fit preference and their connection with optimum size prediction.
2. Develop self-measurement and fit preference reporting procedures that best achieve desired fit.
3. Develop a size prediction model that accommodates fit preference for mass customized apparel ordering.

Hypothesis A

The addition of fit preference to an apparel ordering model better predicts optimum size selection.

Hypothesis B

An apparel ordering model that includes fit preference and self-measurement better predicts optimum size selection than expert measurement alone.

1.7 Significance of Study

The importance of consumer preferences and perception of fit with clothing purchases cannot be over emphasized. The inclusion of fit preference queries with an optimized method of self-measurement may have the greatest potential to deliver this information and allow manufacturers to customize clothing based on fit. Fit preference responses can give manufacturers the ability to optimize size selection or pattern changes for individual consumers and improve overall ordering satisfaction. Collaborative interaction between manufacturer and customer through an electronic ordering medium like the Internet can make this process more effective. This study was designed to evaluate the importance of fit preference reporting.

The study also examines the feasibility of achieving optimized fit without garment fittings. This type of ordering may be required if mass customization for fit is going to be successful using mail-order or Internet based apparel buying. Mass customization allows consumers to purchase garments that are customized in fit, styling and fabric choice. It can eliminate the need for retail inventories and significantly reduce retail selling costs. Seasonal markdowns for unsold merchandise may no longer be required. All garments produced under mass customization are essentially sold before they are manufactured. In terms of manufacturing costs, work in process (WIP) and finished goods inventory holding costs can be virtually eliminated with mass customization. Clearly mass customization can offer strong competitive advantages for American apparel manufacturing firms and provide the basis for a powerful resurgence in this industry sector.

This study is also designed to determine differences between self and expert measurement findings. The results of this examination may be useful for manufacturers in determining accurate size predictions for retail customers. Identifying error rates in reported self-measurements may allow manufacturers to compensate for general tendencies in measurement reporting. Improving the accuracy of customer ordering information is the key for manufacturers to produce garments that better fit the consumer.

CHAPTER TWO
REVIEW OF RELATED LITERATURE

2.1 Manufacturing Alternatives

To better understand the manufacturing requirements for mass customized apparel alternate production processes including mass production and custom manufacturing will be reviewed. Apparel manufacturing is a labor intensive industry characterized by a large number of small firms. Many of these firms lack the capital resources or impetus to develop or apply recent technological advances. In most cases apparel firms rely on traditional production methods utilizing assembly lines and non-automated production equipment. They usually depend on productivity-based compensation systems to ensure the efficiency of their manufacturing operations and the attainment of their production goals. Apparel products are generally mass produced in large batch runs of homogenous products and efficiencies are gained by minimizing costs and optimizing resources.

Custom manufacturing firms produce unique garments based on individual customer requirements. These firms are often organized in craft shop-like settings where a single worker may perform all of the manufacturing tasks for a garment. Custom manufacturing generally has higher production costs and longer throughput times than mass production. Custom manufacturing focuses on meeting customer requirements and filling the customer service gaps provided with common sizing in mass production.

Mass customization combines the strengths of these two production systems and can be considered a hybrid manufacturing process. Mass customization retains many of the efficiencies gained with standardized, repetitive production tasks in mass production and combines these with the customer requirement based orientation found in custom manufacturing.

Joseph Pine summarized this point best when he states that "in mass customization products are produced with maximum differentiation using efficient manufacturing procedures" (Pine, 1993).

2.1.1 Mass Production

Apparel mass production can be categorized into three major operations that include pre-production, cutting, and assembly operations (ILO, Report 3, 1995). Pre-production operations involve design, pattern development, and marker making functions (see Figure 2.1). Pattern development and marker making are often completed using industry-standard CAD systems such as the Lectra or Gerber software programs (Hye, 1998). These systems simplify the process of creating graded patterns and optimized markers and can be used to send digitized markers directly to automated cutters. During cutting operations cloth is pulled from stock according to a production schedule and layered on cutting tables. If printed markers are used, these markers are placed on the top layer of the spread fabric and cutting is performed by hand with a saw-like tool designed to cut multiple layers. With computerized cutting systems, digitized markers guide the cutting blade automatically (Glock & Kunz, 1990). Pattern pieces are then bundled for assembly operations and sent to buffer stock (see Figure 2.1).

Component assembly is completed next and finished garment pieces are sent to buffer stock or queued at downstream assembly stations. At varying stages of production in-process pressing is completed as needed to prepare component and pattern pieces for final assembly operations. These pressing processes can involve underpressing to open seams or shape garment pieces. Assembly operations are sequentially performed based on pattern requirements and the operational layout of the plant. Most factories have traditional assembly-line organizations in which bundles of garments are moved from station to station for different production operations.

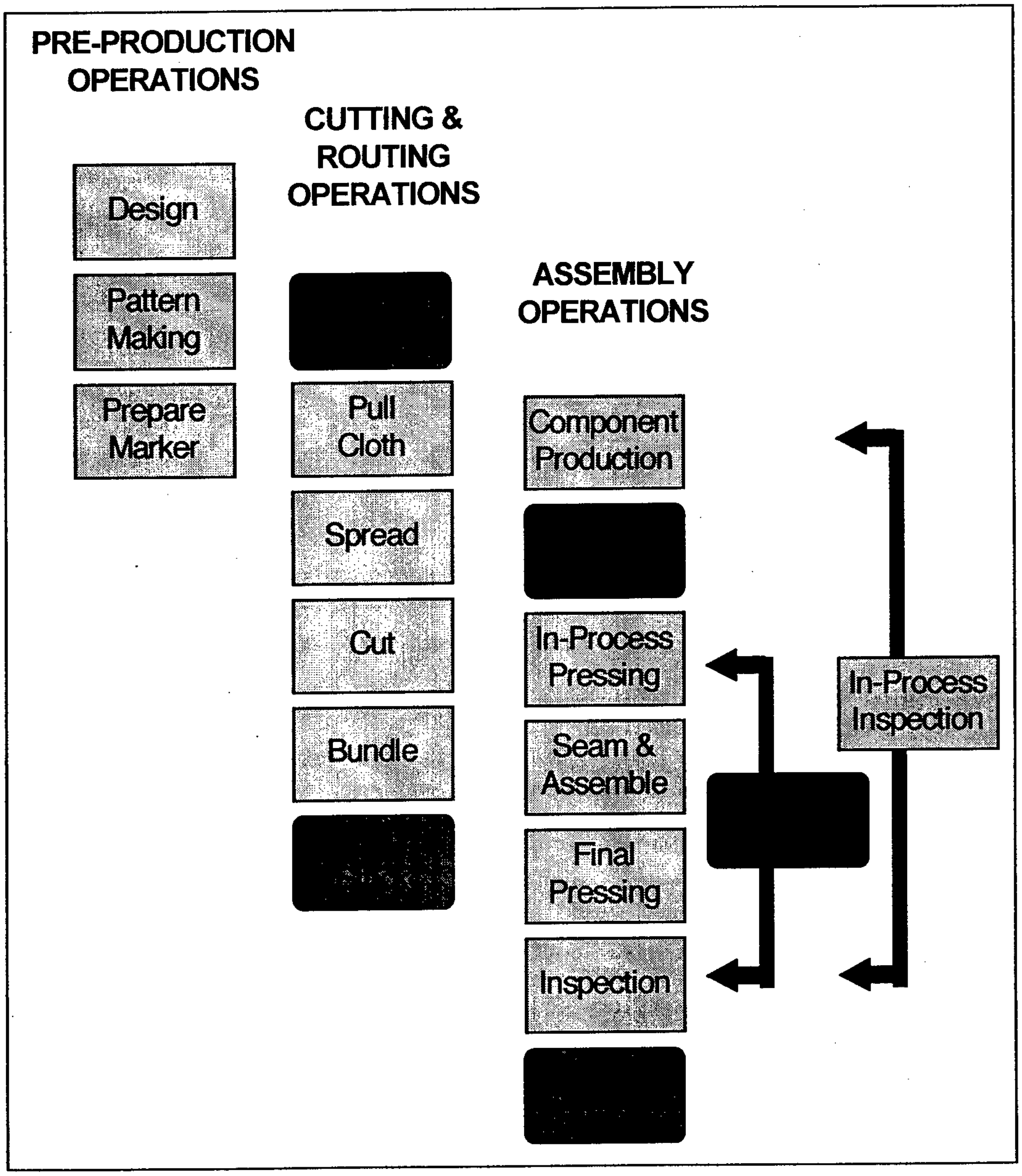


Figure 2.1 Typical Mass Production Operational Layout

In recent years, some firms have moved to cellularized or team-based manufacturing structures where all assembly tasks are completed within a single cell of workers. One advantage of this set-up is the cross-leveling of production activities between members of the cell or team. This can result in smoother production flows and expedited throughput. Final inspection and pressing is completed before finished garments are packed for shipment while buffer stock is generally maintained throughout the assembly process. In-process inspections may also be completed (Glock & Kunz, 1990).

Assembly-line production focuses on standardized, repetitive tasks performed by specialized workers. Smoothing the rate of production flow is seen as an essential component in this process. Bottlenecks are created by difficult, time-consuming tasks, inexperienced workers, labor and equipment shortages, or any combination of these factors. Bottlenecks receive immediate attention from management and are eliminated by applying additional resources or operational improvements. The goal is to smooth production so no operations restrict product flow. Standardization is the key component in this process. Nakamura (1993) summarizes the changing needs of modern manufacturing, new production technologies used to fill these needs, and the goals of standardization in (Figure 2.2).

Like other industries utilizing mass production, apparel manufacturing focuses on the set division of labor. Highly specialized machines and operators are used to complete manufacturing tasks. Cost reduction is a key component of this process. Inefficiencies are constantly identified and eliminated. In most cases this type of traditional assembly-line operation is inappropriate for the production of individually customized goods. Specialized equipment is designed to maximize throughput and lacks the flexibility needed to handle diverse product orders on a recurring basis. Set-up requirements and material handling limitations provide additional problems.

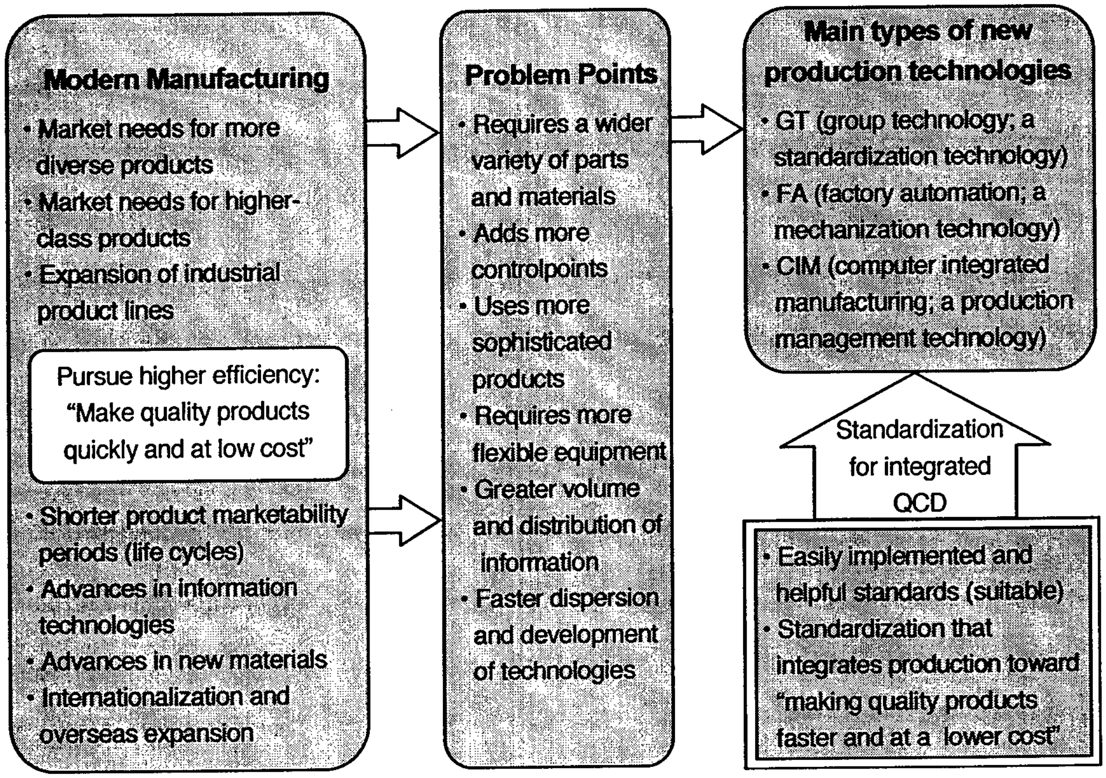


Figure 2.2 Standardization and Manufacturing Needs (Nakamura, 1993)

Joseph Pine, the leading expert on mass customization carefully reviews mass production techniques and cites the primary principles underlying mass production (Pine, 1993). These principles are listed in Table 2.1. In line with Pine's principles apparel production management in a mass production environment is constantly focused on product and process standardization and improvement. Workers use highly specialized machines with set routines to produce garments. These workers have clearly defined roles and rarely perform tasks outside the scope of their positions. In addition, piece-rate compensation systems force workers to focus almost entirely on operational efficiency at their assigned task. Large batch orders for the next selling season are produced at specific times throughout the year and the production flow dictates overall productivity for the plant (Glock & Kunz, 1990).

Table 2.1 Principles of Mass Production (Pine, 1993)

Primary principles:
• Interchangeable parts
• Specialized machines
• Focus on the process of production
• Division of labor
Additional principles:
• Focus on low costs and low prices
• Economies of scale
• Product standardization
• Degree of specialization
• Focus on operational efficiency
• Hierarchical organization with professional managers
• Vertical integration

Assembly-line manufacturing has changed very little since the first apparel factories emerged in the mid 1800's. Scientific management principles are still used to develop highly specialized workers trained on a series of specific, repetitive tasks. Efficiencies are gained through scientific approaches to production problems. Workers that cannot meet task requirements are quickly replaced or leave. Quality control measures have improved in recent years but irregular garments are still produced in mass production settings. Many of these seconds, thirds, and scrap items result from material flaws, cutting errors, and assembly problems. Production workers often have little or no incentive to produce higher quality garments at the expense of set productivity goals. This type of focus is inconsistent with the emerging requirements of mass customization (Glock & Kunz, 1990).

For larger firms, technological advances like EDI, computer assisted design (CAD), computer assisted manufacturing (CAM), and computer integrated manufacturing (CIM) have resulted in significant improvements in apparel mass production flexibility and processes. Retailer links through EDI allow manufacturers to monitor single store sales and refine production forecasts (Wirtz & Adams, 1997). These EDI connections with retailers also enhance and expedite the purchase order process and eliminate transposition errors often found with many manual order entry systems. CAD, CAM, and CIM programs within the factory provide the technical support necessary to cut, track, and sew garments in batch or single garment production runs. EDI transmitted orders from retailers are often designed to queue automated markers for patterns in the cutting system using CAD/CAM. Fabric is then automatically selected and pulled from storage and routed through the production process using CIM technology (Gray, 1998).

Advances in cutting technology allow automated systems to spread fabric and cut large numbers of pattern pieces quickly and accurately. However, some of the most significant advances relate to the reduction of scrap and losses from cutting and spreading operations (Carr, 1972). Unlike mass customizers that can switch from one order to the next using single-ply cutting, mass production firms are generally tied to large batch runs of standardized garments. It is imperative to minimize losses from spreading, marker making, marker fall-out, and remnants in high height cutting operations (Carr, 1972). When multiple layers of fabric are cut at the same time, any errors in cutting, marker placement, or marker making are multiplied times the number of layers spread. Today, automated laser and banded-blade cutting systems can cut hundreds of layers of fabric at a time (Glock & Kunz, 1990).

Other recent advances in apparel mass production include vendor managed inventory (VMI), QR, and flexible manufacturing. These initiatives have changed the way retail inventory acquisition is controlled. Flexible manufacturing and QR require frequent vendor deliveries, reduced work in process (WIP) and lower finished goods inventories. Under VMI and QR only a portion of the season's production is initially shipped to the retailer. Weekly replenishment orders are received via EDI based on revised forecasts. Manufacturers use rapid manufacturing processes to produce garments based on these revised orders requiring close cooperation with textile suppliers. The result is lower inventory holding costs for both the manufacturer and the retailer and better availability of style selection and sizes for the consumer. The manufacturer no longer has to produce and deliver large batch production runs of garment styles and sizes that do not sell through (King & Hunter, 1997).

In terms of routing the progressive bundle system (PBS) is the most commonly used production system in apparel manufacturing. It involves bundles of garment parts moving between production operations where sequential assembly is completed. In contrast the unit production system (UPS) uses overhead transport systems to move single garment sets of material parts through the plant. The modular production system (MPS) is a form of empowered, team-based manufacturing where production cells are established with a small number of employees that perform complete assembly of assigned styles or components (Glock & Kunz, 1990).

From the standpoint of production efficiency, all three production systems offer benefits. PBS is more advantageous when long runs of identical garments are produced and WIP inventories can be managed effectively. PBS allows decreased handling times and improved productivity from individual workers. UPS is most effective when flexibility and control are required in the production process. By eliminating WIP inventories and tracking individual garments, companies can easily shift production to another garment style or expedite orders. MPS is most efficient when pooled worker knowledge is needed to tackle difficult production problems, handle a variety of styles, or improve quality. Goal setting and cross-trained team members are keys to the modular production system. However, increased training and employee involvement are needed to make it work (Glock & Kunz, 1990).

Information systems are least essential in PBS and are critical components of UPS and MPS. Under PBS workers receive new bundles as work is completed. A series of indicator lamps may be used to signal the need for a new bundle but no oversight of completed garments is gained (Glock & Kunz, 1990). With MPS, information flow is built into the distribution system. The close proximity of operations and flexible assignment of workers enhances the communications system. UPS has the most complex information system with automated tracking of individual garments. A computer system is used to route garments through the entire production process, tracking the time required to complete each operation and the location of each garment.

2.1.2 Custom Manufacturing

Craft or custom manufacturing involves the development of unique patterns and clothing for individual customers. Garments are generally sewn in small factories, couture operations, custom tailor shops, or in-home businesses. However, there are a number of large scale, custom manufacturers in certain menswear sub-categories. Dress shirt, suit, and plus-size custom manufacturers are good examples. It is often difficult to draw distinctions between custom manufacturers and mass customizers. For years alteration departments in major retail stores have customized mass produced ready-to-wear suits, pants, and dress shirts. Pine (1993) might classify this process as adaptive mass customization rather than custom manufacturing. In adaptive mass customization manufacturers produce customizable products that are altered by the consumer (Gilmore & Pine, 1997). However, I contend that most tailoring and alteration activities should be classified as custom manufacturers since unique, non-reproducible customization occurs. Whether their raw materials are ready-to-wear suits or bulk fabric the essential elements of production remain individually based and non-repetitive.

In custom manufacturing, garment designs are generally developed by a dress maker, tailor, or fitter who works in close collaboration with the customer. Customers are personally measured and fitted by the tailor or dress maker. Often a number of in-process fitting sessions are scheduled to ensure the proper fit of finished garments. Custom manufacturing can include complete style, pattern, and garment production tasks or it may be limited to minor alterations of ready-to-wear clothing or garment production using common patterns also available to home sewers. Multi-purpose sewing machines are often used to perform the majority of production tasks. Workers generally perform a wide variety of assembly, pre-production, and support operations.

Most custom manufacturers lack the capital resources and requirements to fund technological advances and generally rely on traditional manufacturing procedures and equipment. Custom manufacturers have little need for standardized processes used in mass production and mass customization. Each garment produced in a custom manufacturing setting is unique. Due to limitations in productivity and higher production costs custom manufacturing has seen a significant decline in market share in recent years. Advances in mass production and the emergence of mass customization may continue to limit the profitability of custom manufacturing operations.

Fit preferences are easily incorporated into the in-process fit session and alteration procedures utilized with custom manufacturing. The ability to make alterations to a garment the consumer is wearing has significant advantages over attempting to communicate accurate fit preferences in the mass customization ordering process. Under mass customization consumer fit preferences, body measurements, and garment characteristics must be combined to achieve a satisfactory fit without the garment being fit tested on the consumer prior to purchasing.

2.1.3 Mass Customization

Stan Davis calls mass customization an oxymoron in his forward to Joseph Pine's (1993) Mass Customization: The New Frontier in Business Competition. While it is true that mass production and custom manufacturing are opposites in terms of manufacturing techniques, their blending allows apparel manufacturers to overcome the limitations inherent in each system. Mass customization provides expanded productivity and flexibility that effectively and efficiently meets consumer needs. Mass customization offers a strong competitive advantage for American apparel manufacturers and provides the basis for a powerful resurgence in this industry sector.

Under mass customization, consumers can purchase garments that are customized in fit, styling, fabric choice, and other variables. The need for retail inventories becomes obsolete, significantly reducing inventory holding costs, markdowns, and return rates. The efficiencies gained under this system benefit both the consumer and the manufacturing base. Customers have the ability to purchase the latest styles customized for fit, color, and fabric choice at any time of the year. Manufacturers and retailers are able to reduce fixed overhead costs and focus solely on end-user requirements.

In a 1996 North Carolina State University study, King and Hunter find that QR strategies result in better overall retail performance than importing apparel products. Mass customization may be the ultimate form of QR. The flexibility gained by American apparel firms using mass customization technologies provides rapid response to changing market conditions. Manufacturers have the ability to adjust the level and scope of customization offered under mass customization. The loss of large-scale efficiencies and cost-per-item reductions under pure mass production is quickly offset by lower inventory holding costs for raw materials and finished goods. Focus on first-run quality also reduces rework and return costs for mass customizers.

Mass customization is a collaborative effort between manufacturers and customers that Gilmore and Pine (1997) propose fills customer service gaps in sizing, selection, and responsiveness. These service gaps represent unfulfilled customer demands and provide a competitive niche for mass customizers to fill. One example of a mass customization strategy is individualized sizing adjustments made to garment patterns. This type of collaborative customization has demonstrated that customized clothing can be made as fast and inexpensively as other mass produced garments (Port, 1994). Prior to ordering, customer body measurements are taken using a variety of methods. Customer specifications are then transmitted to the manufacturer through Electronic Data Interchange (EDI), the Internet, and a variety of other traditional communication methods. Garments are produced to individual specifications.

Technological advances like Computer Assisted Design (CAD), Computer Assisted Manufacturing (CAM), and new production techniques provide the tools necessary for firms to operate efficiently using mass customization (Port, 1994). CAD technology enables the development of unique patterns and markers from customer specifications. CAM, flexible and team-based manufacturing, and quick response allow firms to have profitable single garment production runs. Effective mass customization embodies the culmination of agile manufacturing and technological applications.

Pine and Gilmore analyze the differences between mass production and mass customization by contrasting the focus, goals, and key features of each manufacturing system. The authors contend that "variety and customization through flexibility and quick responsiveness" is the key focus of mass customization (Gilmore & Pine, 1997). Fundamental features of mass customization are listed in (Table 2.2).

Table 2.2 Features of Mass Customization (Pine, 1993)

Primary features:
• Fragmented demand
• Heterogeneous niches
• Low-cost, high quality, customized goods and services
• Short product development cycles
• Short production life cycles

The features of mass customization appear to compliment apparel manufacturing requirements quite well but mass customization is not limited to the apparel industry. A large number of US firms in both the manufacturing and service sectors are busy implementing mass customization programs. Technological advances have played an important role in speeding the adoption of this new manufacturing concept. Pine and Gilmore see the goal of mass customization as "developing, producing, marketing, and delivering affordable goods and services with enough variety and customization that nearly everyone finds exactly what they want" (Gilmore & Pine, 1997).

According to Gilmore and Pine (1997) customization for apparel manufacturing can include individual selection of fit, style, color, fabric, construction, design, surface treatment, findings, and almost anything else. Pine sees mass customization as the synthesis of "two long-competing systems of management." In his eyes, mass production and custom manufacturing have merged to mass produce individually customized goods and services (Gilmore & Pine, 1997). The implications of employing new manufacturing techniques like mass customization are widespread. Significant changes are needed to address the complexities of QR, improved quality, team-based manufacturing, cellularization, job design, and skill development needed to successfully produce a mass customized product. Unless these issues are addressed, the successful implementation of mass customization practices in US apparel production is in question.

Specialized software applications, expedited delivery services, flexible manufacturing, and expanding consumer demand are examples of emerging technologies and conditions that give mass customization a significant advantage over mass or custom production approaches. Current market trends provide a competitive niche for apparel manufacturers that utilize a mass customization approach in production, marketing and merchandising.

Gilmore and Pine (1997) indicate that mass customizers have identified points of "common uniqueness" among customers that allow firms to fill "customer sacrifice gaps." This concept of common uniqueness can be seen in the issue of sizing and fit. Consumer preferences and sizing are not homogeneous. Differences exist between the characteristics of garments designed for the average consumer. The sacrifice gap represents unfulfilled customer demand and a competitive niche that mass customizers and custom manufacturers can fill (Gilmore & Pine, 1997). Mass customizers also have a significant advantage over mass production firms because of mass customization's shorter production life and development cycles. Mass customizers enjoy economies of scale in manufacturing over custom garment producers. With production techniques designed to meet the specific demands in the sacrifice gap, only minor style and sizing adjustments are made from garments normally produced in a mass production setting (Gilmore & Pine, 1997). These style, fit, and subsequent pattern adjustments for individual orders are made during pre-production operations and single-ply cutting is used to cut garment pieces. The result gives consumers better fitting apparel in the color and style desired and at a lower cost than small scale craft/custom manufacturers can produce.

Team-based production involves the grouping of workers into product clusters where they share task responsibilities and work in concert to produce finished goods. Both flexible manufacturing and team-based production provide apparel firms with competitive advantages in product turnover, reduced inventories, and quicker throughput. Mass customized manufacturing in a team-based setting includes many of the same basic operations as mass production (see Figure 2.3). However, buffer stocks are almost always eliminated and assembly operations are organized into manufacturing cells.

A team-based organization can be used to produce small or single garment production runs with greater efficiency than assembly-line techniques. Small production runs are essential when product orders are unique and driven solely by consumer demands. Production workers are required to master a greater variety of skills in team-based settings. The varied product mix created by individually customized orders requires workers to perform less repetitive tasks and more set-up operations. This along with first-run quality concerns result in a much different focus for production workers over mass production requirements.

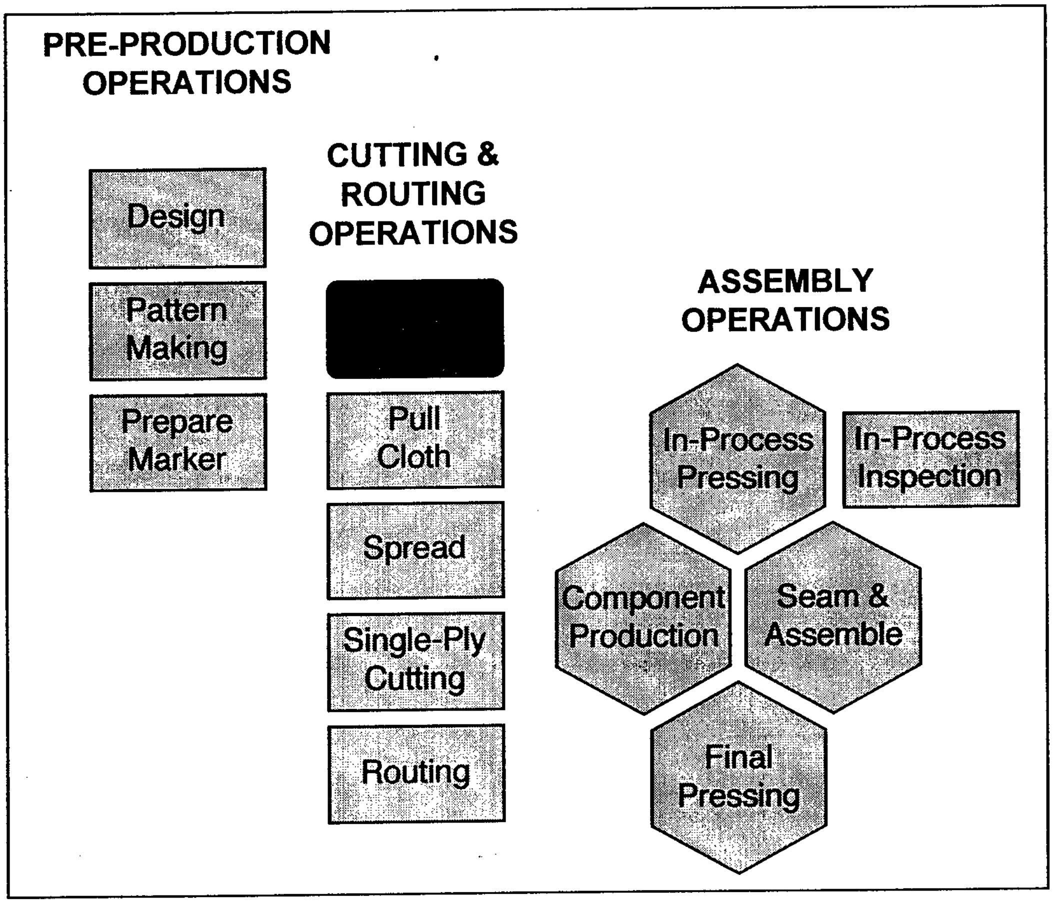


Figure 2.3 Mass Customization Operational Layout

Team-based and modular manufacturing systems allow WIP inventory reductions by establishing a pull system of production (Mazzioti, 1993). A pull system of manufacturing ensures that each sewing operation is not competed until it is called for by a downstream operation. This eliminates excess inventory levels for component pieces and smoothes the flow of production. Modular production methods are the opposite of traditional manufacturing methods that use push systems of manufacturing, production bundles, and piece-rate compensation systems (Mazzioti, 1993). Under these traditional systems, workers are rewarded for number of processes completed rather than the completion of individual garments. WIP and finished goods inventory costs under traditional systems can account for a high percentage of manufacturing costs and greatly decrease profitability (Burns & Bryant, 1997).

EDI, CAD, CAM, CIM, the Internet, and single-ply cutting allow mass production firms an easier transition into the mass customized production arena. Internet connections allow manufacturers deal directly with consumers on their own retail websites. Consumers can place orders directly over the Internet by providing style and sizing information for the manufacturer. Retailer links also allow merchants to place customized orders with the manufacturer over the Internet or through EDI connections (Wirtz & Adams, 1997). CAD, CAM, and CIM programs within the factory provide the technical support necessary to cut, track, and sew single garments rather than large batch production runs.

Customer orders are transformed into patterns that are organized in markers using CAD/CAM. Patterns are either graded to established sizes or altered to fit individual measurements. These body measurements are either self-reported or taken by employees in a retail setting. Fabric can then be selected and pulled from storage and routed through the production process using CIM technology. Single-ply cutting allows the mass customizer to quickly shift from one order to the next by cutting single garments on high speed machines. Custom manufacturers cannot afford the equipment or technology needed to run such operations. Mass production firms are tied to large batch runs of standardized garments (Glock & Kunz, 1990).

CIM integrates computerized processes like CAD, CAM, inventory control, and finance to develop a common manufacturing database. For example inventory pulls of raw materials may be determined from CAD marker making projections and production planning software (King & Hunter, 1997). The result is efficient operations linked across all manufacturing and support functions. This system provides real-time data that can be used in costing analysis, forecasting, production scheduling, inventory control, and other planning functions. CIM moves inventory management out of the safety stock business and provides the tools needed for inventory level reductions in raw materials and finished goods (Burns & Bryant, 1997).

Expedited delivery services like Federal Express provide the ability to ship completed garments to customers in a matter of days at a comparatively low cost. This gives apparel firms increased flexibility by eliminating the need for finished goods inventories. If a garment style does not sell well it can easily be removed and replaced in the firm's marketing plan. Quick response allows mass customizers to move with fashion trends and provide the consumer what they want anytime. Since an apparel manufacturing firm's inventory carrying costs can equal 15 to 30 percent of inventory value, inventory management and the application of enabling equipment technology can determine a firm's financial success (Mazzioti, 1993). Mass customization effectively eliminates inventory holding costs for finished garments.

Efficient, short-cycle manufacturing required under mass customization often uses automated systems like the UPS and focuses on single garment production runs that require intensive inventory management for materials and finished goods. UPS is an automated transport system that can track, move, and expedite individual garments and customer orders (Glock & Kunz, 1990). Since mass customization generally requires the use of single-ply cutting operations, it needs an inventory management system that can accommodate a wide variety of style, size, and material selections. Flexible, responsive inventory management systems are needed to maintain and pull material from storage; move it through cutting, spreading, and sewing operations; and quick delivery to the customer. WIP inventory levels are virtually eliminated under this system of manufacturing (Burns & Bryant, 1997).

UPS and MPS offer the most promise for mass customization. MPS offers increased quality, a pull-system of production, and pooled worker knowledge to solve manufacturing problems. If managed effectively, it can provide quality, customized garments expeditiously. UPS offers flexibility and fast turnover between garment styles and orders. Individual order tracking under UPS offers real-time data on order status and ensures garments are completed and shipped on-time. Generally, PBS is ineffective in a mass customized environment unless standard component parts can be manufactured and assembled in a customized manner (Glock & Kunz, 1990).

Along with mass customization, apparel production firms have adopted activity based costing (ABC) methods to identify and eliminate non-value added activities in the production process. The three principle cost categories for apparel manufacturing include direct material, direct labor, and overhead costs. Direct material costs include fabric, thread, trim, and findings. Direct labor costs include wages for cutters, sewers, spreaders, finishers, and other employees working directly with the product in the manufacturing plant. Overhead costs include indirect labor, non-variable or fixed, variable, and general operating costs. Fixed costs include such items as rent, insurance, and taxes. These costs do not vary with the level of apparel production. Variable costs that are dependent on production levels include equipment maintenance, marker material, and machine parts. Depending on the compensation system, direct labor costs can be either variable or fixed. Indirect labor costs include wages for maintenance, security, materials handling, and quality control personnel. These personnel are essential to the apparel production process but they do not work directly with products in manufacturing. General operating costs include costs associated with clerical support, engineering, merchandising, accounting, and management functions (Glock & Kunz, 1990).

Costing methods like ABC help identify non-value added activities in the production process and reduce non-essential costs. Non-value added activities can include training, quality control, engineering, automation, equipment, inventory storage, product handling, and other activities that do not directly add value to the finished garments. Costing reports and analyses are used to determine the need for additional activities. Those activities that are not cost effective or increase overhead costs without increasing product quality, productivity, or efficiency are closely managed or eliminated. Manufacturing firms can dramatically increase their profitability by only institutionalizing value-added activities (Glock & Kunz, 1990).

With the application of technological innovations, advanced manufacturing organizations, revised accounting systems, strong focus on responsiveness, quality control issues, and customer focus, it is easy to see how mass customization differs from traditional mass production systems. Mass customizers have the ability to compete on style, fit, and other customizable garment features rather than price alone.

Men's sportswear manufacturing is one segment of the apparel industry where mass customization can be highly effective and fit preference can play a pivotal role. Men's sportswear is designed and sized to fit a majority of men with significant ease and overlapped coverage between sizes. Boswell (1993) reports that common sizing for men's sportswear generally encompasses four size categories; small, medium, large, and extra large. Unfortunately, many consumers are unsatisfied with the compromises in fit that result from this method of sizing or do not fall within common sizing categories (Boswell, 1993). Customized fit is one solution to this problem.

Certainly the unique production requirements of mass customization will guide the development of future apparel ordering models. Manufacturers have several options in sizing garments customized for fit. Some manufacturers may choose to develop special pattern grades and select fixed patterns based on individual measurements and fit preferences. In this process unique pattern development is eliminated for individual customer orders. Other manufacturers may choose to use CAD software programs to develop individual patterns based body measurements. Ease determination in this process may be made based on reported fit preferences and style or pattern requirements. Both of these sizing alternatives have important repercussions for mass customization and may determine the production layout, component assembly, inventory, workgroup organization, and quality control measures for an apparel plant. The level of mass production and custom manufacturing steps included in this new manufacturing organization will be determined by the operational focus of the company and the level of customization selected.

2.2 Sizing Systems

In traditional sizing, specifications for fit are established for each size and style of garment produced. These specifications include "measurements, allowable tolerances, and specific points of measurement" (Glock & Kunz, 1990). Once a garment pattern is developed that meets these specifications, firms attempt to achieve consistency of fit by producing garments that fall within manufacturing tolerances. The ability of firms to achieve these goals is a direct measure of their quality and performance standards. Under mass customization, first-run attainment of garments within close manufacturing tolerances is critical to product acceptance.

There is relatively little standardization in ready-to-wear apparel sizing. US government standards for some body types were established based on data from anthropometric studies conducted in the 1940s (Glock & Kunz, 1990). However, manufacturers have changed their sizing practices to reflect growth and proportion changes in their target customers. These changes are guided by the manufacturer's interpretation of sizing needs rather than accurate data on anthropometric measurements. There can be significant differences in fit and sizing standards employed by different manufacturers. Garment proportions for similar apparel items in the same size can vary considerably. This creates confusion in the purchasing process and requires customers to try on a number of garments from different manufacturers in a variety of sizes before purchasing. This is particularly true for women's clothing for which size designations rarely refer to body measurements. However, even with men's clothing sized for specific body dimensions variations in style and ease result in differences in same-sized clothing.

To further complicate differences in ready-to-wear apparel sizing, many manufacturers use different grading practices in their apparel lines. Cooklin (1990) states that most grading systems change the waist and seat girths by the same amount from size to size. In contrast, crotch depth and rise are not always adjusted to directly reflect proportional changes in other garment dimensions. Changes that are evident in crotch seam lengths are often the result of sizing changes in other portions of the garment (Cooklin, 1990).

Many sizing systems divide men's figure types into short, regular, and tall size categories with the use of a height chart. The height for a men's short figure type is generally 5'3" to 5'7", men's regular figure type is 5'7" to 5'10", and men's tall figure type is 5'10" to 6'3". Other size classifications for men's figure types include men's long, men's slim, men's trim, and men's full cut.

Common garment ease for men (lower torso) is given as 1.27 cm for the hip. The same adjustment is given for the waist and abdomen. Waist to crotch ease for total depth is given as 3.83 cm (Cooklin, 1990). However, waist to crotch ease is dependent on garment type. These ease factors are given for pattern makers to use when sizing test garments on model forms. The author states that movement ease or comfort ease allowances are added to the body measurements to assure fit of the garment. The suggested ease amounts are based on medium weight woven fabric and a basic fitted garment. The author states that more or less ease may be required depending on fabric, garment type, styling, details and construction.

2.3 Garment Fit

The size of ready-to-wear garments is based on century-old techniques that involve proportional sizing from base patterns (Ashdown, 1995). These techniques include the use of fit models to assist in the development of base patterns. After the manufacturer has established a target group for a particular line or style of clothing, patterns are developed. These patterns are used to manufacture sample garments. Fit models assist in refining these patterns to achieve the desired drape and ease. Proportional grading is then used to develop a range of sizes for each garment in the product line. Figure 2.4 provides an example of the special grade used to determine crotch length variations in the base test short used in the study.

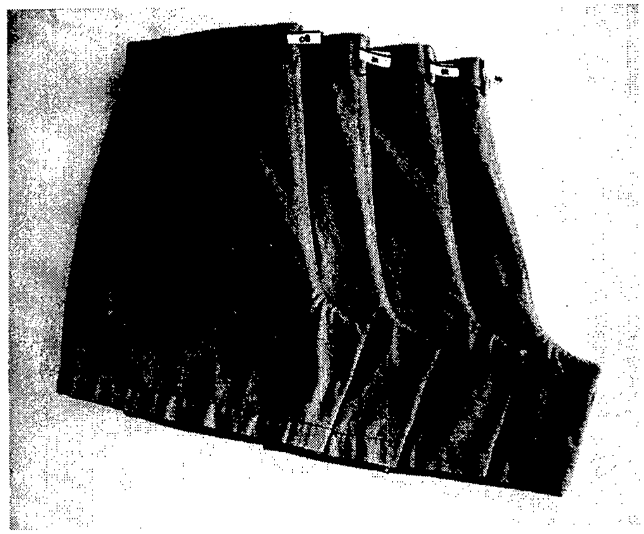


Figure 2.4 Special Grade for Base Test Shorts

Individuals outside the sizing range or grading proportions established for the target group by the manufacturer in are unlikely to purchase these items due to improper fit. These individuals are forced to search for clothing lines that meet their particular body types or obtain customized clothing. As manufacturers attempt to gain competitive advantages by refining target groups and providing improved fit for these individuals, more and more retail customers are left without good fitting clothing in ready-to-wear apparel lines.

Glock and Kunz (1990) define fit as "how a garment conforms to or differs from the body." Certain allowances are made for comfort ease, movement, style factors, fabric type, and garment use. Variation in comfort ease determination and choice of different target market body types are the primary reasons for disparity in sizing for ready-to-wear clothing between different manufacturers. Production decisions made to reduce material costs can impact this determination as well as the manufacturer's interpretation of its target customer requirements. Like comfort ease, styling ease can vary by manufacturer, current fashion trends, and a number of social variables.

Farmer and Gotwals (1982) list these social variables relating to fit as socioeconomic status, age, gender, religion, race and ethnicity, and fashion. Fashionable fit has generally been associated with high social status. Similarly, much of designer-label appeal has been linked to the "status-symbol aspect of fit" (Farmer & Gotwals, 1982). Age-related variables also impact consumer fit requirements. Older consumers focus more on freedom of movement and comfort issues than younger age groups. Teens have been found to focus almost entirely on social acceptability and fashion trends in the fit of apparel products. Many devout religious groups associate fashionable garment fit with worldliness and pleasure-seeking and have established strict guidelines on acceptable garment styles and fit. Race and ethnicity factors can also impact the acceptance of fit standards in clothing (Farmer & Gotwals, 1982). Fashion is probably the most important social factor relating to garment fit. Changes in fashion can result in drastic changes in fit standards.

Isolating and identifying these social variables and incorporating them into ordering methodologies for mass customized apparel products can be an extremely difficult process. The inter-relationships among these variables combined with variation in body measurements and individual fit preferences make optimized fit models difficult to quantify. It becomes clear from initial research that garment style and selection must remain targeted at specific consumer groups. Styling objectives for mass customized clothing must be communicated to the consumer. Apparel ordering models must isolate individual preferences and inform consumers about the characteristics of good fitting clothing within the range of styles offered.

The structural features of garments also play an important role in fit. Farmer and Gotwals (1982) contend that structural seams and darts in clothing determine the overall fit of the garment. Pattern designers must distinguish between the structural and decorative factors of a garment. Farmer and Gotwals (1982) state that "basic patterns rely on structural darts for fit" and suggest that advanced designs can be created by substituting dart equivalents like gathers, tucks, and pleats. These equivalents can have a softer appearance than darts but designers must be careful to maintain the features in their final designs (Farmer & Gotwals, 1982).

Fasteners and fabric variations can also impact the fit characteristics of finished garments. Strechability and stability in base fabrics and linings are important features. Knits and woven fabrics made from a variety of natural and man-made fibers provide different aspects of fit for finished garments. Variable fasteners such as Velcro or the selection of fastening options such as two button choices for a shirt cuff make fit adjustments possible within a sized garment. The style and fashion features of most garments impact the consumer's perception of fit.

2.4 Fit Preference

Fit preference, body measurements and garment characteristics are complex, interrelated variables that affect sizing and satisfaction of fit for consumers (Staples, 1994). These aspects can vary in significance and definition for both consumers and manufacturers. Fit preference involves an individualized bias toward a particular look, size, or feel of a garment in relation to the body (LaBat & DeLong, 1990). There is no established ordering methodology for obtaining consumer fit preference information. Individual variation in the intended and perceived meaning of these preferences make standardized responses difficult to obtain.

Nevertheless, fit perception and fit preference data are needed for the production of custom-fit clothing and improved fit in ready-to-wear sizing. An individual's fit preference involves aesthetic, functional, and tactile responses to clothing. Their perception of garment fit in these response areas may dictate their overall acceptance of an apparel product. Perception can vary greatly between individuals and is extremely difficult to quantify in relation to body proportions, garment characteristics, and functional requirements. An individual's responsiveness to minor variations in garment sizing also varies considerably and can effect ease and sizing factors used by the manufacturer. An individual may prefer a tight fitting garment in a particular style or fabric and a loose fitting garment in another pattern or style.

In the traditional retail setting, individuals are able to try on a variety of different garments in diverse sizes and styles before making their decision to purchase an item. In the mass customization arena, customers are generally unable to try-on garments until the manufacturing process is complete. It is essential that manufacturers communicate garment characteristics with the consumer and establish ordering methodologies that accurately capture fit preference data. It may become necessary to categorize perception of fit levels in order for manufacturers to effectively process clothing orders customized for fit. Individuals highly sensitive to variations in fit may require closer collaboration in the ordering process than individuals who are willing to accept a more standardized size. Ordering methodologies that identify these individuals and automatically adjust ordering processes to accommodate various levels of fit preference and perception of fit have the potential to dramatically improve satisfaction of fit for the apparel consumer.

DeLong, et al. (1993) conducted a series of ease studies to explore the inter-relationship of garment dimensions, ease factors, body measurements, and fit preferences. The overall goal of this study was to find data requirements needed for computerized production of mass customized apparel. The studies used female volunteers ranging in age from 23 to 65. In the first experiment, researchers measured and adjusted two waist-related dimensions, hip or seat circumference, and full crotch length in test subjects and customized pant patterns. A series of muslin pants with a variety of ease factors were presented to test subjects for fit testing. Alterations were made to these patterns based on individual input and final wear tested pants were produced in both a control fabric and a fabric chosen by the test subjects. It required an average of two and a half fit sessions to achieve an acceptable fit for muslin pants. On average, subjects rated control fabric wear tested pants higher in acceptability than pants constructed from subject chosen fabric. This demonstrates that variations in fabric alone can alter satisfaction of fit for consumers even when individual alterations are performed. The requirement to perform multiple alterations on pants physically worn by test subjects in a number of fit sessions indicates the difficulty in achieving satisfactory fit for garments ordered without wearing them.

DeLong, et al. (1993) contends that manufacturers often produce "oversized" garment styles to counteract the problems associated with individualized fit. Certainly, manufacturers must find a balance between the styling and fit features of customized garments. Fabric selection must be carefully managed to ensure that garment fit characteristics do not deteriorate or change when the customer is allowed to make customized fabric choices. In addition, factors relating to the fit characteristics of specific fabric selections must be incorporated into customized pattern development processes. This means ease requirements will vary depending on fabric selection, garment style, individual fit preference, and body proportions. Individual body proportions determined by soft tissue areas can vary periodically. However the range of these variations and fabric characteristics have relatively distinct values that can be quantified. Fit preference and garment style are less tangible values. Accurate communication of these factors is essential in achieving acceptable fit for the consumer.

Additionally, DeLong, et al. (1993) concluded that subjects tend to overestimate desired ease allowances during initial fit sessions. These subjects actually prefer less ease when final wear tested pants were produced. DeLong, et al. (1993) surmise that experience in wearing a garment customized to fit individual body proportions significantly impacts desired fit preferences. Rather than drafting custom patterns based on individual body proportions, fit preferences, garment style, ease factors, and fabric selection, I contend that base patterns can be graded in multiple dimensions greatly expanding the one-dimensional standard grading procedures. In effect, this creates a matrix of available patterns that consumers can be assigned based on the sizing factors previously mentioned. Fit preference and fabric selection variables would be assigned weighted factors and combined with body proportions to determine appropriate garment size. Research in this area can also help to determine adjustments needed to arrive at desired fit based on fit preference responses. This information can be used for custom pattern development as well as assigning established sizes from a matrix of available patterns.

In Ashdown's 1995 study on perception of fit, waist variations as small as ± 0.5 cm were consistently detected by test subjects as well as hip and crotch variations as small as ± 1.5 cm. Logically, the minimum increments for pattern sizing variations should be aligned with the smallest difference in garment dimensions that can be consistently perceived. This implies that waist variations as small as 0.5 cm and crotch variations as small as 1.5 cm should be included in the matrix of available patterns. However, variations in perception of fit can also occur when garment dimensions are changed at other areas of the body. For example, a shorter crotch length can give the wearer the perception that the waistband is tighter as well. This convulsion of sensory perceptions can be used to the advantage of the manufacturer in many cases. By changing one dimension of the garment, manufacturers can achieve an acceptable fit when multiple changes are identified by consumer responses. A tighter crotch in effect can meet a subject's requirement for a tighter waist. Manufacturers may not have to vary all garment dimensions in accordance with the smallest perceptible variations by consumers.

As a representative sample of men's sportswear, casual shorts provide an excellent test garment for fit preference and self-measurement reliability and validity. The relationship between crotch length and waist measurements can be measured in relative isolation from other body dimensions. As in the case of the DeLong, et al. (1993) variations in seat dimensions may also impact satisfaction of fit for consumers. In addition, thigh measurements for male test subjects may impact perception of fit and satisfaction. This can be especially true for test subjects with extreme values in seat and thigh dimensions. Nevertheless, the majority of fit preference adjustments can be made by varying only crotch and waist measurements according to a pre-determined set of grading rules (Ashdown & DeLong, 1995).

2.5 Measurement Techniques

As a sub-discipline of anthropology, anthropometry involves the systematic measurement of the human body (Gordon, et al., 1988). Anthropometric studies are used to gather information on population body sizes and range of variation. The basic tools used by researchers to take anthropometric measurements include calipers, anthropometers, measuring tapes, and other customized devices. In the 1988 US Army anthropometric survey conducted by the Natick Research Center 132 directly measured dimensions were used to help ensure that Army clothing, equipment, and systems accommodated soldiers (Gordon, et al., 1988).

Anthropometers are used to take linear dimensions and serve as the basic tools for anthropometric measurements. Various landmarks are used to ensure consistency and accuracy in measurements and establish anchor points for measuring devices. Landmarks can be drawn on the body or found from easily-identifiable features such as the omphalion or the acronium. Anthropometric measurements are not designed to reflect traditional tailoring requirements or aid in the construction of garment patterns.

There are currently three main methods for determining body measurements for apparel applications. The first method employs experts that use a variety of measurement apparatus. These measurements are generally taken at retail establishments for alterations or customized manufacturing. The second method involves whole-body laser or optical scanning that downloads three-dimensional images of subjects into computer-based plotting systems (Staples, 1994). Identifiable landmarks are then used to extract precise body measurements from the three-dimensional image. This method is expected to eventually provide measurements for mass customization and its development has been largely responsible for increased emphasis on this emerging production technique. Self-measurement is the final method. Customers use varying techniques to determine body measurements (Roberts, et al., 1997). Self-measurement has been commonly used by the catalog industry for many years. Sizing data obtained from self-measurements are generally used to identify the appropriate size for an individual from a range of established sizes.

The precision and validity of each measurement method has had significant drawbacks in terms of customized apparel ordering. Body scanning is expensive and currently has limited availability (Staples, 1994). Along with expert measurement, both procedures require visits to retail establishments. Expert measurement provided by trained retail associates can offer a relatively low cost and reasonable accuracy but precision and measurement methodology can vary significantly among personnel and retail establishments. I believe self-measurement is a viable option for mass customized apparel ordering. Self-measurement is convenient, fast, and non-intrusive. It allows customers to take discreet measurements in privacy. However, manufacturers must determine consumer tendencies underestimate body measurements and perform common measuring errors (Roberts, et al., 1997). Manufacturers must manage these shortcomings in self-measurement and combine this information with reported fit preference and garment fit characteristics to improve overall customer satisfaction of fit and improved size selection.

2.6 Apparel Ordering

Customization will not work if manufacturers are unable to obtain or interpret accurate information on order requirements, individual measurements, and fit preference (Ashdown & DeLong, 1995). The critical link in the ordering process becomes the collaboration between the customer and the manufacturer. Clear, interactive communication and ordering formats that exploit available technologies must be established in order to make this process successful. Internet connections can provide such an interaction and allow manufacturers to obtain digital information from the customer ready for input into the production process (Schonfeld, 1998).

The mail-order catalog industry generally uses telephone or mail-order forms as the preferred method of communications (Chidambaram, 1997). This technique does not provide accurate, timely, and/or detailed information for the customization process. Today, consumers can place self-guided orders directly over the internet and can include a variety of detailed information on styling and fit preference (Emert, 1996). Current ordering systems solicit size designation and/or body measurements from the customer that are obtained from a variety of sources. These systems seldom provide information on fit preference for customers. The development of an ordering model that defines requirements, standardizes measurements, and conveys fit preference will provide a better communication tool to provide customers with their desired clothing.

G. B. Latamore presents four rules of electronic commerce for the apparel industry in his 1996 Bobbin article, "Electronic commerce: Window of opportunity." He stresses the marketing aspects of Internet retailing rather than the technical aspects. He believes that good marketing is the first rule of electronic commerce for apparel firms. The second rule he stresses is the fact that relatively unknown companies can come and build a strong presence on the Internet. His third rule is that companies must maintain a focus on quality and customer service. Finally, the fourth rule states that apparel retailers must update constantly (Latamore, 1996). Both the third and fourth rules can be addressed through mass customization initiatives. The development of effective methods of fitting the consumer addresses the focus on quality and customer service and the customizable, constantly changing product line helps meet the timeliness requirement.

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 Overview

In order to meet the proposed research objectives, this study was designed to examine apparel ordering, self-measurement, and fit preference. The response results from test subjects along with expert measurement were utilized in an attempt to predict optimum garment size. Initially, a review of waist and crotch length measurements from an anthropometric database of 1,774 US Army men was conducted (Gordon, et al. 1989). The results of this examination were used to establish base sizing for test shorts and provide control data for use in data analysis. Crotch length and waist circumference were the only two pattern dimensions directly varied in the study.

Test shorts were manufactured by Hagale Industries. Hagale is a mid-sized men's apparel manufacturer located in Ozark, Missouri. Army anthropometric survey (ANSUR) data was compared with crotch and waist dimensions from a base short pattern with limited style features provided by Hagale Industries. The intent of this comparison was to determine adjustments needed to align crotch and waist ranges in base short sizes with mean data from the Army ANSUR. In theory, this alignment would provide a better fit for test subjects and allow pattern grading above and below the mean crotch lengths for each waist size.

Testing procedures were established and pilot tested to substantiate self-measurement procedures, test short grading, and fit preference formats. Procedures were divided into four phases: apparel ordering and self-measurement, expert measurement, fit testing, and questionnaire response. A mock Internet website was constructed to guide subjects through self-measurement and fit preference reporting procedures and provide additional information on test shorts. Fit preference questions were also added to the website along with an electronic order form.

Test shorts were designed to provide a range of perceptible choices in fit generated by incremental variations in crotch and waist dimensions. Limited funding was available to manufacture these shorts so it was important to find the optimum range and increment values for short sizing. In preliminary analysis, the base crotch length for each waist size in the graded nest was aligned with the mean crotch length for the appropriate waist size group of subjects from the Army ANSUR. Expert measurement procedures also from the Army ANSUR were pilot tested and refined for use in the second phase of research testing (see Appendix F, p 219).

Fit testing procedures were established to ensure that test subjects focused on fit rather than the style and fashion characteristics of the test shorts. A final survey questionnaire was developed to obtain demographic data, background purchasing information, and satisfaction of fit for final test short selections. Test subjects were asked to perform a series of body movements while wearing each pair of shorts to position them on the body and allow a more thorough evaluation of their fit characteristics.

Prior to each fit session, a spreadsheet based size prediction model was used to evaluate website generated data provided by the test subjects on body measurements and fit preferences. This size prediction model calculates appropriate short sizes from body measurements using tabulated sizing charts. The initial predictions include short sizes generated from self-measurement and self-measurement plus fit preference data. The size prediction model was also used to determine a third short size based on expert measurement data that was obtained during the fit sessions. The pilot test was conducted to validate testing procedures and to adjust the size prediction model in June 1999. Primary testing was conducted between 11 and 15 October 1999. A total of 35 test subjects completed the study. In final data analysis, results for self and expert measurements were compared to determine if the addition of fit preference responses increased the likelihood of selecting the best fitting size. The size prediction model was also optimized based on response data from the fit test sessions.

3.2 Major Assumptions

In order to develop initial size charts for test short predictions, a number of assumptions were made about the application of ANSUR data. In general, anthropometric measurements based on physiological landmarks do not align with measurements used in apparel design and production. For example, waist circumference taken at the omphalion or the natural indentation may not be the same as a waist measurement taken at the preferred waistline. Waist circumference (omphalion) measures the horizontal distance around a subject at a level centered on the navel (Gordon, et al. 1988). Waist circumference (natural indentation) measures the horizontal distance around a subject at a level of the greatest indentation on the right side (Gordon, et al. 1988) This measurement is taken regardless of where the indentation on the left side may actually be. Waist circumference (preferred) measures the distance around a subject at a level corresponding to the subject's preferred waist height for pants or shorts.

In order to overcome the limitations of using anthropometric measurements for apparel sizing, it was assumed that waist measurements taken at the omphalion and the preferred waist would be highly correlated. This assumption allowed the alignment of mean waist circumference (omphalion) taken from the ANSUR study with the 33 inch short size in

Hagale's base pattern. Waist sizes from the ANSUR study were aligned with base pattern sizes in order to determine the corresponding crotch length ranges for test shorts in each waist size range. Supporting data for decisions made in developing test shorts included a review of pattern specifications for Hagale shorts, waist requirements from a sample of catalog sizing charts, and the common ease factors used for waist and crotch dimensions in men's shorts from a grading system developed by Cooklin (1992).

Once the mean waist circumference (omphalion) from the ANSUR study was aligned with Hagale's base pattern, it was assumed that changes in mean crotch length for half-inch ranges in waist circumference at the omphalion would be the same as changes for waist ranges taken at the preferred waistline. It was also assumed that the range of appropriate crotch lengths and corresponding waist circumferences, regardless of the landmark location, have similar relationships. This meant that changes in the mean and standard deviation of crotch lengths for a specified waist range, whether taken at the omphalion or the preferred waistline, were comparatively equal.

These assumptions were only used to determine crotch length ranges for test shorts. No waist size adjustments were made based on these assumptions. In general, anthropometric data were useful in stratifying crotch and waist size ranges for manufactured test shorts. As a result of these assumptions crotch lengths for each waist size were shifted to more accurately reflect the mean crotch lengths for subjects in the ANSUR study.

Since fit preference and satisfaction of fit are extremely subjective measures that are difficult to communicate and quantify, limitations exist concerning other factors that can influence final test short selection. The first limitation is that individuals can be potentially influenced by past experience with clothing fit and may develop a bias toward poor fit. Since few consumers have made-to-measure clothing custom manufactured to meet their body proportions and fit preferences, a bias towards the fit of standardized, mass produced garments may be present in test responses. Mass produced garments offer only limited size selections designed to cover a wide range of body types. This may result in a poor fit for most consumers and a tendency by test participants to select test shorts that fit more like mass produced shorts than made-to-measure clothing.

The second limitation is that overall acceptance of apparel items may be linked to fashion and styling considerations. Evaluations for satisfaction of fit may be adversely impacted by the specific styling features of test shorts. In addition, current fashion trends may differ significantly from test short design and result in difficulty obtaining accurate satisfaction of fit selections. It is unclear whether final test short selection based on fit criteria alone will change if style and fashion features in test shorts were changed. Along with styling and fashion, fabric selection and tensile characteristics may play an important role in determining overall satisfaction of fit for test shorts.

The third and final limitation is that kinesthetic after effects from consecutive fit appraisals can adversely impact test results and final test short selection. Kinesthetic after effects result from the sensory imprint of fit characteristics from previously fitted shorts. These after effects can significantly impact the perception of fit for a new pair of test shorts. With kinesthetic after effects, test subjects may lose their ability to discern minor sizing variations after performing only a few fit appraisals.

3.3 Preliminary Analysis

In preliminary analysis mail-order catalog sizing information and measurement instructions were analyzed to find procedural commonalties and common sizing charts currently used by the apparel industry. Data from a 1988 ANSUR study was analyzed to determine crotch length ranges for individual waist sizes (Gordon, et al. 1989). Final size range determination involved the statistical analysis of catalog and ANSUR study data. This analysis was essential in the sizing of the base pattern and subsequent crotch length variations. Crotch and waist measurements provided by mail-order and Internet sizing charts helped verify the accuracy of anthropometric data analysis and related assumptions concerning the similarities between waist and crotch measurements taken at different landmarks.

3.3.1 Mail-Order Catalog Sizing

A total of 25 mail-order apparel catalogs were reviewed to assist in determining common sizing, waist groupings, and measurement procedures. By comparing waist size requirements for common sizing, predicted measurement ranges for waist circumferences could be determined for test shorts when used in conjunction with ease factors. The apparel catalogs sampled represented a wide cross section of men's apparel products.

Of the 25 retailers 15 provided measurement instructions and 17 had sizing charts in their catalogs (see Appendix A, pp 156-159). However, only 12 catalogs had sizing charts for waist measurements. Two catalogs published by Land's End and Eddie Bauer had sizing and measurement information related to crotch length. The average waist size ranges for common sizing are given as the modes in Appendix A, p 160. On average 74.6% of retailers had waist size ranges at these levels.

Catalog retailer measurement instructions varied from an in-depth instruction booklet from Land's End to simple height measuring instructions used to determine regular or tall sizing categories by Deerskin. Three manufacturers included information on shrinkage concerns. Of these three, J. Crew instructs customers not to order larger sizes since items are cut and sized to allow for shrinkage factors. Land's End mirrors J. Crew's approach to shrinkage concerns while Patagonia lists approximate shrinkage percentages. Patagonia states that their clothing does most of its shrinkage in length and instructs customers to use their shrinkage estimates to determine how much length-loss will occur. Patagonia reports that they test all of our clothing for shrinkage before they manufacture in quantity and that they will note any items for which they expect 6% shrinkage or more. In this case, Patagonia builds in an allowance for shrinkage, and states this allowance in their catalog.

Performance Bicycle only noted that cycling apparel can fit differently than normal clothing and did not provide additional measurement instructions. Some shirt retailers like the DeSantis Collection ask for sleeve and collar measurements on their order forms but do not provide measurement instructions or sizing charts. Of the 25 catalogs surveyed, J. Crew, Land's End, Patagonia, and L. L. Bean provided the most comprehensive measurement and sizing information. However, unnecessarily detailed measurement instructions can detract from the effectiveness of ordering models. Compromises must be made in the complexity and number of measurements required by a manufacturer in order for consumers to successfully complete the apparel ordering process.

Most manufacturers require customers to take waist measurements against the body rather than over clothing. A few companies instruct customers to measure over old clothing that fits well. There are advantages and disadvantages to both systems. In the case of pants and shorts, accurate measurements can be obtained if customers take measurements in clothing that is similar to the item they intend to purchase. This allows the customer to incorporate preferred ease and waist measurements in their order. When measuring over the body, the majority of manufacturers instruct customers to insert one finger between the tape and the body to ensure that the tape measure is not pulled too tightly. Customers are generally instructed to take waist measurements at the height they normally wear pants. Difficulties can arise using these measurement procedures due to uncertainty in determining accurate waist height. In addition, waist height can vary considerably depending on garment type and related fit characteristics. These variations may lead to inaccurate measurements and poorly fitting garments.

All manufacturers surveyed with inseam measurement instructions asked customers to take measurements directly from a good fitting pair of pants. These inseam measurements are generally taken while the garments are laid on a flat surface. However, several retailers instruct customers to measure good fitting pants or trousers while they are worn on the body.

Consistency in measurement instructions and sizing charts for men's apparel catalogs has important ramifications for e-commerce and Internet ordering formats. Initial formats for these newer applications should ensure that common procedures used in mail-order purchasing are initially maintained. Enhancements should be added later to take advantage of the technological advances and interactive communication offered by these mediums. However, the basic ordering models should be validated before any significant enhancements are applied.

Along with mail-order catalog instructions, several websites from leading Internet retailers and sizing information from industry experts were reviewed to determine measurement instructions and sizing information. Internet retailers included J. Crew, Lands End, and Interactive Custom Clothes Company Designs (IC3D). Measurement instructions from the IC3D website served as the model for self-measurement instructions in the mock research website. Modifications to these instructions were made based on the results of the mail-order catalog review and testing requirements. Since IC3D creates unique patterns for every customer no sizing charts were available from their website.

Sizing charts and ease factors given by Gerry Cooklin, an apparel industry expert, were used to aid in determining body measurement requirements for test short sizes and to validate sizing charts used in the size prediction model (Cooklin, 1992). Suggested values for ranges and ease factors in waist, hip, and crotch requirements for all figure types were averaged along with common ranges for men's regular casual slacks and compared with US Army anthropometric survey findings (see Appendix A, pp 160-161). Cooklin's sizing charts were critical in initially determining which measured waist circumferences and related crotch lengths were appropriate for specific short sizes. Since Cooklin used crotch depth instead of crotch length, a comparison of the percentage change in measurement requirements between sizes was used to validate crotch requirements in the prediction model (see Appendix A, p 161).

The mean waist measurements for Cooklin's sizing chart averaged 0.4 inches different from the values obtained from the Army study. However, limitations in waist size ranges from Cooklin may have shifted these values. For example, no waist, hip, or crotch measurement requirements were given for men's long and regular sizes for a 34-inch waist size. Other measurement requirements were also omitted for other body types and waist sizes. Overall, Cooklin's body measurement ranges closely matched the waist ranges found in the Army study.

3.3.2 US Army ANSUR Data

The 1988 Anthropometric Survey of US Army Personnel was used to establish initial size ranges for waist and crotch length dimensions in test shorts (Gordon, et al., 1989). The total Army study included anthropometric measurements for 8,997 test subjects covering some 298 dimensions. From the complete database, a working database of 1,774 male test subjects and 2,208 female test subjects was extracted. For purposes of this research study, only information on the male test subjects was used. Of the total 298 dimensions in the Army study, 42 were directly related to lower body dimensions and included in my initial statistical evaluation. Of these 42 dimensions many were not directly applicable to men's short sizing and were eliminated. Through regression analysis a final grouping of six dimensions were found to be statistically significant.

The primary measurements used to determine sizing increments for test shorts were crotch length and waist circumference taken at the omphalion. Other test measures evaluated included buttock circumference, thigh circumference, weight, and height. Detailed instructions and diagrams for taking these measurements are listed in Appendix F, pp 220-227. Results for test subjects 30 years of age and under were extracted from the working database and analyzed separately to reflect demographic considerations projected in the Cornell research sample resulting in 1234 subjects. For all male subjects in the Army study, the mean and standard deviations for each of the six measurement variables were generally greater than the values for the subjects who were 30 and under. The only exceptions were the mean for height and the standard deviation for thigh circumference (see Appendix B, pp 163-166). A decision was made to use the 30 and under data for the development of size ranges.

Correlation and regression data were analyzed for both the 30 and under sample and the all male sample from the Army study (see Appendix B, pp 163-166). For both samples, buttocks circumference had the highest correlation with other measurements and the height measurement had the lowest correlation with every other measurement. This indicates that height may not be as good a predictor of test short size than the other variables. In regression analysis with waist circumference as the dependent variable, all measurement were shown to be statistically significant and an R-squared value of 80.9% was obtained for the 30 and under sample.

Variations in crotch and waist dimensions can significantly alter the feel of a garment on the body. The interaction these dimensions can change the subject's perception about satisfaction of fit. A longer crotch length may shift the position of shorts and alter the feel of the waist. Conversely, a larger waist may allow subjects to wear shorts lower on the body giving the perception of a longer crotch length. For these reasons a wide range of crotch lengths was needed to accurately assess fit preference responses and optimum test short selection. By providing a range of crotch lengths for each waist size, subjects could achieve greater precision in identifying optimum test short selections. It is important to note that crotch length and waist circumference are not highly correlated. In a review of the ANSUR data, the correlation of only 0.246 was found for waist circumference (omphalion) and crotch length (see Figure 3.1). From the scatterplot of waist versus crotch for all male subjects in the Army study a very weak linear relationship was found.

Pearson Product-Moment Correlation		
	WAIST	CROTCH
WAIST	1.000	
CROTCH	0.246	1.000

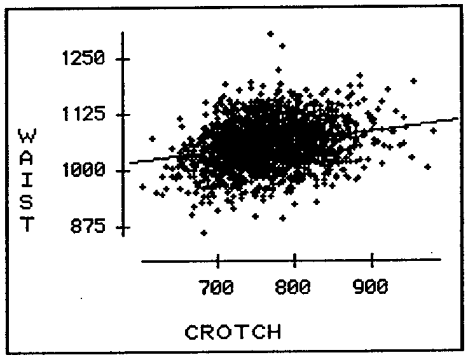


Figure 3.1 Correlation of Waist and Crotch Dimensions

The same test measures used with the 30 and under sample were used to analyze the entire male sample from the Army study. There was a total of 1774 males in the study of which 1234 were 30 years old and under (see Appendix B, pp 163-166). The higher mean and standard deviation values for the majority of test measures in the all male sample are indicative of age related growth patterns in lower body dimensions for older males. The shorter values for height are consistent with generational growth patterns seen in the US population.

Correlation and regression data for the entire male sample revealed that waist, buttocks, thigh, crotch, and weight measurements had high correlation. Height measurements did not have high correlation with other measurement factors. This indicates that height was also not a good predictor of short size for the entire male sample. However, the other five measurements could be used to build a self-verifying model to determine short sizing for any age. In regression analysis with waist circumference as the dependent variable, all measurement were shown to be statistically significant and an R-squared value of 82.3% was obtained for the entire male sample (see Appendix B, p 166).

3.3.3 Size Ranges

Mean crotch length and waist circumference data for the 30 and under sample were used to build crotch length grade rules for test short pattern adjustments. These values were found in order to determine a range of waist sizes needed to fit the middle two-thirds (66.7%) of test subjects. This equated to a range of waist sizes one standard deviation above and below the sample mean. The mean waist circumference for the 30 and under sample was 33.2 inches with a standard deviation of 3.1 inches. This resulted in a waist range of 30.1 inches to 36.3 inches. Table 3.1 lists the mean, standard deviation and applicable ranges for waist circumference in both centimeters and inches.

Table 3.1 Waist Circumference (Omphalion) 30 and Under Sample

	MEAN	SD	(-1SD)	(+1SD)	RANGE
CM	84.4	8.0	76.5	92.4	15.9
IN	33.2	3.1	30.1	36.4	6.3

SD - Standard Deviation
CM - Centimeters
IN - Inches

A range from 76.5 cm to 92.4 cm was established which equates to 30.1 inches for the smallest waist circumference and 36.4 inches for the largest waist circumference. This range was then divided by a series of values that varied from 6 to 12 to establish final waist sizes for manufactured test shorts. The goal was to align waist sizes in half-inch increments. Half-inch increments were chosen based on prior research on perception of fit (Ashdown & DeLong, 1995). A ten size solution provided the best fit for this purpose. Table 3.2 lists the ten size solution, corresponding half-inch waist sizes, and size ranges for test shorts in both centimeters and inches. Once these waist size groupings were made it was possible to determine the relative change in mean crotch lengths versus waist circumferences. Since waist size ranges were based on measurements taken at the omphalion rather than the preferred waist, changes between the mean, range, and standard deviation were averaged to adjust grade rules and shift the base pattern size (see Appendix B, p 179).

Table 3.2 Ten Size Solution and Waist Size Ranges

TEN SIZES		1/2" WAIST SIZES			SIZE RANGES	
CM	IN	CM	IN	SIZE	CM	IN
76.5	30.1	76.5	30.1	30.5	76.5 - 78.0	30.5 - 31.0
78.1	30.7	78.1	30.7	31.0	78.1 - 79.6	31.0 - 31.5
79.7	31.4	79.7	31.4	31.5	79.7 - 81.2	31.5 - 32.0
81.3	32.0	81.3	32.0	32.0	81.3 - 82.8	32.0 - 32.5
82.9	32.6	82.9	32.6	32.5	82.9 - 84.3	32.5 - 33.0
84.4	33.2	84.4	33.2	33.0	84.4 - 85.9	33.0 - 33.5
86.0	33.9	86.0	33.9	33.5	86.0 - 87.5	33.5 - 34.0
87.6	34.5	87.6	34.5	34.0	87.6 - 89.1	34.0 - 34.5
89.2	35.1	89.2	35.1	34.5	89.2 - 90.7	34.5 - 35.0
90.8	35.8	90.8	35.8	35.0	90.8 - 92.3	35.0 - 35.5

3.4 <u>Test Shorts</u>

A men's short pattern from Hagale Industries was used as the base for crotch and waist adjustments in the development and manufacture of test shorts. All test shorts were made close fitting in style with a neutral color and stable fabric to focus subject responses on fit and fit preference rather than style or fabric variables (Ashdown & DeLong, 1995). The Hagale pattern arrived in a Gerber pattern making format and was converted to the Lectra software system. Several peculiarities arose with Lectra as a result of this conversion. A row of numeric sizing titles was duplicated for each pattern piece and several global commands would not function initially. These problems were easily overcome with no adverse effects on the pattern. After detailed analysis of the base pattern and applied grading rules, a comparison with the anthropometric data from the Army study was used to adjust the pattern grade rules in order to generate a set of appropriate test shorts. The primary comparison was made between the change in mean crotch lengths for each waist size grouping and the crotch seam measurements for each graded waist size in the base pattern. This would then establish the base size for the crotch grade that was added to each of the waist sizes so that an appropriate range of crotch lengths could be generated for each waist size.

The size 33 waist short was chosen as the base size for grading adjustments. All mathematical calculations were derived using the values from this size as the base. A size slider command in Lectra was used to shift from the original base size of 34 to size 33. Once this task was completed, crotch seam length was adjusted for all waist sizes. In order to adjust the crotch lengths for both the front and back pattern pieces both waist and inseam endpoints for each crotch seam were adjusted with grading rule changes. The crotch endpoint was shifted in the y-direction only, in order to maintain pattern integrity and adjoining seam requirements. The waist endpoint of the crotch seam was adjusted in both the x and y-directions. On the back pattern piece, a uniform adjustment of 3.35 mm in the y-direction for both endpoints was used (see Figure 3.2). A uniform adjustment of -3.35 mm in the x-direction for the waist endpoint was also used. This particular grading adjustment was found by incrementally changing the grading value until the desired seam lengths were reached.

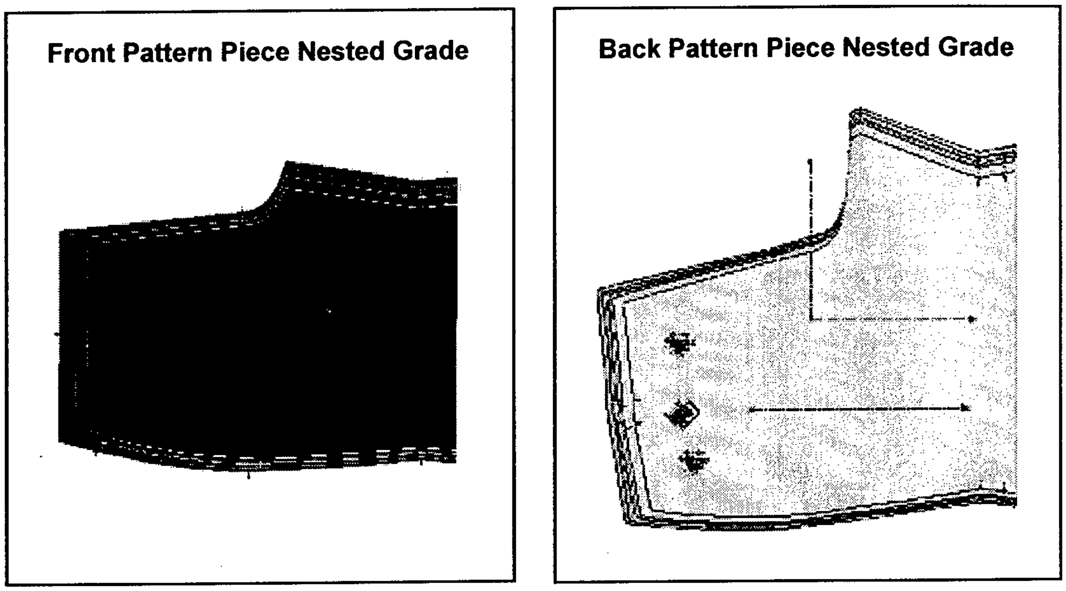


Figure 3.2 Nested Grade for Front and Back Pattern Pieces

The Lectra software system allows an overlay of special grading rules to be applied that modify the base pattern and provide an additional dimension of pattern change. This type of grading is not available in most industrial pattern making programs and therefore not all programs can read patterns that have had special grading rules applied. As these patterns would eventually be converted back to the Gerber system that does not support special grading, the special grading rules were added to the pattern and point-by-point shifts were recorded for manual entry in a separate process. Since only the base size 33 pattern had to be adjusted on a point-by-point basis, this procedure was relatively simple to complete.

Values were incrementally tested using the special grading function to shift the base pattern crotch seam lengths to reflect the minus one, plus one, and plus two standard deviation values determined from the ANSUR data analysis (see Appendix B, p 180). This was a trial and error process that resulted in a final uniform value being added or subtracted to grading points to obtain the pre-determined seam lengths. The Lectra system proportionally grades the remaining points along the crotch seam.

After obtaining crotch length mean and standard deviation values for the ten assigned waist size ranges from the Army study, I determined the change in centimeters between means and the average change in means (see Appendix B, p 179). I concluded that there was an average change in crotch length of 0.91 cm between waist sizes. Mean crotch length and waist size ranges appear to have a positive linear relationship. However, the same relationship was not found for crotch length and waist size measurements for individual subjects. The average number of test subjects per grouping by half-inch waist increments was 90. With one exception, mean crotch length at the omphalion increased for every waist size range change. The only exception was between the 32.5 and 33.0 inch waist size ranges. The mean crotch length for the entire 30 and under sample was 76.71 cm. From the crotch length analysis for each waist size, a mean of 76.19 cm resulted for the new base size of 33 inches (see Appendix B, p 179).

The change in crotch lengths for Hagale's original pattern averaged only 3.1 mm. From Hagale's graded short pattern, I determined the change in front, back, and total seam measurements for crotch length between waist sizes (see Table 3.3). Half inch waist sizes were added to the original pattern which was initially graded in 1" waist increments before conducting this analysis. Half size shorts were evenly spaced in terms of grade rules between adjacent whole inch sizes. There is an average of only 0.31 cm total change in crotch length between waist sizes of the original graded shorts including half sizes. This change appears to be equally split between the front and back seam measurements for crotch length. I determined that an additional adjustment of 0.59 cm was needed from the base pattern to more accurately reflect crotch length measurements from the Army study for the base crotch length shift.

Table 3.3 Pattern Crotch Length Adjustments in Centimeters

Waist Size	Army Mean	Change	Pattern Front	Change	Pattern Back	Change	Pattern Total	Change	Adjust
30.5	71.56	1.74	27.67	0.16	40.89	0.15	68.56	0.31	0.59
31.0	73.30	0.75	27.83	0.16	41.04	0.16	68.87	0.32	0.59
31.5	74.05	0.49	27.99	0.16	41.20	0.15	69.19	0.31	0.59
32.0	74.54	1.12	28.15	0.15	41.35	0.15	69.50	0.30	0.59
32.5	75.66	0.53	28.30	0.15	41.50	0.15	69.80	0.30	0.59
33.0	76.19	0.47	28.45	0.16	41.65	0.16	70.10	0.32	0.59
33.5	76.66	1.36	28.61	0.16	41.81	0.16	70.42	0.32	0.59
34.0	78.02	0.45	28.77	0.16	41.97	0.15	70.74	0.31	0.59
34.5	78.47	1.25	28.93	0.16	42.12	0.16	71.05	0.32	0.59
35.0	79.72		29.09		42.28		71.37		

Sum	8.16
Avg	0.91

Sum	2.81
Avg	0.31

A total of 0.91 cm was added to the crotch length measurement interval for each waist size. This adjustment was divided equally between the front and rear crotch seams to maintain the same relationships between the front and rear sections. The range of crotch lengths for waist sizes 30.5 inches to 35 inches increased 5.35 cm from 2.81 cm to 8.16 cm. This increase in range and the related crotch length for each waist size is directly correlated with the average crotch length for the waist size ranges I extracted from the Army study. The crotch length for the 30.5 inch waist size had the greatest change from the original pattern, losing 2.99 cm from 68.56 cm in the original pattern to 65.57 cm in the adjusted pattern (see Table 3.4). Similarly, the crotch length for the 35 inch waist increased 2.36 cm from 71.37 cm to 73.73 cm.

Table 3.4 Pattern Crotch Length Changes in Centimeters

Waist Size	New Front	Change	New Back	Change	New Total	Old Total	Pattern Change
30.5	26.18	0.45	39.38	0.45	65.57	68.56	-2.99
31.0	26.64	0.45	39.84	0.45	66.47	68.87	-2.40
31.5	27.09	0.45	40.29	0.45	67.38	69.19	-1.81
32.0	27.54	0.45	40.74	0.45	68.29	69.50	-1.21
32.5	28.00	0.45	41.20	0.45	69.19	69.80	-0.61
33.0	[redacted]						
33.5	28.90	0.45	42.10	0.45	71.01	70.42	0.59
34.0	29.36	0.45	42.56	0.45	71.91	70.74	1.17
34.5	29.81	0.45	43.01	0.45	72.82	71.05	1.77
35.0	30.26		43.46		73.73	71.37	2.36

In effect a positive baseline shift in crotch length was accomplished to mirror the mean crotch length sizes for each waist range in the Army study. The average crotch length for the original base garments was 69.96 cm. This value decreased slightly to 69.65 cm for the adjusted pattern with the majority of changes occurring in the smallest and largest waist sizes. An analysis of standard deviations for subjects in the waist size ranges extracted from the Army study revealed that 3.07 cm was the average standard deviation for the stratified samples. This average was used to calculate the special grade to provide a range of crotch length measurements for each waist size two standard deviations above and below the base crotch length measurement (see Appendix A, pp 179-180). This gives a total range in crotch length for each waist size of 12.28 cm and a total of 50 shorts.

After considering the restrictions in the number of test shorts that could be manufactured due to budget restrictions, it was decided that a slight change in the number of waist sizes and crotch lengths was needed. A total of six shorts made from the original pattern grade were delivered by Hagale for use during the pilot test. In order to allow for this number of shorts in the pilot test, 6 shorts had to be eliminated from the number produced with the adjusted pattern. Since only 13.5% of subjects in the Army study would potentially require shorts –2 standard deviations below the mean crotch length for a given waist size and these subjects could still fit in shorts with larger crotch lengths, shorts with –2 standard deviations in crotch for all waist sizes were eliminated. This reduced the total number of test shorts for the adjusted pattern to 40. It was determined that the budget would allow for the production of 44 shorts. Consequently, a new 30 inch waist size with 4 crotch length variations was added to bring the total number test shorts to 44. Table 3.5 lists the final crotch length values for each waist size in the graded pattern.

Table 3.5 Final Pattern Crotch Length Sizes in Centimeters

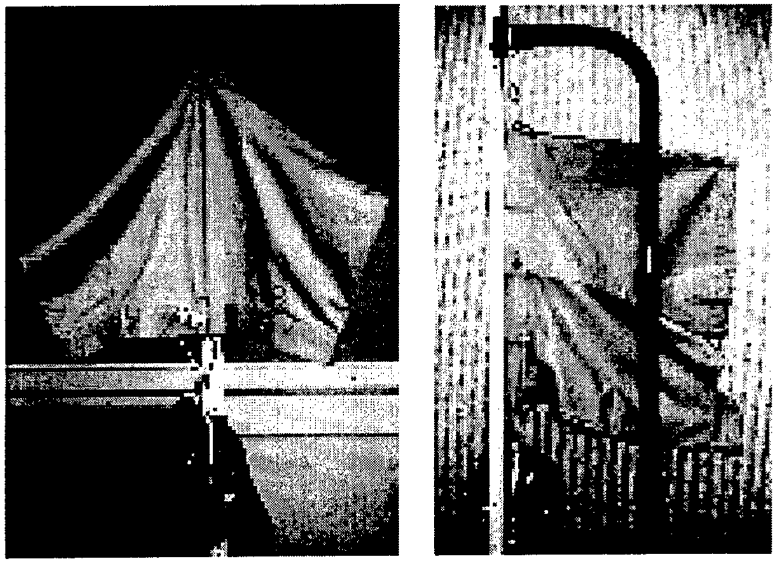
Sz	- 1Sd	Base	+ 1Sd	+ 2Sd
30.0	61.59	64.66	67.73	70.80
30.5	62.50	65.57	68.64	71.71
31.0	63.40	66.47	69.54	72.62
31.5	64.31	67.38	70.45	73.52
32.0	65.22	68.29	71.36	74.43
32.5	66.12	69.19	72.26	75.34
33.0	[redacted]			
33.5	67.94	71.01	74.08	77.15
34.0	68.84	71.91	74.98	78.06
34.5	69.75	72.82	75.89	78.96
35.0	70.66	73.73	76.80	79.87

The grade for base shorts in each waist size was revised essentially to reflect the mean crotch length for 30 year-olds and under in the Army study. The shift from the manufacturer's grading indicates that the apparel industry may add more crotch length to the smaller waist sizes and less crotch length to the larger waist sizes than is desirable based on anthropometric analysis.

Several factors can influence industry grading rules including target market, aesthetics, fashion, pattern styling features, and limited knowledge of anthropometric findings for population averages. Great pains are taken to fit the 34 inch waist size base short to an appropriate fit model in the pattern development process. Proportionally based grading rules are then applied in accordance with historical findings or experience.

After several failed attempts to reconvert Lectra pattern files back to Gerber files, hard-copy pattern markers had to be printed and sent to Hagale with grading rules and point coordinates annotated. These paper markers were digitized by Hagale and entered into the Gerber system. The rear pockets were removed from the short pattern to decrease the manufacturing cost that totaled $14.00 per short. A total of 44 unique shorts were manufactured at cost by Hagale for testing purposes. The completed shorts arrived within three weeks of sending the pattern markers to Hagale. The shorts were manufactured in a base cotton twill fabric with a neutral color. Hagale provided coded cloth sizing labels for all shorts with a five digit pattern code indicating the crotch length and a separate waist size designation.

Upon arrival all test shorts were measured for compliance with intended size specifications. In order to provide accuracy and consistency in crotch seam measurements, a testing apparatus was constructed to secure the test shorts at the crotch midpoint (see Figure 3.3). A series of weights were then attached to the waistband or belt loops to consistently stretch the shorts. The front and back of the shorts were then horizontally aligned and the crotch depth measurement was taken.



Crotch Length Testing Apparatus

Waist Size Testing Apparatus

Figure 3.3 Waist and Crotch Testing Apparatus

Initially five pound weights were attached to the front and back of the test shorts. These heavier weights were used to remove kinks and creases in the fabric and give the garment a consistent initial stretch. After the five pound weights were removed, 1-1/4 pound weights were attached to the front and back of the test shorts. Crotch measurements were then taken. These measurements were compared across waist sizes and crotch sizes to determine consistent grading (see Appendix B, p 184). A total of four shorts were outside the pre-determined 0.5 cm tolerance established for size variations. However, the largest pattern error for crotch seam length was only 0.8 cm. No adjustments were made to correct the crotch length discrepancies.

Test short waist measurements were taken by hanging the golf short on a dress form suspension arm. A yardstick was mounted in the suspension arm to determine waist circumference. As with crotch measurements, shorts were initially stretched using two five pound weights that were replaced with 1-1/4 pound weight for the actual measurement readings. The shorts were attached to the dress form arm by a pattern hook. Measurements were taken at the top and bottom of the waistband crease. This measurement was doubled to determine waist circumference. Again, measurements were compared across waist sizes and crotch sizes to determine consistency in grading (see Appendix B, p 183). Only one short was outside the pre-determined 0.5 cm tolerance for waist size with an error of 0.6 cm for the size 32M short. These error was easily corrected by moving the waist button 0.4 cm and refastening it to the test shorts. Overall, Hagale Industries demonstrated stringent manufacturing tolerances and outstanding execution in the manufacture of test shorts.

3.5 Additional Test Instruments

In addition to the test shorts, test instruments included a mock Internet website, a size prediction model, a fit test survey, and several test forms that were used during the fit test sessions. Other test instruments included a 300-pound floor scale for measuring subject weight, a cloth tape measure incremented in inches for taking expert measurements, and a wall mounted ruler for determining height. The fit test survey was presented to test participants at the fit test session. The questionnaire had a total of 31 questions that were divided into four major sections (see Appendix E, pp 212-214). The first section included three questions on evaluation of optimum test short selections. The second section asked demographic and historic sizing information. The third section asked 21 questions on apparel purchasing experience and preferences. The final section presented four questions on the format of the mock Internet website. There was a total of seven short answer and fill-in-the-blank questions, 21 questions that utilized a five-point Likert scale to quantify results, two multiple choice, and one yes/ no question.

Subject responses were entered into a spreadsheet and imported into the DataDesk statistics package for analysis (see Appendix C, pp 189-190). Responses for multiple choice and yes / no questions were given numeric values in accordance with the coding response chart to facilitate statistical analysis (see Appendix E, pp 215-218). Mean, range and standard deviation values were calculated for each question and graphical data displays were reviewed to determine response distributions. Short answer responses were transcribed and grouped by question (see Appendix C, pp 191-193). These responses were then reviewed for significant issues and general themes.

During pilot testing test participants were asked to complete the fit test survey before completing the website ordering requirements. Since test participants in final testing completed the website at home or school, these subjects were asked to complete the questionnaire at the conclusion of their fit test session. The fit test survey used in the pilot test included additional questions on the Internet website, self-measurement procedures, and fit preference reporting. The answers to these questions were used to modify testing procedures and improve the website format prior to final testing.

In addition to the fit test questionnaire a standard consent form was used to provide an overview of test subject requirements and explain the usage and reporting of test results (see Appendix E, p 208). This form is a Cornell University requirement and established test subject agreement complete testing requirements. All subjects were required to sign the consent form prior to participating in their fit test sessions. During the fit test sessions an expert measurement / fit evaluation form was used to record eight expert measurements, predicted and additional short sizes, and scaled responses to satisfaction of fit questions for each pair of test shorts (see Appendix E, p 210). Evaluators also annotated which of the three predicted shorts had the highest satisfaction of fit and which short provided the optimum fit.

Finally a discrepancy question form and a manual order form were used during fit test sessions. In pilot testing manual order forms were used exclusively to record self-measurements and fit preference responses for test participants. The website requirements were completed on site in the pilot test and manual order forms were returned to test evaluators once the website ordering requirement was completed. The manual order form contained the same data elements as the electronic order form used in final testing (see Appendix E, p 209). During final testing the manual form was used for test participants that needed to complete the website ordering requirements concurrent with their fit test sessions.

The discrepancy question form was given to test participants who reported self-measurements greater than two inches away from expert measurement findings. Subjects completed this form at the same time they completed the fit test survey form. Evaluators highlighted the self-measurements outside established tolerances at the top of the discrepancy question form and subjects answered a total of five questions (see Appendix E, p 211). Two questions focused on the difficulty of understanding website measurement instructions. Two questions concerned the type and perceived reliability of measurement devices used by test participants and a final question asked if test subjects would use different procedures if they were actually purchasing the shorts. In cases of extreme variations test participants were asked to repeat self-measurement procedures with the evaluator present. A total of eleven test subjects were required to complete the discrepancy question form.

3.5.1 Internet Website

Considering the website designs of leading Internet apparel retailers, a mock testing website was developed to guide research subjects through online ordering procedures for men's shorts. Due to their extensive use of customization and detailed self-measurement procedures, the IC3D website had the greatest influence on the final design and content of this research website. The mock company was named Red Bird Golf and the website includes information on a variety of apparel products, policies, sizing, fit preference, and ordering (see Appendix G, p 228).

The Internet ordering site was designed to provide test subjects with the feel of an actual retail apparel ordering experience. The golf focus was designed to generate increased interest in participation for male test subjects. The site supplies catalog information on golf shorts, golf shirts, and golf caps as well as online help and general background information on the company. Aside from presenting test shorts in a realistic setting, the research site was designed to provide limited information on the mass customization process and convey the company's strong commitment to overall customer satisfaction. There are two major sections in the website. The first section includes the company's homepage, catalog information on apparel products, policy information, and online help. The second section includes sizing, self-measurement, fit preference and ordering information. There is a total of 14 pages in the site but only nine pages contain information directly relevant to the research project. The remaining five pages are designed to add realism to the site and provide background information on the mock company.

Catalog and Internet self-measurement instructions were reviewed to determine common measurement procedures for use in the mock website ordering experience. The sizing section contains detailed instructions on girth, waist, seat, and crotch length self-measurements as well as fit preference questions for each self-measurement area. The results from the analysis of catalog and Internet retailer sizing and self-measurement procedures were used to develop the step-by-step procedures listed for self-measurement. Several modifications were made to these measurement procedures following the conclusion of pilot testing. These enhancements included the addition of digitized pictures portraying correct and incorrect measurement procedures. The pictures and the related text are designed to eliminate common measurement errors and guide research subjects easily and accurately through self-measurement procedures.

Digitized pictures were also added to the fit preference page to display waist height variations and remind test subjects of various measurement locations. An online ordering form was also added to allow test subjects to submit self-measurement and fit preference results electronically. Once completed, the electronic order form was sent via e-mail for direct transposition into short sizes generated by the size prediction model. This process allowed the appropriate size of shorts to be selected prior to the arrival of a test subject at their fit session and greatly expedited the testing process. Subjects were given the website address and were able to complete this part of the test procedures from the computer of their choice. For those subjects that did not have access to an online computer, a computer was made available adjacent to the fit testing site.

The overview page for sizing provided information on shrinkage factors, general sizing, and preparation for self-measurement. Subjects were instructed not to add additional allowances for shrinkage factors in their self-measurement and fit preference responses. Test subjects were also instructed to wear a comfortable fitting pair of shorts or pants that closely matched their desired fit preferences when taking self-measurements. Finally subjects were instructed to list the type of pants or shorts worn during self-measurements on their order forms.

The girth measurement instructions provided on the website are equivalent to anthropometric procedures for taking waist circumference (omphalion) measurement in the Army ANSUR. The name of this particular measurement was changed from waist circumference (omphalion) to the more common term girth to improve its ease of understanding for research subjects. Descriptive pictures were used to depict correct and incorrect measurement procedures and help reduce common measuring errors by test subjects. An online ordering form was provided to transmit research subject information and orders using conventional e-mail. Website pages required by test participants were linked using a "next" menu button at the top center of each page. This button moves website visitors along a specified path (see Figure 3.4). Required text was also highlighted in blue to help expedite the completion of the website ordering requirements and emphasize important information for test participants.

The website was designed to give test participants the feel of an actual retail website while ensuring the completion of all testing requirements. Participants were instructed to explore the site until they felt comfortable with it and were ready to place an order for test shorts. In addition to the online order form, a manual form was used for test participants who arrived at the fit testing session without completing the website ordering requirements. The manual form was used exclusively during pilot testing and for nine primary test participants. The manual order form had the short type and color pre-printed in the header information and online instructions talked test participants through the remainder of its completion (see Appendix E, p 209).

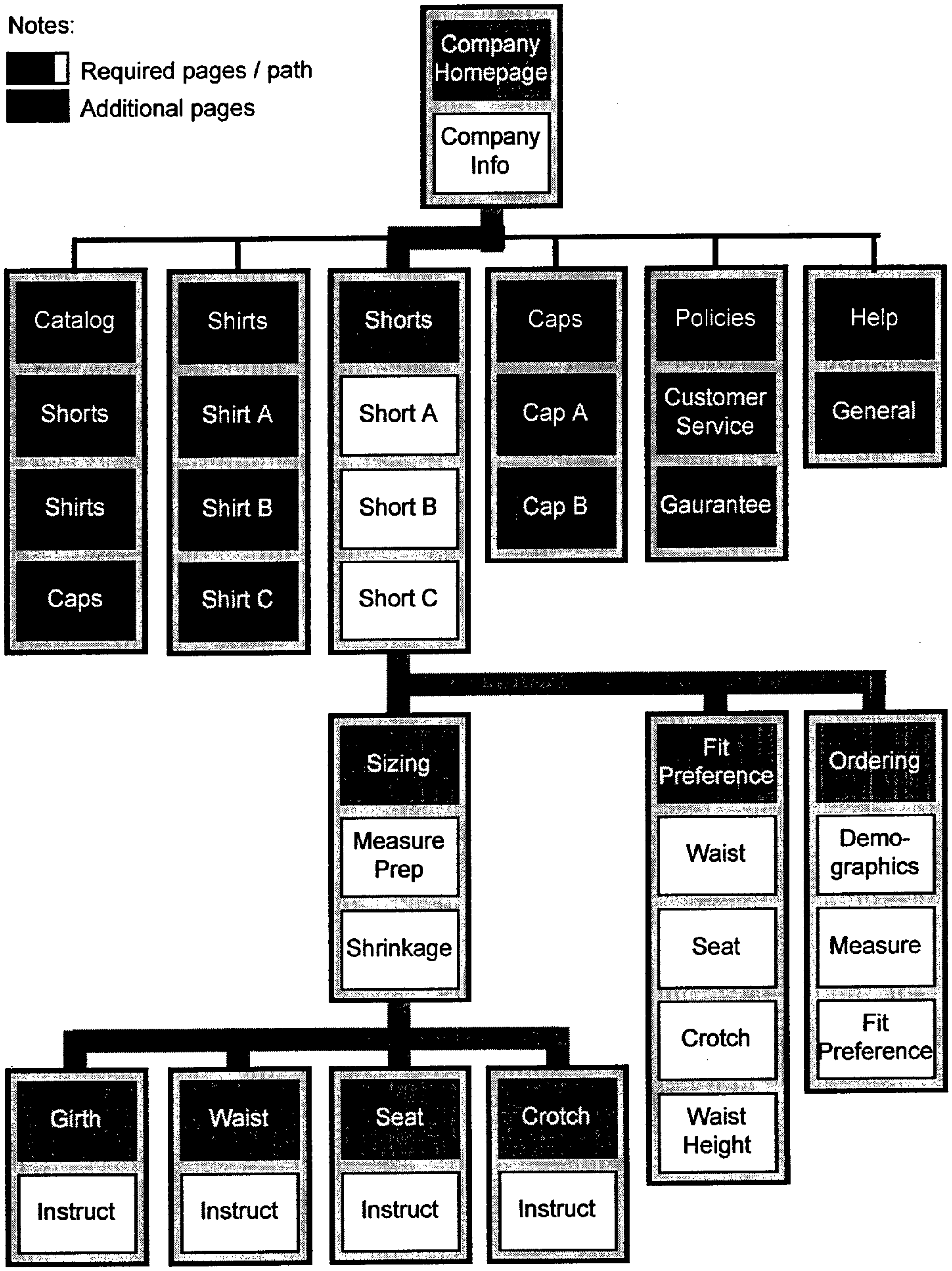


Figure 3.4 Research Website Diagram

Self-measurement and fit preference information from the manual form was entered into the size prediction model for selection of sizes of shorts for preference data during the pilot test. A critique of the website format was also completed by test participants during both pilot test and primary testing. Several changes were made to the site's format before the primary test. A diagram of the website format highlights the expedited testing path and supported pages (see Figure 3.4).

3.5.2 Size Prediction Model

A spreadsheet-based size prediction model created in Microsoft Excel was developed from the results of US Army anthropometric data analysis, industry grading, ease, and sizing rules, and common sizing information for apparel mail-order catalog retailers. Table 3.6 lists expert waist measurements ranges with test short sizes at the top of each column. The shaded cells indicate expert waist measurement ranges used to predict the appropriate test short size. Expert measurements are taken over underwear and Lycra® shorts that did not compress the body. Self-measurements were taken over a variety of individually selected shorts and pants.

In Table 3.6 the sizing categories, Small (S), Medium (M), Large (L), and Extra Large (XL), listed in the far left column indicate crotch sizes for the test shorts. Small (S) sizes are one standard deviation below the base sizes in crotch length, Large (L) sizes are one standard deviation above, and Extra Large (XL) sizes are two standard deviations above the base sizes in crotch length. Crotch length measurement ranges used in both expert and self-measurement sizing charts were adjusted from the garment pattern measurements by subtracting 2 inches for seam allowances and 2-1/2 inches for a common ease factor. The range for each crotch length size category is equal to one standard deviation, 1.2 inches (3.1 cm).

Table 3.6 Expert Measurement Sizing Chart in Inches

	30	30.5	31	31.5	32	32.5
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	20.5 - 21.6	20.9 - 22.0	21.2 - 22.4	21.6 - 22.7	22.0 - 23.1	22.3 - 23.4
M	21.7 - 22.9	22.1 - 23.2	22.5 - 23.6	22.8 - 23.9	23.2 - 24.3	23.5 - 24.6
L	23.0 - 24.1	23.3 - 24.4	23.7 - 24.8	24.0 - 25.1	24.4 - 25.5	24.7 - 25.9
XL	24.2 - 25.4	24.5 - 25.7	24.9 - 26.1	25.2 - 26.4	25.6 - 26.8	26.0 - 27.2

	33	33.5	34	34.5	35
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	22.7 - 23.8	23.0 - 24.1	23.4 - 24.5	23.7 - 24.9	24.1 - 25.2
M	23.9 - 25.0	24.2 - 25.4	24.6 - 25.7	25.0 - 26.1	25.3 - 26.4
L	25.1 - 26.2	25.5 - 26.6	25.8 - 26.9	26.2 - 27.3	26.5 - 27.6
XL	26.3 - 27.5	26.7 - 27.9	27.0 - 28.2	27.4 - 28.6	27.7 - 28.9

NOTES
- Column headers indicate test short waist size
- Row headers indicate test short crotch size
- Shaded blocks indicate body measurement ranges in inches for waist sizes
- Remaining blocks specify body measurement ranges in inches for crotch sizes

Errors in self-measurement procedures and reporting combined with variations in the thickness of self-selected pants and shorts were projected to increase the variance in self-measurements for waist and crotch sizes. To address these concerns, the self-measurement sizing chart reflects a one-half inch shift above the range determined by expert measurement for waist size (see Table 3.7). The crotch measurement ranges from the expert measurement prediction chart were also increased by 1.2 inches (3.1 cm) to reflect these same issues. To predict initial test short sizes for expert and self measurement, the size prediction model automatically finds the appropriate column for waist size range, then follows the column down until the appropriate crotch size range is located.

Table 3.7 Self-Measurement Sizing Chart in Inches

	30	30.5	31	31.5	32	32.5
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	21.7 - 22.9	22.1 - 23.2	22.5 - 23.6	22.8 - 23.9	23.2 - 24.3	23.5 - 24.7
M	23.0 - 24.1	23.3 - 24.4	23.7 - 24.8	24.0 - 25.1	24.4 - 25.5	24.8 - 25.9
L	24.2 - 25.3	24.5 - 25.6	24.9 - 26.0	25.2 - 26.4	25.6 - 26.7	26.0 - 27.1
XL	25.4 - 26.6	25.7 - 27.0	26.1 - 27.3	26.5 - 27.7	26.8 - 28.0	27.2 - 28.4

	33	33.5	34	34.5	35
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	23.9 - 25.0	24.2 - 25.4	24.6 - 25.7	25.0 - 26.1	25.3 - 26.4
M	25.1 - 26.2	25.5 - 26.7	25.8 - 26.9	26.2 - 27.3	26.5 - 27.6
L	26.3 - 27.4	26.7 - 27.8	27.0 - 28.1	27.4 - 28.5	27.7 - 28.9
XL	27.5 - 28.7	27.9 - 29.1	28.2 - 29.5	28.6 - 29.8	29.0 - 30.2

<u>NOTES</u>
- Column headers indicate test short waist size
- Row headers indicate test short crotch size
- Shaded blocks indicate body measurement ranges in inches for waist sizes
- Remaining blocks specify body measurement ranges in inches for crotch sizes

Sizing charts in the size prediction model were modified at the conclusion of final testing in an attempt to optimize size predicted made by self and expert measurements. All waist measurement ranges in the expert measurement sizing chart were increased 0.05 inches. Crotch measurement ranges were also changed in the expert measurement chart by subtracting 0.35 inches from all range values. Adjustments in the self-measurement sizing chart were limited to a 1.05 inch reduction in crotch measurement ranges. In addition to sizing chart adjustments for self and expert measurement in the size prediction model, measurement adjustments were made to the derived crotch and waist measurements used to calculate fit preference modified sizes from the sizing charts.

For expert measurement plus fit preference adjustments, waist measurements were decreased 0.025" and crotch measurements were decreased 0.4". These adjustment values were found using trial and error. Size prediction results for fit preference adjustments were monitored as a range of values were attempted as adjustment factors. For self-measurement plus fit preference adjustments, waist measurements were decreased 0.375" and crotch measurements were decreased 0.2". Using adjustment factors to optimize the fit preference size predictions was easier than creating separate sizing charts and helped facilitate the size prediction model optimization.

Prior to pilot testing initial fit preference adjustments were anticipated for responses to questions in five general sizing areas: waist, seat, crotch, thigh, and overall. At the conclusion of pilot testing the thigh and overall fit preference test measures were removed and waist height fit preference was added. Figure 3.5 graphically displays the four final fit preference categories.

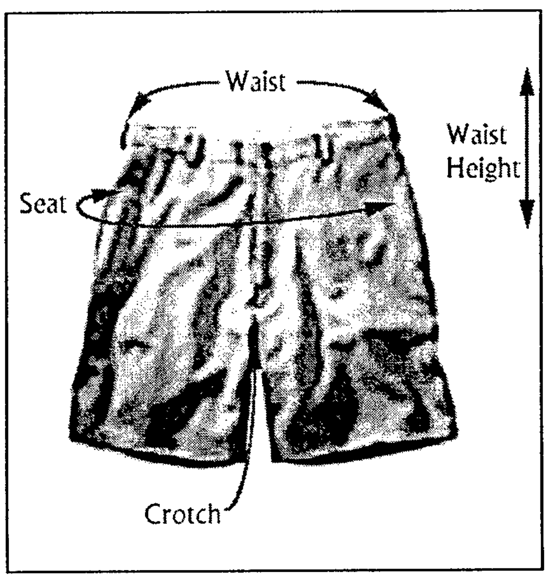


Figure 3.5 Final Fit Preference Categories

Fit preference response adjustments were initially determined using the weights listed in Table 3.8 and the values listed in Table 3.9. Using a response scale from 1 to 5, which represented very snug, snug, average, loose, and very loose fit preference responses, adjustments were calculated for each fit preference response. In the next step, weights were multiplied by response values. Crotch length had no relation to waist size so it was not assigned a factor weight for waist size adjustments. Similarly, waist size was not assigned a factor weight for crotch length adjustments. Table 3.8 lists factor weight assignments for initial fit preference factors.

Table 3.8 Initial Fit Preference Weights

	Waist	Crotch
Waist	0.60	0.00
Seat	0.15	0.15
Crotch	0.00	0.60
Thigh	0.05	0.05
Overall	0.20	0.20

NOTES
- Column headers indicate waist or crotch factors
- Row headers indicate fit preference categories

Crotch and waist fit preference responses had the highest factor weight assigned for their respective adjustments. Overall fit preference responses for both waist and crotch length had the next highest factor weighting in both crotch and waist adjustments followed by seat fit preference responses. Fit preference responses for thigh measurements were assigned a factor weight of 0.05 for both adjustments. Since waist and crotch lengths are the only dimensions varied in the test shorts, sizing adjustments and were not calculated for other pattern dimensions. The only calculations that were made involved the impact variations in fit preference were judged to have on waist and crotch lengths. Analysis of the data from this research will provide information on the necessity of adjusting pattern dimensions in men's shorts for other body measurements.

Waist and crotch length size changes for various fit preference responses in the initial size prediction model are listed in Table 3.9. Plus or minus 0.5 inches moves the predicted short size up or down one waist size in the waist adjustment section of the table. In the crotch adjustment section of Table 3.9 plus or minus 1.2 inches in crotch length is equivalent to the standard deviation of crotch lengths for each waist size extracted from the Army study. Crotch adjustments of 1.2 inches have the effect of moving the predicted crotch size up or down one size.

Table 3.9 Fit Preference Adjustment Charts

Waist Adjustment

	1	2	3	4	5
Waist	-2	-1	0	1	2
Seat	-1	-0.5	0	0.5	1
Crotch	0	0	0	0	0
Thigh	-1	-0.5	0	0.5	1
Overall	-1	-0.5	0	0.5	1

Crotch Adjustment

	1	2	3	4	5
Waist	0	0	0	0	0
Seat	-1.2	-0.6	0	0.6	1.2
Crotch	-2.4	-1.2	0	1.2	2.4
Thigh	-1.2	-0.6	0	0.6	1.2
Overall	-1.2	-0.6	0	0.6	1.2

NOTES
- Shaded column headers indicate scaled fit preference responses
- Table data is given in inches

As an example, a random test subject has the following fit preference response values: Waist (4), Seat (2), Crotch (4), Thigh (1), and Overall (2). The sizing adjustments from the waist circumference adjustment chart and weights would total plus 0.375 inches for waist circumference and plus 0.48 inches for crotch length. These values would then be added to self-measurements for crotch length and preferred waist circumference.

In addition to the fit preference adjustment values listed in the Table 3.9, several other fit preference values and weights were examined for their ability to refine test short size predictions. Of these variables preferred waist height had a significant impact. At the conclusion of pilot testing a derived waist circumference value was obtained for waist height fit preference by relating the subject response to graduated scale bounded by waist circumference at the omphalion and preferred waist circumference. This value is then multiplied times a compression ratio obtained from a comparison of subject height to subject weight. For example, the same random test subject has a preferred waist circumference of 35 inches and a waist circumference at the omphalion of 37 inches. This subject's height and weight are self-reported as 72 inches and 185 pounds. Their compression ratio equals 1.108 and given a waist height fit preference of (4), low waist height, a waist circumference adjustment of minus 0.42 inches is obtained. Combining this value with the plus 0.375 inch adjustment from the previously listed fit preference responses equals a waist adjustment of minus 0.04 inches.

These early adjustments improved the accuracy of size predictions generated by the initial size prediction model. However, it was determined that the addition of waist height fit preference in this format was too complex to isolate initial errors in final research testing. From a further review of pilot test fit preference adjustments it was determined that thigh responses and weights were insignificant in improving size predictions. In addition, overall fit preference responses often conflicted with other fit preference responses negating the effect of these adjustments. Both thigh and overall fit preference questions and related adjustments were removed from the study. A fit preference question on waist height was added but no adjustment factors or weighting was applied to waist height in initial size predictions for final testing.

A simplified factor weighting and adjustment chart were developed for final testing (see Table 3.10). Waist and seat fit preference responses and weights were now the only determinants of fit preference adjustments for waist size predictions. Waist fit preference adjustments were given a factor weighting of 0.75 while seat adjustments were given a 0.25 factor weight. Similarly, crotch and seat fit preference and weights determined crotch fit preference adjustments. Crotch fit preference adjustments received the same 0.75 factor weighting as waist responses and seat adjustments had a 0.25 factor weight.

Table 3.10 Intermediate Fit Preference Adjustments and Weighting

Waist Adjustments

	1	2	3	4	5
Waist	-1	-0.5	0	0.5	1
Seat	-1	-0.5	0	0.5	1

Waist	0.75
Seat	0.25

Crotch Adjustments

	1	2	3	4	5
Crotch	-2.4	-1.2	0	1.2	2.4
Seat	-2.4	-1.2	0	1.2	2.4

Crotch	0.75
Seat	0.25

<u>NOTES</u>
- Column headers indicate waist or crotch factors
- Row headers indicate fit preference response categories
- Top tables list fit preference adjustments in inches
- Bottom tables list fit preference weights

After the completion of final testing, fit preference factors were once again modified to optimize the size predictions generated by the adjusted size prediction model. Adjustments for waist height fit preference were added in this final model and weights and adjustments for waist, crotch, and seat fit preference responses were again modified (see Table 3.11). Adjustments ranging from -1.8 inches to plus 1.8 inches were used for crotch, seat, and waist height adjustments in the crotch adjustment section of the size prediction model. Adjustments ranging from -1 inches to plus 0.75 inches were used for waist, seat, and waist height adjustments in the waist adjustment section. Weights for waist and seat adjustments remained consistent with the intermediate weights but an additional factor weight of 0.25 was added for waist height adjustments. Weights for crotch adjustment factors were significantly modified from the intermediate factor weight values. The factor weight for crotch fit preference adjustments was increased from 0.75 to 1.0 in the adjusted size prediction model. Seat fit preference adjustments were increased to a 0.65 factor weight from a 0.25 factor weight with the intermediate adjustments. Waist height received a factor weight of 0.35 for the adjusted size prediction model.

Table 3.11 Final Fit Preference Adjustments and Weighting

Waist Adjustments

	1	2	3	4	5
Waist	-1	-0.5	0	0.38	0.75
Seat	-1	-0.5	0	0.38	0.75
W Height	-1	-0.5	0	0.38	0.75

Waist	0.75
Seat	0.25
W Height	0.25

Crotch Adjustments

	1	2	3	4	5
Crotch	-1.8	-0.9	0	0.9	1.8
Seat	-1.8	-0.9	0	0.9	1.8
W Height	-1.8	-0.9	0	0.9	1.8

Crotch	1.00
Seat	0.65
W Height	0.35

<u>NOTES</u>
- Column headers indicate waist, crotch or waist height factors
- Row headers indicate fit preference response categories
- Top tables list fit preference adjustments in inches
- Bottom tables list fit preference weights
- W Height stands for Waist Height

As with the complex waist height adjustment factors used in optimizing the initial size prediction model used in pilot testing, waist height adjustments in the final fit preference adjustments became very complicated. In addition to the measurement adjustments for fit preference and sizing chart changes listed in Section 3.4, an additional waist height related compression ratio was added as an adjustment factor for waist size prediction only. This compression ratio involves a scaled factor determined from a comparison of waist circumference (omphalion) to waist circumference (preferred) and value for waist height fit preference responses. The intent of this adjustment was to relate waist height preferences with differences in self and expert measured body dimensions. These waist height compression adjustments were made in addition to the factor weighted waist height fit preference adjustments for crotch and waist size prediction listed in Table 3.11.

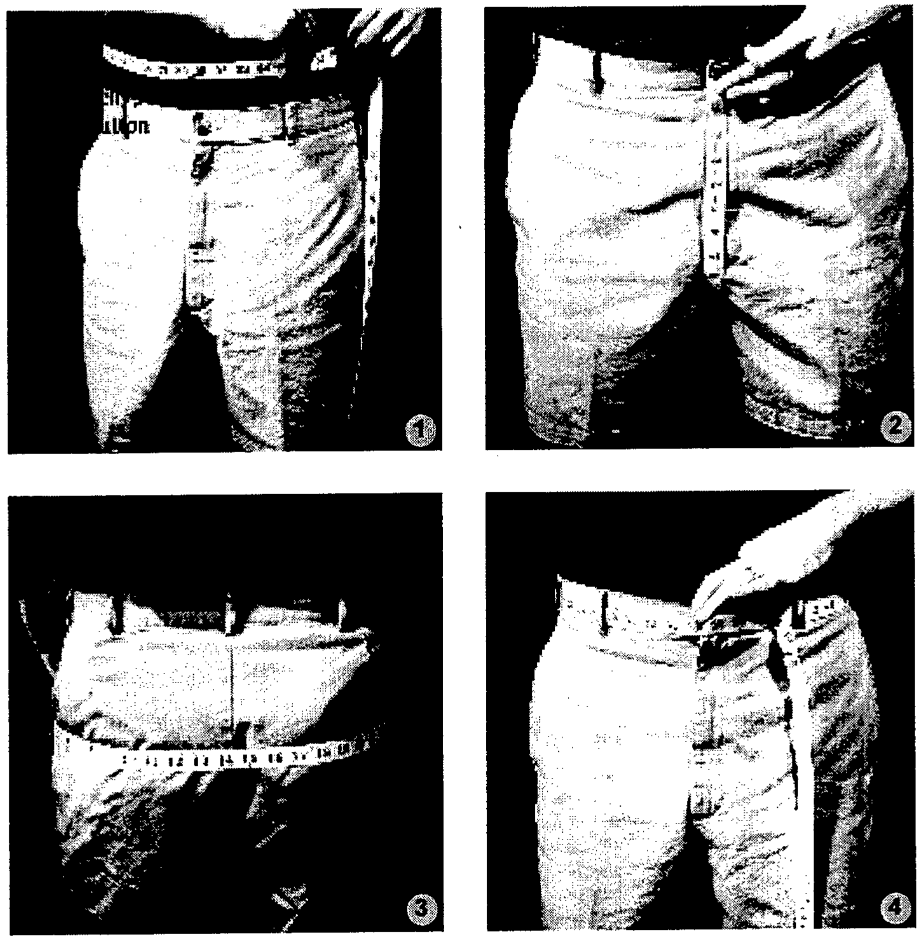
3.6 Measurement Procedures

During pilot testing subjects were asked to take a total of five body measurements. These measurements included girth, waist, seat circumference, thigh circumference, and crotch length. The girth measurement was renamed from the waist circumference (omphalion) measurement in the Army ANSUR. The waist measurement was based on the waist circumference (natural indentation) in the Army ANSUR but was modified for landmarks along the preferred waistline. The seat circumference measurement was renamed from buttocks circumference measurement in the Army ANSUR.

In addition to these five measurements subjects were asked to report estimated height and waist data on their initial questionnaires. During pilot testing this questionnaire was administered at the beginning of the testing sessions. However, during final testing this questionnaire was completed at the conclusion of the fit test session. As a result self-reported height and waist questions were removed since subject data for these measurements had already been determined by expert measurement procedures. The self-measurement for thigh circumference was also removed from final self-measurement procedures for test subjects. Since fit preference responses for the thigh area had been removed from fit preference reporting requirements, this measurement was no longer needed in the ordering data.

Self-measurement instructions for final testing are included in the hard copy website pages (see Appendix G, pp 249-260). Self-measurement instructions were primarily modified from IC3D measurement instructions. Additional sources for modifications to the measurement instructions were obtained from the review of mail-order catalog procedures and the ANSUR measurement instructions (see Appendix A, pp 156-159). Figure 3.6 displays pictures of the four final self-measurement procedures.

Expert measurements included waist circumference (omphalion), waist circumference (preferred), crotch length, seat circumference, thigh circumference, height, weight, and omphalion to preferred length. ANSUR study procedures were closely followed for these measurements (see Appendix F, p 219). As with self-measurements changes were made to the instructions for waist circumference (natural indentation) in order to measure the preferred waist circumference. In this procedure subjects were asked to adjust the waist height of the Lycra® shorts to their preferred waist height. Measurements were taken at the bottom edge of the waistband. Measurements for omphalion to preferred length were modified from ANSUR instructions for waist (natural indentation) to waist (omphalion) length. This measurement determines the vertical distance in inches between the omphalion and the preferred waistline. The bottom edge of the waistband served as the lower landmark for this measurement.



1 - Girth
2 - Crotch Length
3 - Seat
4 - Waist

Figure 3.6 Final Self-Measurements

Expert crotch length measurements used the bottom edge of the waistband on the Lycra® shorts as a landmark. This corresponded to the preferred waist height. Otherwise the same measurement procedures listed for the crotch length (omphalion) from the ANSUR study were used. The height measurement was the same as the stature measurement in the

ANSUR study (see Appendix F, p 220). Both height and waist measurements were taken with test subjects in Lycra® shorts and stocking feet. Figure 3.7 displays pictures of expert measurement procedures from the actual fit test sessions.

1 - Thigh
2 - Waist (Preferred)
3 - Height
4 - Waist (Omphalion)
5 - Crotch Length

Figure 3.7 Expert Measurements

3.7 Subject Recruitment

During pilot testing, subjects were recruited using campus flyers and personal requests (see Appendix E, p 209). A total of ten subjects participated in the test. While no monetary incentives were offered in the recruitment process, gourmet ice cream was provided as an inducement for participation. Six additional subjects expressed interest and scheduled fit sessions but either canceled at the last minute or failed to show up for their appointments. Since the entire range of manufactured test shorts were unavailable for pilot testing, the small sample size was adequate to refine website information and fit testing procedures.

During recruitment for primary subjects, an initial random sample of 1000 male undergraduate, graduate, and professional students from Cornell University received e-mail messages requesting their participation in the study. Representatives from the Dean of Student Services and Computer Information Technology (CIT) Offices at Cornell University approved the e-mail message, drew the actual sample from a population of approximately 10,000 male students, and sent the message. My e-mail address was inserted as the sender to aid participants in replying to the message. A monetary incentive of $5.00 payable at the conclusion of each fit test session was offered to each test participant. Waist circumferences for test subjects were restricted to a range represented by mass produced men's pants in waist sizes 30 to 35 inches. No other restrictions were presented to test participants. A total of 67 applicants responded favorably to the initial e-mail and were sent a subsequent message instructing them to complete ordering procedures at the website developed for the study. In addition, subjects were instructed to request a date and time for their fit test session during the week of 11 to 15 October, 1999.

A second sample of 1500 students was requested from CIT and the Dean of Student Services Office. An identical message was sent to this sample of the Cornell population four days after the first message. The second message generated 54 additional responses. I experienced significant problems getting applicants to complete website and scheduling requirements after receiving their initial e-mail responses. I sent two additional e-mail messages to encourage applicants to complete ordering and scheduling requirements in a timely manner.

In addition, I personally contacted the ROTC Department at Cornell to coordinate the distribution of flyers to all male cadets. I made several changes to the initial flyer I used during pilot test recruitment to emphasize my rank and connection with the US Army. I also posted flyers at strategic points around campus to generate more interest in the study. Test reminders were sent to all scheduled test participants 48 hours prior to their scheduled fit testing session. Figure 3.8 provides a diagram of the communication flow during the entire recruitment process. Website generated order forms included requested fit testing session times from applicants.

Several factors may have impeded the successful recruitment of more test subjects. These factors include the timing of the study in conjunction with mid-term exams for many students, low monetary incentives, time and procedural requirements for website ordering, and the overall complexity of research procedures. The website's realism made several applicants question whether they were actually paying for shorts when they completed the ordering requirements. Many applicants also commented that they would be on an extended Fall break and unable to participate in the study.

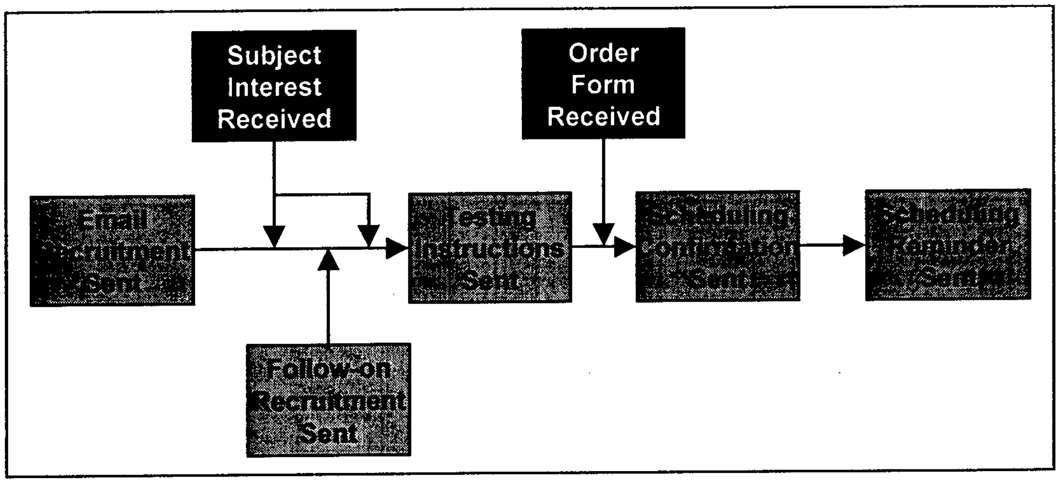


Figure 3.8 Recruitment Communication Sequence

Due to the limited number of subjects able to participate in the study and the various restrictions imposed by limiting the acceptable waist size range, a randomized sample of test subjects could not be attained. All individuals that responded and met the sizing criteria were allowed to participate in the study. During pilot and primary testing, we were able to assign subjects to two test groups randomly by using an odd-or-even random number generator. Final registration deadlines for the pilot and primary tests were established as mid-June and late-September, 1999.

3.8 <u>Pilot Testing</u>

The pilot test was conducted 6-8 July, 1999 to validate test procedures, verify short size prediction scales, and evaluate website effectiveness. Male test subjects from Cornell University's general student population were recruited using personal solicitation, flyers, and campus postings. The pilot test followed the same format and selection procedures as the primary test with one exception. Rather than trying on incrementally graded shorts, test subjects donned mass produced shorts in their waist size while test evaluators used binder clips, pins, other devices to adjust the sizing of the shorts. A total of ten test subjects were screened and found to have waist and crotch length measurements within the range of variation identified by ANSUR data. These ten subjects were all volunteers and received no monetary incentives to participate in the study. During testing, a five step, four stage testing format was utilized (see Figure 3.9).

1. Self-measurements, fit preferences, and demographic information from survey and website responses were gathered in Stage 1.

2. In Stage 2, expert evaluators measured test subjects and the size prediction model was used to predict test short sizes.

3. In Stage 3, subjects donned pilot test shorts and alterations to waist and crotch length were made to determine optimal sizing.

4. Concurrently with Step 3, subjects responded to questions on satisfaction of fit for each pair of test shorts.

5. In Stage 4, a final questionnaire on testing procedures was administered.

Figure 3.9 Four Stage Pilot Test Procedures

The average duration of a pilot test session was 47 minutes. However, custom manufactured test shorts were not yet available for pilot testing. The six shorts mass produced by Hagale Industries and used for the pilot test had minor cosmetic or manufacturing flaws. These shorts came in a size range from 30 to 35 inches. The minor manufacturing flaws made the shorts unsuitable for first-quality retail sales purposes. However, these factors did not impact on the size or fit characteristics required for pilot testing. Once test subjects found the best fitting pair of sample shorts, they were asked to direct adjustments in accordance with their reported fit preferences. These fit preferences were accommodated by adjusting the waist and crotch dimensions with a variety of binder clips and pins. Since the sample shorts followed Hagale's grading rules, it was hypothesized that the crotch lengths would be out of line with mean crotch lengths for minimum and maximum waist size ranges.

Pilot test participants completed website ordering requirements on site during their fit test session. Self-reported test measures included a series of lower body measurements for the waist, seat, crotch, thigh, height, and weight, along with fit preference responses. Subjects were given a detailed initial questionnaire upon arrival at the test site. In their initial questionnaire, test subjects are asked to estimate their body dimensions and list the waist sizes of pants and shorts that they normally wear. In a final survey test subjects provided responses to the fit of all shorts they tested. Additional test measures included expert lower body measurements and fit analysis by trained evaluators. Subjects completed a series of questionnaires on fit preference responses, internet ordering issues, self-measurement, and short selection by the end of testing.

All fit sessions were videotaped and reviewed to determine testing anomalies. Expert measurement and fit session procedures were revised to streamline operations. Information from the pilot test was used to adjust fit preference and self-measurement ordering models and sizing predictions charts used to assign test shorts sizes. Initially, I used mail-order catalog sizing charts, mean data for each size range extracted from the Army database, and research on the accuracy of self-measurements to develop size prediction charts.

3.9 Final Testing

Final testing procedures were similar to the procedures used in pilot testing. However, subjects were instructed to complete website ordering before they were scheduled for a fit test session. An overview of the steps in final testing is provided in Figure 3.10. In Step 1 subject order forms with scheduling requests, fit preference, and self-measurement data are received. In Step 2 self-measurement and self-measurement plus fit preference short size predictions are made with the size prediction model. Subject data are transposed into a Microsoft Excel spreadsheet for input into the size prediction model and scheduling confirmations are sent. The actual fit session begins in Step 3 with subject sign-in. This task involves the completion of a consent form and a payment sheet. Subjects are given a brief overview of the testing procedures and directed to change into Lycra® shorts. Expert measurements and expert short size predictions are made in Steps 4 and 5. In Step 6 fit analysis is conducted for predicted and additional test shorts and in Step 7 subjects complete final questionnaires and additional required forms.

Since satisfaction if fit is a highly subjective measure, blind testing was needed to mask the actual size of test shorts. Shorts were coded with a two letter size designator to mask their size and subjects were not told which measurement method predicted the shorts presented during fit testing. Shorts predicted by expert measurement, self-measurement, and self-measurement with fit preferences were presented to test subjects in random order as much as practical given the time constraints of the fit test session. After the subject determined the best fitting pair, additional shorts larger and smaller in size were presented to the test subject based on responses to satisfaction of fit questions for further analysis. Ultimately, a pair of shorts that best maximized individual satisfaction of fit was determined.

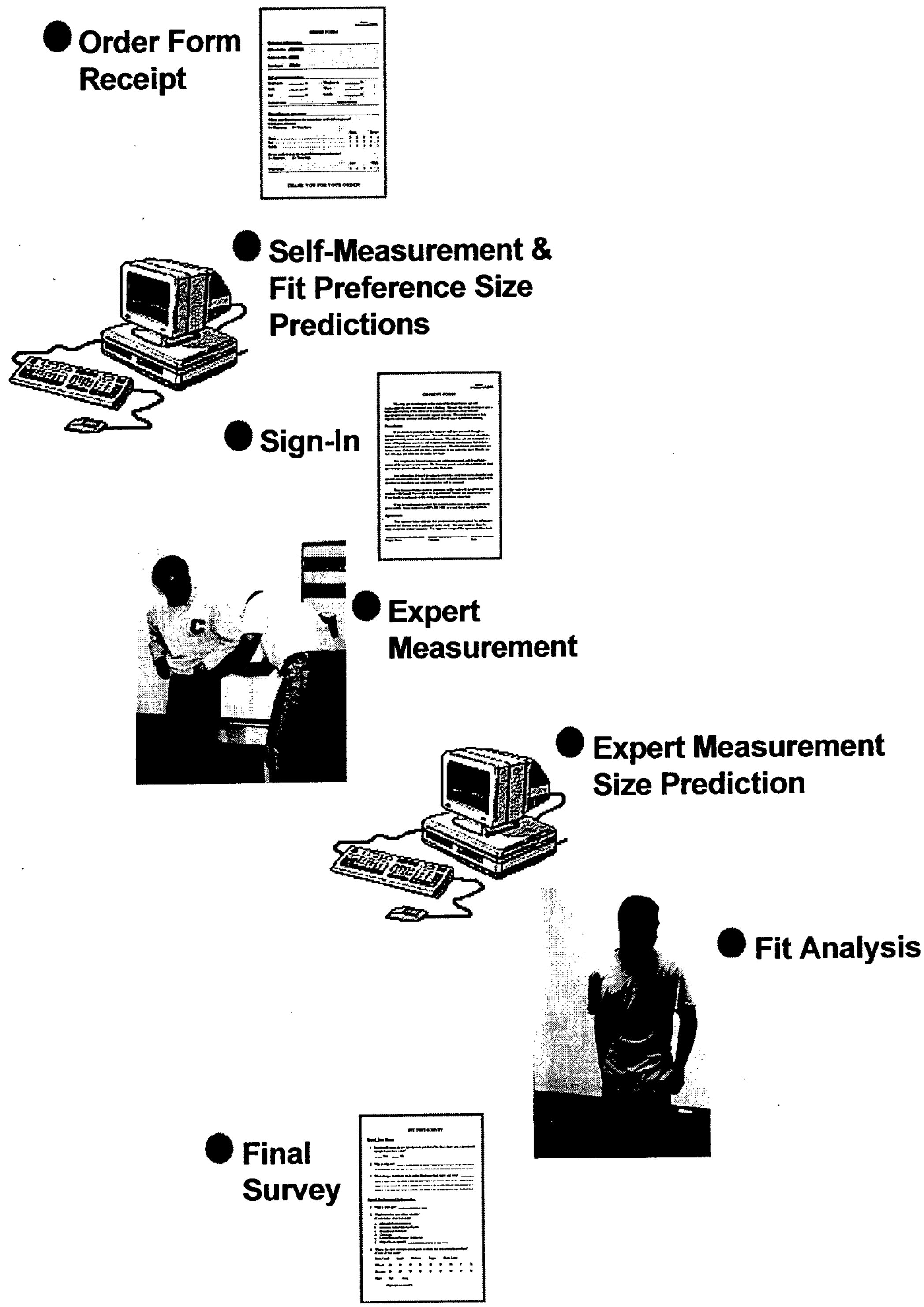


Figure 3.10 Overview of Final Testing Steps

Subjects were required to wear a pair of Lycra® shorts during the initial expert measurement portion of the study. These Lycra® shorts came in three sizes and subjects were given an appropriate size based on self-measurement data. Subjects were instructed to wear their own undergarments during fit testing for test shorts. They were also instructed to tuck their shirts into the test shorts. Extra T-shirts were on hand to replace thick shirts or sweaters worn by test participants. These subjects were asked to change their shirts at the start of fit testing. After donning a pair of test shorts, subjects were guided through a series of body movements. These movements included sitting in straight, high-backed chair, placing an empty box on a low table, and bending forward at the waist in an attempt to touch their toes. These movements served a variety of purposes that included proper placement of the test shorts on the body and an opportunity for test subjects to evaluate the dynamic fit characteristics of the test shorts.

During fit testing subjects were asked a series of questions concerning satisfaction of fit for test shorts in five categories: waist, seat, thigh, crotch, and overall. Evaluators recorded subject responses using a five point scale with five equal to fully satisfied and one equal to unsatisfied. Results were annotated on the fit evaluation form. A flowchart of fit testing is included in Figure 3.11. Test subjects were presented predicted short size selections first. After evaluating these three shorts subjects were asked to pick the best fitting pair. Based on their satisfaction of fit responses subjects were presented with up to three additional shorts. Subjects evaluated each pair using the same procedures as the predicted shorts. Based on the responses to satisfaction of fit questioning subsequent short sizes were chosen. If an optimum fitting pair had not been selected by the sixth pair of shorts presented subjects were asked to select the best fitting pair from all the presented subjects were asked to select the best fitting pair from all the shorts. Once a subject was fully satisfied with the fit of a short testing was stopped and the final size selection annotated by the evaluator. All test subjects were required to try on a minimum of four test shorts. Large mirrors were available for subjects to visually evaluate the fit of test shorts.

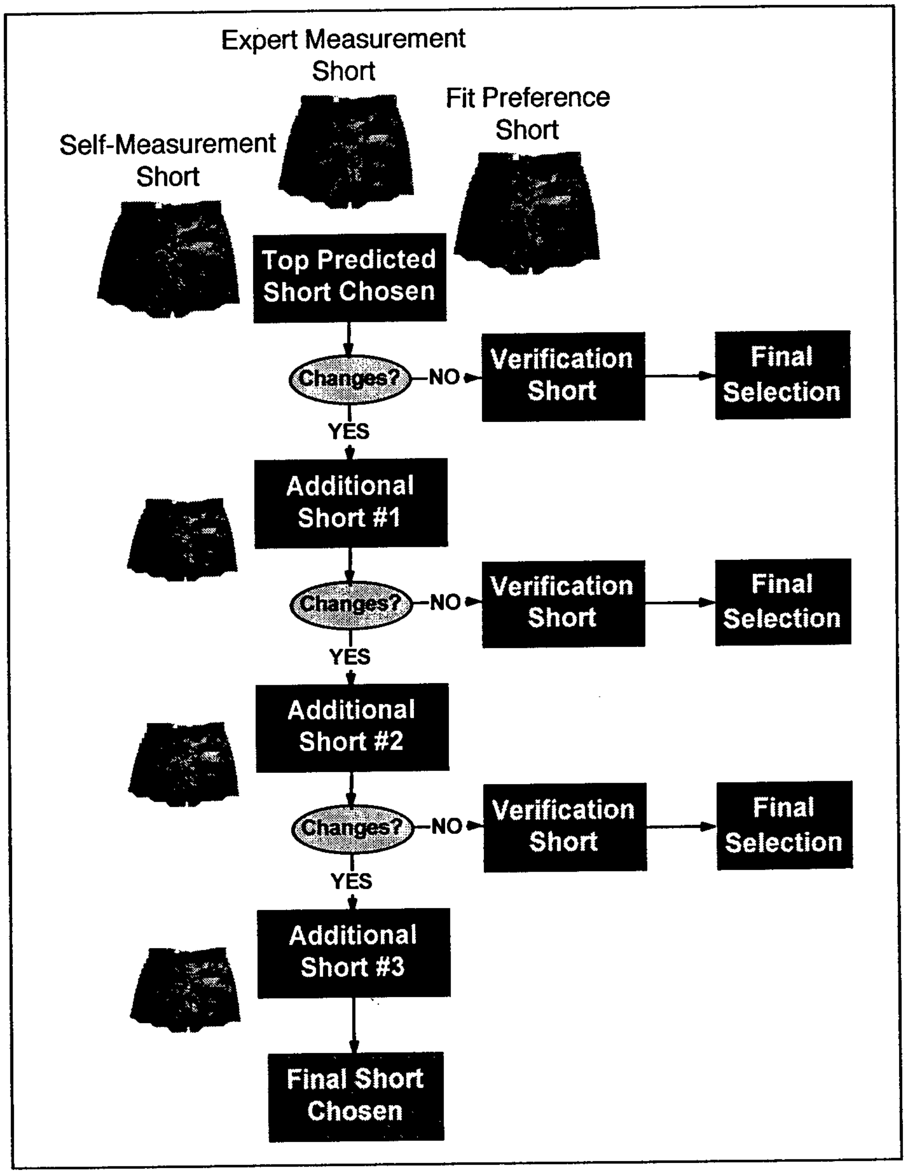


Figure 3.11 Fit Testing Flowchart

Once optimum short selection was made subjects were instructed to change back into their own clothing and presented with the final questionnaire. Subjects that had self-measurement discrepancies of greater than two inches for any measurement were asked to complete a measurement discrepancy form. This form was used to help isolate error tendencies and modify self-measurement procedures. At the completion of testing test subjects were offered refreshments and reimbursed with their $5 testing fee.

3.10 Data Analysis

Data Desk, a statistical software package was used to analyze test and supporting anthropometric data. Single sample regression analysis was be conducted to evaluate the predictability of final short selection for the independent variables self-measurement, self-measurement with fit preference, and expert measurement. Single sample regressions with a 0.025 level of significance was used to evaluate the significance of each measurement technique. Descriptive statistical measures for stratified subsets of Army subject data were calculated to estimate size ranges for test participants and facilitate test short manufacturing.

In final data analysis, the correlation of expert and self-measurement variables were evaluated and a two-level variable established for identification and evaluation purposes. Likert scales used in the satisfaction of fit questionnaires were translated into quantitative variables for analysis purposes. A variety of graphical display methods were employed for initial and final data analysis. Hypothesis testing was completed by a comparison of error rates between predicted short sizes generated from various measurement techniques and fit preference adjustments with the sizes of optimum shorts. Since test shorts are sized in both crotch and waist dimensions there is not a linear progression between short sizes. This restricts the comparison of actual short sizes. Error rates between sizes were determined to be a viable alternative for comparison. These error rates combine the normalized differences between waist and crotch measurements in predicted and optimum shorts. Values are normalized by dividing the difference in inches between predicted and optimum shorts by the size of the optimum short. Mean error rates for each prediction method provide another basis for comparison and hypothesis testing.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Sample Characteristics

A total of 35 test participants participated in the primary testing portion of this research project. All participants were male Cornell University graduate and undergraduate students enrolled in Fall Semester, 1999 courses. One student's test results were removed from the study when it was found that his size requirements were much smaller than the manufactured test shorts accommodated. In addition to his measurement and testing data, this participant's questionnaire responses were also removed from the study since he was unable to complete the full study. All other test participants were able to achieve satisfactory fit results with their final test short selections.

The mean age for the sample was 21.1 years old with a standard deviation of 4.9 years. The median age was 19 with twelve test participants 18 years old and nine participants 19 years old (see Figure 4.1). The youngest test participant was 17 years old and the oldest test participant was 35 years old. Besides the 35 year old test participant, there were two additional test participants over 30 years of age with one 31 years of age and one 33 years of age. Overall, the test sample was a good representation of the ages found in the ANSUR study. Although a 30 year old and under data set was extracted from the ANSUR data to make initial testing assumptions, the inclusion of three test participants 31 years of age and older does not appear to require any alterations to initial assumptions.

Frequency breakdown of		Age
No Selector		
Total Cases	34	
Group	Count	%
17	1	2.941
18	12	35.294
19	9	26.471
20	3	8.824
21	1	2.941
24	1	2.941
25	1	2.941
27	1	2.941
29	2	5.882
31	1	2.941
33	1	2.941
35	1	2.941

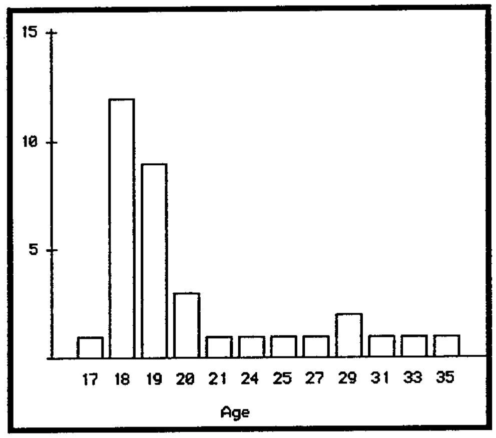


Figure 4.1 Test Sample Age Frequencies

A much larger percentage of test participants was of Asian decent in the test sample than found in the ANSUR data. In the complete ANSUR study only 1.6% of males were listed as Asian while 23.5% of the male test participants from the Cornell University sample were Asian (see Figure 4.2). In addition, a much smaller percentage of Black participants (5.9%) was present in the Cornell sample as compared to 25.8% of Black males in ANSUR study working data base. A higher Asian and lower Black ethnic mix was anticipated early in the preliminary analysis phase of the research project. The 67.6% of Cornell participants reported as White was consistent with the 66.1% found in the ANSUR data.

Frequency breakdown of		Race/Ethnicity
No Selector		
Total Cases	34	
Group	Count	%
Asian	8	23.529
Black	2	5.882
Hispanic	1	2.941
White	23	67.647

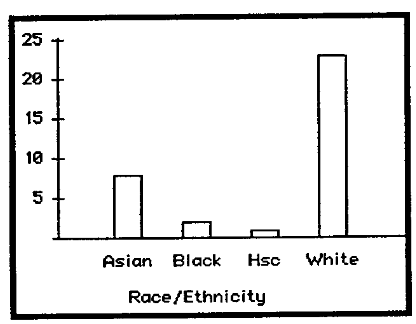


Figure 4.2 Test Sample Race/Ethnicity

Due to the higher percentage of Asian students an initial review of the sample pool of Cornell University students revealed that the test short sizing requirements for the research sample may be smaller than the sizing required for the subject mixture predominantly found in the ANSUR study. This assumption was based on the disparity in average anthropometric measurements reported for Black and Asian racial groups. Because of this fact a 30-inch waist size short with four crotch length variations was added in final pattern development rather than the 35.5-inch short was indicated in the ANSUR data review. The anticipated Cornell University sample characteristics also led to a base sizing shift from the 34-inch base size short in Hagale's original pattern to a 33-inch base size short in the final test short pattern. This task was accomplished by moving the base size designation from Hagale's 34-inch waist size short to their 33-inch waist size short. Aside from a smaller waist circumference, no other racial or ethnic-based assumptions were made about test participant characteristics or sizing requirements and no other demographic information was gathered from the test participants.

4.2 Background Purchasing Information

In terms of apparel purchasing information, test participants were asked to report common sizes of pants and shorts normally worn. A total of 73.5% of test participants reported wearing pants or shorts in waist sizes between 32 and 34 inches (see Figure 4.3). The mean reported waist size worn was 32.5 inches with a standard deviation of 1.5 inches. Only 19 participants reported wearing pants or shorts in general size categories (S, M, L, XL). Of these respondents, two participants reported wearing a small size while nine reported wearing a medium and eight reported wearing large (see Appendix

C, p 189). Twenty participants reported purchasing clothing items with additional sizing identifiers. These identifiers were evenly spread between short, tall, and long (see Appendix C, p 189). In general inseam lengths reported ranged from 30 to 34 inches. Several test participants reported wearing clothing in a small range of waist, inseam, and general size categories rather than a consistent size. This finding is indicative of the lack of standardization in sizing for mass produced clothing items and variations found between different manufacturers.

Frequency breakdown of **Waist Size**
No Selector

Total Cases 34

Group	**Count**	**%**
30	6	17.647
31	2	5.882
32	9	26.471
33	5	14.706
34	11	32.353
36	1	2.941

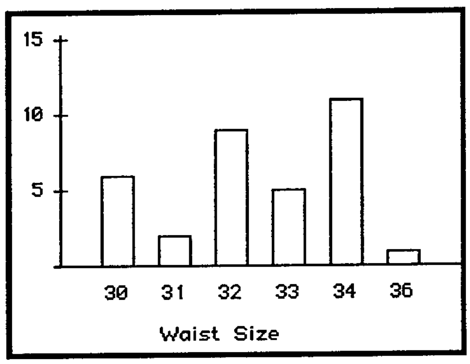


Figure 4.3 Reported Waist Sizes

In a review of reported waist size versus the waist size of the optimum test shorts selected during the fit testing session, reported waist sizes averaged 1/2-inch larger than the optimum test short sizes (see Figure 4.4). However, there was a large variance between these waist sizes indicating important issues relating to testing and mass produced apparel sizing. First, the sizing measurements used by apparel manufacturers and communicated to customers through labeling and hang tags may not accurately represent garment dimensions and may not be consistent between manufacturers. Second, test participants may have made compromises in their acceptance level for fit satisfaction in order to wear mass produced apparel items and third, test short sizing appears to average 1/2-inch smaller than common mass produced apparel sizing for waist circumference. This last finding may be due to the waist size shift in base patterns from a 34-inch waist size to a 33-inch waist size.

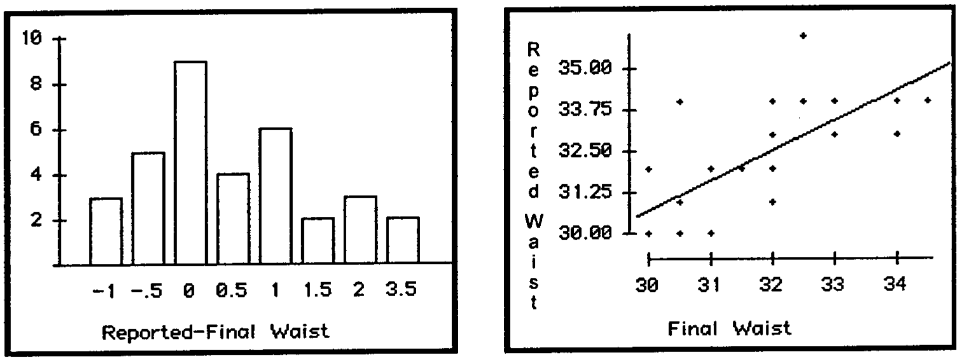


Figure 4.4 Differences in Final and Reported Waist Sizes

On average, participants report that they purchase 83.6% of their own clothing. Five participants indicated that they purchased 100% of their clothing while one participant reported that he purchased only 25% of his own clothing. One participant did not respond to the question. An inference can be made that test participants reporting higher percentages for self-purchases may have broader experience in retail purchasing and sizing-related issues.

Of the 16 participants whose optimum test shorts were either correctly predicted or one size off using a combination of self-measurement and fit preference in the adjusted size prediction model, four reported purchasing 100% of their clothing themselves, three reported purchasing 95% and another six reported purchasing 90%. This may indicate that subjects with greater retail purchasing experience can be more successful in providing ordering information that predicts clothing that maximizes satisfaction of fit.

Participants reported that the majority of their clothing purchases were made in retail department stores followed by discount clothing stores and then sporting goods retailers (see Appendix C, p 189). Only five test participants reported purchasing clothing over the Internet and this accounted for only 10% of their total clothing purchases. It was surprising to see the extremely small number of Internet clothing purchases made by this age group. This may be more an indication of the currently limited number Internet retail clothing sites rather than a general dislike for this type of purchasing option. Eleven participants reported using mail-order catalogs to make clothing purchases. Considering the age of test participants, it is not surprising that catalog ordering was somewhat limited. Most retail mail-order catalog retailers offer highly specialized products designed for specific target customers that cannot generally meet their retail purchasing requirements in traditional stores.

Twenty-seven out of 34 test participants reported that they try on garments before purchasing them. Slightly more than half of these participants look at manufacturer sizing information but only 17.6% of all test respondents reported following these sizing instructions. This may indicate a general distrust for sizing information provided by apparel manufacturers and perceived need to try on garments before purchasing them. In terms of attribute significance, test participants rated comfort and fit with the highest levels of importance when purchasing shorts (see Table 4.1). Features and fabric selection received the lowest ratings for purchasing importance. Since this questionnaire was completed at the conclusion of fit testing sessions, increased awareness of the test participants toward fit-related factors in apparel may have significantly influenced the findings for this series of survey questions. Administering this line of questioning prior to the fit test session may have increased the validity of responses to this question. In Table 4.1 subjects rated the importance of garment characteristics on a scale of one to five with five being very important and one being not important.

Table 4.1 Short Attribute Significance

Summaries
No Selector

Variable	Count	Mean	Median	StdDev
Fit	34	4.44118	5	0.746352
Style	34	4.17647	4	0.833779
Durability	34	3.70588	4	0.871412
Features	34	3.29412	3	0.871412
Comfort	34	4.55882	5	0.746352
Fabric	34	3.41176	3.5	0.74336
Price	34	4.02941	4	0.936961

Similarly, responses on the ease of finding good fitting ready-to-wear clothing may have been influenced by recent experience with fit testing analysis. Participants reported greater difficulty in finding good fitting ready-to-wear pants in comparison to shorts. The main problem reported was the common mismatch between waist and inseam sizes or the non-availability of the correct sizing mix between these two variables. However, test participants did not appear to have any great difficulties in finding good fitting ready-to-wear clothing. Since the subject pool was limited to students with waist circumferences between 30 and 35 inches corresponding to plus or minus one standard deviation from the mean waist size in the ANSUR study, this finding was not at all surprising. The farther waist size ranges get from the mean for the population, the greater the difficulty men may have in finding good fitting, mass produced clothing items in the correct range of sizes.

Only one test participant reported having alterations done on clothing items previously purchased. This is further indication of the ease in which this group of participants can potentially purchase good fitting ready-to-wear clothing. All test participants reported that the way their clothing feels on their body is important to them. They also all reported that the clothing they wear most often is generally the most comfortable. These questions may have required rewording to improve their importance and effectiveness. This could be accomplished changing the scale of responses to gain more precision and variation in responses. Otherwise, these questions could be eliminated since all test participants provided the same answers.

Only two test participants reported on the questionnaire that they generally preferred shorts and pants with a tighter feel on the body. This finding conflicts with fit preference responses from the Internet website. Four test participants indicated they preferred shorts with an overall tighter fit on their order forms. A total of seven test participants also indicated tighter fit preferences in one or more lower body areas in their fit preference responses from the Internet website. Since background fit preference questions on the final survey followed the same format as the fit preferences queries on the Internet website, one could conclude that experience gained in the fit analysis stage of research testing changed participant awareness of fit preference responses. By instructing retail customers to try on a variety of clothing items with different fit characteristics prior to completing a fit preference questioning section, the accuracy of ordering responses may be improved. This hands-on reconfirmation of fit preference could occur with clothing the customer already owns or it could involve shopping at a clothing retailer's store. Recent experience with traditional retail clothing purchases may increase sizing and accurate fit preference awareness for customers.

4.3 Size Prediction Model Results

The size prediction model was originally designed to predict short sizes from expert measurement, self-measurement, and self-measurement plus fit preference data. After the conclusion of fit testing, the model was optimized and a fourth prediction category was included to provide a short size generated from expert measurement plus fit preference data. This category was created to test the hypothesis that the addition of fit preference responses to an apparel ordering model improved satisfaction of fit regardless of whether the base measurements are made by the subject or by an expert. Once optimum test short selections were made by test participants during the fit testing sessions predictions for short sizes could be analyzed for accuracy.

The original size prediction model yielded nine short predictions with 100% accuracy in waist and crotch dimensions from expert measurements (see Table 4.2). Another four test short predictions for expert measurement were one size off in either waist or crotch size. For self-measurement prediction only two shorts were predicted with 100% accuracy while another nine short predictions were one size off in either the crotch or waist size. Six shorts were predicted accurately with self-measurement plus fit preference size predictions while an additional nine predictions were one size off. For both expert measurement and self-measurement plus fit preference, the size prediction model had greater accuracy in predicting crotch sizes than waist sizes. The accuracy for crotch sizes decreased dramatically for self-measurement predictions in the original model. This may indicate self-measurement problems resulting from taking measurements directly over the subjects' clothing. This can introduce sizing variations due to style differences.

In Table 4.2 exact and one size off waist and crotch size predictions are highlighted as exact/ acceptable fit. The remaining predictions are highlighted and grouped as either marginal or poor fit. On average test participants overstated their crotch measurements by 0.8 inches. Fourteen of the 34 test participants overstated their crotch lengths by 1-1/2 inches or more (see Appendix D, p 202).

Table 4.2 Initial Size Prediction Model Results

Waist	EM	SM	FP
Exact	13	11	12
1 off	10	13	10
2 off	7	5	6
3 off	4	1	2
4 off	0	2	0
5 off	0	2	4

Crotch	EM	SM	FP
Exact	16	7	14
1 off	11	18	13
2 off	7	5	4
3 off	0	4	3

EM - Expert Measurement
SM - Self-Measurement
SM/FP - Self-Measurement plus Fit Preference
Exact - Predicted size equals optimum size
 # off - Number of sizes away from optimum size
 # / # - Waist sizes off / Crotch sizes off

Exact / Acceptable Fit
Marginal Fit
Poor Fit

Total	EM	SM	FP
Exact	9	2	6
0/1	2	6	4
1/0	2	3	5
1/1	7	8	4
2/0	4	1	1
0/2	2	2	2
2/1	1	2	2
1/2	1	2	1
3/0	1	0	1
0/3	0	1	0
2/2	2	0	1
3/1	1	1	1
1/3	0	0	0
4/0	0	1	0
3/2	2	0	0
2/3	0	2	2
4/1	0	0	0
5/0	0	0	1
3/3	0	0	0
4/2	0	0	0
5/1	0	1	2
4/3	0	1	0
5/2	0	1	0
5/3	0	0	1

Self-measurement and self-measurement plus fit preference predictions resulted in an average of 7.5 test short size predictions a total of four or more size increments away from the optimum fitted short size in a combined total of waist and crotch size increments. Expert measurement had five test short size predictions in this range of misfit. Over 88% percent of expert measurement predictions were within two waist sizes or better of the optimum test short size and over 79% were within one size or better of the optimum crotch length. Both self-measurement and self-measurement plus fit preference had lower accuracy for individual size predictions for waist and crotch dimensions.

While expert measurement had the most consistent results for identifying either exact or one-size off garment sizes when judging crotch and waist fit separately the same results were not found when looking at predictions for locating the best fit in both dimensions. Including predictions for exact or single size off in either crotch or waist size (but not both), the self-measurement plus fit preference size predictions resulted in the highest level of prediction accuracy. A total of 44.1% of test shorts was predicted in this range using self-measurement plus fit preference. For expert measurement, 41.1% of test short predictions demonstrated this level of accuracy while only 32.4% of self-measurement predictions achieved this goal. However, expert measurement proved to be the best predictor for finding the greatest number of short sizes closest to the optimum fitted pairs when all test participants were considered. The primary reason for this finding appears to be the wide variance in reported self-measurement results.

In single sample regression analysis, the hypothesis is that the individual mean errors for expert, self, and self plus fit preference measurement predictions equal zero. Mean error rates were calculated using a comparison pattern waist and crotch measurements for predicted and optimum short sizes. Since the error rates are reported as absolute values, the alternate hypothesis is that the individual mean errors for expert, self, and self plus fit preference measurement predictions are greater than zero.

Therefore, this is a single sided t-test. An alpha level of 0.025 was used as the significance level for testing. A measurement category is a better predictor of the optimum test short the closer the mean error rate for a respective category is to zero.

Predicted and optimum test short sizes were compared by waist circumference and crotch length measurements in inches rather than predicted short sizes. The differences between the optimum and predicted short sizes for each measurement category were then found. Each result was divided by its respective optimum waist and crotch size to give the relative error rate for the prediction model measurement category. A total error rate for each measurement category was found by combining the absolute value of error rates for both waist and crotch size predictions. These error rates were then used to evaluate the effectiveness of the prediction model. Identical calculations were made for expert, self-measurement, and self-measurement plus fit preference predictions.

The total error rates were recorded in a text file and imported into DataDesk for statistical analysis. The mean total error rate for expert measurement was 5.0% while the mean total error rate for self-measurement was 7.4%. The mean total error rate for self-measurement plus fit preference was 6.4% indicating that expert measurement provided the greatest accuracy in test short prediction (see Table 4.3).

From the number of exact short size predictions for the initial size prediction model the inclusion of fit preference with self-measurement appears to improve the accuracy of this category. However, in single sample regression analysis with an alpha level of 0.025, the hypothesis that the mean error rates for all measurement categories were zero was rejected (see Appendix D, pp 203-205). This means that alternate hypothesis which states the mean error rates for each measurement category are greater than zero is supported and indicates that none of the measurement category models are statistically good predictors of optimum test short size. Individual test shorts accurately predicted by their respective measurement categories are highlighted in gray in Table 4.3 and have a value of zero.

Table 4.3 Initial Size Prediction Model Total Error Rates

	Expert	Self	Self + Fit
	8.1%	5.0%	5.0%
	6.4%	10.5%	10.5%
	0.0%	8.4%	3.1%
	5.3%	3.0%	0.0%
	5.1%	11.9%	14.9%
	8.9%	7.3%	0.0%
	10.3%	5.2%	5.2%
	4.8%	5.8%	5.8%
	5.8%	2.9%	10.4%
	8.5%	7.3%	0.0%
	4.9%	4.8%	4.8%
	0.0%	9.4%	9.3%
	0.0%	15.4%	15.7%
	0.0%	4.5%	4.7%
	4.7%	4.5%	4.5%
	5.8%	9.1%	2.9%
	0.0%	0.0%	3.0%
	14.2%	13.4%	13.4%
	3.1%	5.1%	3.1%
	10.6%	5.3%	10.6%
	5.8%	10.4%	8.7%
	4.7%	7.4%	0.0%
	0.0%	13.7%	13.7%
	5.3%	5.3%	0.0%
	4.9%	4.9%	4.9%
	0.0%	0.0%	0.0%
	9.8%	5.0%	4.9%
	4.6%	13.3%	13.3%
	0.0%	10.1%	10.3%
	0.0%	10.2%	10.2%
	10.0%	14.3%	5.0%
	10.0%	3.0%	3.0%
	5.2%	5.3%	5.3%
	2.9%	10.0%	9.9%
Avg	5.0%	7.4%	6.4%

In several instances there are large range of error rates between size predictions in the initial size prediction model and the optimum sizes. Assuming the accuracy of the base model, this disparity could be caused by one or any combination of four variables. They include waist height variations, variations in fit preference understanding and reporting, measurement errors, and undetermined factors. In some cases accurate self-measurement or self-measurement plus fit preference predictions occurred when expert measurement findings produced high error rates. If the model itself is accurate, then it should be reasonable to assume that high error rates in the expert measurement category would also result in high error rates for all the self-measurement categories (assuming that expert measurement is a more reliable method). When this result is not found it indicates that seemingly accurate predictions for self-measurements and self-measurement plus fit preference may be due more to a combination of the four variables previously mentioned rather than the accuracy of the prediction model.

In order for self-measurement based size predictions to be considered accurate, large error rates for expert measurements must be explained or nonexistent. If the lack of fit preference information combined with expert measurement contributes to the inaccuracies in expert measurement predictions, then the combination of these fit preference adjustments with self-measurement findings may result in accurate predictions. However, this can only occur if measurements generated by expert and self-measurement procedures are similar. When larger variations in self-measurements that result from a lack of reliability are combined with fit preference adjustments and yet they yield accurate predictions, serious questions have to be raised about the overall validity of this type of prediction model.

Major shifts in waist height may cause differences between expert and self-measurements and explain the lack of accuracy in some size predictions. Of the six shorts predicted accurately by the self-measurement plus fit preference in the size prediction model, three had self-measurements with large differences between their corresponding expert measurements. One subject had a self-measured preferred waist 2 inches larger than expert measurement findings and a crotch length 4 inches smaller. A second subject had a self-measured crotch length 3 inches shorter than expert measurement and the third subject had a preferred waist 1.75 inches smaller and crotch 1 inch smaller than expert measurements. Yet all three subjects had correctly predicted the optimum shorts with self-measurement and fit preference results. The first short with the largest error rates could be explained if preferred measurements were taken at a high waist level and the participant wore his optimum shorts at a low waist level. This fact would explain the larger waist and shorter crotch length. The other two shorts can not be explained by this approach.

An expert measurement model that provided statistically significant prediction results may be needed before an expanded model that includes self-measurement and self-measurement plus fit preference can be developed. However, it is important to note that expert measurement alone may not predict optimum short size without the inclusion of fit preference. The resolution of this suggested expert measurement model could be much lower than the tolerances tested in this research project. It is possible that, for example, half-inch waist increments are not necessary to provide fit satisfaction. More sizes may not add to the level of fit satisfaction. In this case a lower resolution prediction model could be more successful. As another example, an expert measurement size prediction model that used one inch increments in waist sizes and two or three larger variations in crotch size might provide the baseline data needed to evaluate self-measurement and self-measurement plus fit preference prediction results. At a minimum the accuracy rates for a baseline prediction model are needed to check the statistical significance of other measurement and prediction techniques.

The fact that the test participants may have the ability to perceive waist and crotch variations as small as 1/2 inch does not mean that sizing models can accurately predict optimum short selections at this level of resolution. By decreasing the level of resolution in the model, statistically significant predictions can first be made first for expert measurements then for self-measurement and self-measurement plus fit preference. Measurement categories can then be evaluated for their effectiveness in prediction and their statistical significance. After noting some of the deficiencies in the initial size prediction model, optimizing the model with its inherent errors and unresolved factors may only serve to enhance and magnify the problems.

As discussed in Section 3.5.2 the size prediction model was adjusted to improve accuracy rates for all measurement predictions. Optimization included shifting the sizing chart for waist and crotch measurement ranges, adjusting fit preference weighting and adjustment values, applying a waist height fit preference adjustment, and interpreting the difference between waist circumference measured at the omphalion and the preferred waist. The adjusted size prediction model yielded nine short predictions with 100% accuracy in waist and crotch dimensions for expert measurements (see Table 4.4). Another five test short predictions for expert measurement were one size off in either waist or crotch size. For expert measurement plus fit preference ten shorts were predicted with 100% accuracy and another ten shorts were one size off in either measurement area. For self-measurement prediction five shorts were predicted with 100% accuracy while another nine short predictions were one size off in either the crotch or waist size. With self-measurement plus fit preference size predictions nine shorts were accurately predicted while an additional seven were one size off.

Table 4.4 Adjusted Size Prediction Model Results

Waist	EM	EM/FP	SM	SM/FP
Exact	14	16	11	12
1 off	9	8	13	12
2 off	7	5	5	4
3 off	4	5	1	1
4 off	0	0	2	4
5 off	0	0	2	1

Crotch	EM	EM/FP	SM	SM/FP
Exact	16	21	15	19
1 off	12	9	9	7
2 off	6	3	8	8
3 off	0	1	2	0

Total	EM	EM/FP	SM	SM/FP
Exact	9	10	5	9
0/1	3	4	2	2
1/0	2	6	7	5
1/1	6	2	3	2
2/0	3	3	1	1
0/2	2	2	4	1
2/1	2	1	2	2
1/2	1	0	3	5
3/0	2	2	1	1
0/3	0	0	0	0
2/2	2	0	0	1
3/1	1	2	0	0
1/3	0	0	0	0
4/0	0	0	1	3
3/2	1	1	0	0
2/3	0	1	2	0
4/1	0	0	0	0
5/0	0	0	0	0
3/3	0	0	0	0
4/2	0	0	1	1
5/1	0	0	2	1
4/3	0	0	0	0
5/2	0	0	0	0
5/3	0	0	0	0

EM - Expert Measurement
EM/FP - Expert Measurement plus Fit Preference
SM - Self-Measurement
SM/FP - Self-Measurement plus Fit Preference
Exact - Predicted size equals optimum size
 # off - Number of sizes away from optimum size
 # / # - Waist sizes off / Crotch sizes off

Exact / Acceptable Fit
Marginal Fit
Poor Fit

For all measurement and fit preference categories the size prediction model had greater accuracy in predicting crotch sizes than waist sizes. Expert measurement plus fit preference resulted in the best overall prediction results. In Table 4.4 exact and one size off waist and crotch size predictions are highlighted as exact fit. The remaining predictions are highlighted and grouped as either marginal or poor fit. Poor fit predictions were four or more sizes of in the total prediction table, four or more sizes off in the waist prediction table and three or more sizes off in the crotch prediction table.

Sixteen shorts from expert measurement plus fit preference predictions were 100% accurate in waist sizing and 21 shorts were 100% accurate in crotch sizing. Self-measurement plus fit preference had the second highest accuracy in crotch size predictions with 19 out of 34 short sizes correctly predicted. Expert measurement alone had the second best waist size prediction results with 23 out of 34 or 68% of sizes within one size or better of the optimum waist size. In terms of overall error rates, expert measurement plus fit preference had the best results. Expert measurement alone was the second best predictor of short size followed by self-measurement plus fit preference in a close third. The average error rate for expert measurement plus fit preference was 4.5%. This is an increase of over 0.5% from expert measurement results in the initial size prediction model.

Including predictions for exact or single size off in either crotch or waist size, a total of 58.8% of test shorts was accurately predicted in this range for expert measurement plus fit preference. This is a 14.7% increase over the best results obtained from the initial prediction model. Both expert measurement and self-measurement achieved a level of 41.2% accuracy for test short predictions in the adjusted size prediction model while 47.1% of self-measurement plus fit preference predictions achieved this level of accuracy.

In single sample regression analysis, the hypothesis to be tested is that the individual mean errors for expert, expert plus fit preference, self, and self plus fit preference measurement predictions are zero. The alternate hypothesis is that the individual mean errors for expert, expert plus fit preference, self, and self plus fit preference measurement predictions are greater than zero. This is a single sided t-test since the absolute values for error rates are used and the results are bounded by zero. An alpha level of 0.025 was again used as the significance level for testing. In terms of specific results, expert measurement plus fit preference was the best predictor of the optimum test short size with a mean error rate closest to zero (see Table 4.5). Error rates were found using the same procedures as in the initial model.

Table 4.5 Adjusted Size Prediction Model Total Error Rates

	Expert	Exp + Fit	Self	Self + Fit
	8.1%	5.0%	0.0%	3.1%
	6.4%	3.2%	10.5%	10.6%
	0.0%	0.0%	13.7%	5.3%
	8.9%	8.9%	3.0%	3.0%
	5.1%	5.2%	11.9%	19.7%
	8.9%	8.9%	2.8%	2.8%
	10.3%	10.3%	10.3%	10.3%
	4.8%	2.9%	10.4%	7.5%
	4.9%	4.6%	7.5%	10.4%
	8.5%	8.5%	2.8%	2.8%
	4.9%	4.9%	0.0%	0.0%
	4.7%	0.0%	9.4%	9.4%
	0.0%	0.0%	10.6%	10.6%
	4.5%	7.3%	4.5%	0.0%
	2.8%	2.8%	0.0%	0.0%
	5.8%	5.8%	4.6%	0.0%
	0.0%	0.0%	0.0%	0.0%
	14.2%	12.6%	13.4%	8.8%
	0.0%	0.0%	3.1%	0.0%
	10.6%	15.8%	5.3%	10.6%
	5.8%	0.0%	5.8%	11.7%
	4.7%	0.0%	2.9%	5.7%
	0.0%	0.0%	13.7%	9.1%
	5.3%	3.2%	10.5%	5.3%
	4.9%	6.0%	4.9%	4.9%
	0.0%	0.0%	0.0%	0.0%
	5.1%	9.8%	5.0%	5.0%
	0.0%	2.9%	8.7%	8.7%
	0.0%	5.0%	10.1%	10.1%
	0.0%	0.0%	10.2%	11.8%
	10.0%	6.1%	9.5%	0.0%
	10.0%	5.1%	3.0%	0.0%
	5.2%	5.2%	3.1%	3.1%
	2.9%	2.9%	9.9%	11.5%
Avg	4.9%	4.5%	6.5%	5.9%

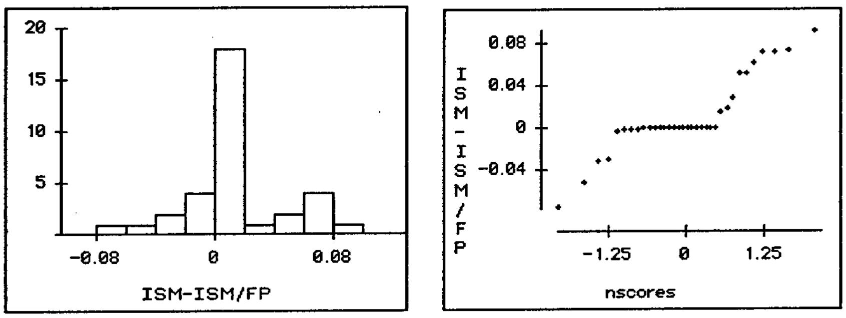
The mean total error rate for expert measurement was 4.9% while the mean total error rate for expert measurement plus fit preference was 4.5%. The mean total error rate for self-measurement was 6.5% while self-measurement plus fit preference resulted in a mean rate of 5.9%. From the number of exact short size predictions in the adjusted model the inclusion of fit preference with both expert and self-measurement appears to improve the accuracy of both categories. However, in single sample regression analysis with an alpha level of 0.025, the hypothesis that the mean error rates for all measurement categories were zero was rejected (see Appendix D, pp 203-205). This means that the alternate hypothesis which states the mean error rates for each measurement category are greater than zero is supported. It also indicates that none of the measurement categories in the size prediction model are statistically good predictors of optimum test short size. Individual test shorts accurately predicted by their respective measurement categories are highlighted in gray in Table 4.5 and have a value of zero.

The optimization of the size prediction model does a good job maximizing the prediction results for the research sample. Weights and adjustment values for waist, crotch, and seat fit preference provide an excellent base for future model testing. Adjustments for waist height fit preference and disparity between waist circumference taken at the omphalion and the preferred waist need further review. It is unclear if these additional adjustments are correcting unexplained errors in ordering procedures or correctly adjusting for their intended purposes. Accuracy rates for the adjusted model require a baseline measure to determine their effectiveness.

4.4 Hypothesis Testing Results

Hypothesis A proposes that the addition of fit preference to an apparel ordering model better predicts optimum short size. In order to evaluate this hypothesis error rates for self-measurement and self-measurement plus fit preference predictions from both the initial and adjusted size prediction models were tested along with expert measurement and expert measurement plus fit preference predictions from the adjusted model. A paired t-test with the null hypothesis, H_0: $\mu(1\text{-}2) = 0$ and an alternate hypothesis H_a: $\mu(1\text{-}2) > 0$, was used. Since this is a one-sided test an alpha level of 0.025 was used for significance testing. If test results show a failure to reject the null hypothesis, this would indicate a greater probability that there was no statistical difference between predictions generated by body measurements and body measurements plus fit preference adjustments. If the null hypothesis is rejected this would provide support for the alternate hypothesis and indicate that fit preference adjusted body measurements for a particular measurement method are a better predictor of optimum short size.

Self-measurement and self-measurement plus fit preference error rates generated by the initial size prediction model were tested first. Paired t-test results failed to reject the null hypothesis at an alpha level of 0.025 (see Figure 4.5). Judged at this level of significance, self-measurement plus fit preference predictions in the initial size prediction model are not a significantly better predictor of optimum test short size than self-measurement alone. However, the p-value of 0.0494 indicates that the null hypothesis would have been rejected at an alpha level of 0.05 or greater. There is a 95% or greater probability that fit preference adjusted self-measurement from the initial size prediction model provides better optimum short size predictions than self-measurement alone. The normality of error rate distributions was verified with a normal probability plot and a histogram (see Figure 4.5). The diagonal straight line in the normal probability plot indicates that the data appear to follow a normal distribution. Since the initial size prediction model was not optimized to improve overall accuracy of the size prediction model it is more important to evaluate significance tests for the adjusted size prediction model.

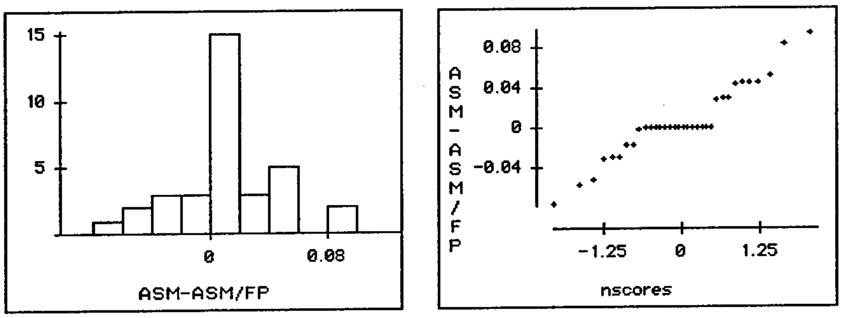


Paired t-Test of μ(1 - 2)
No Selector
Individual Alpha Level 0.0250
Ho: μ(1 - 2) = 0 Ha: μ(1 - 2) > 0

In Self - In Self/Fit :
Test Ho: μ(In Self-In Self/Fit) = 0 vs Ha: μ(In Self-In Self/Fit) > 0
Mean of Paired Differences = 0.010415059 t-Statistic = 1.699 w/33 df
Fail to reject Ho at Alpha = 0.0250
p = 0.0494

Figure 4.5 Paired t-Test for Initial Self-Measurement Errors

For self-measurement and self-measurement plus fit preference error rates generated by the adjusted size prediction model paired t-test results also failed to reject the null hypothesis at an alpha level of 0.025 (see Figure 4.6). This means it is improbable that fit preference adjusted size predictions for self-measurement in the adjusted size prediction model are better predictors of optimum test short size. The large p-value of 0.1864 indicates a high probability that self-measurement and self-measurement plus fit preference predictions from the adjusted size prediction model are equivalent. This means the addition of fit preference adjustments for self-measurements in the adjusted size prediction model may not improve optimum short size selection. Normality was again verified with a normal probability plot and a histogram.

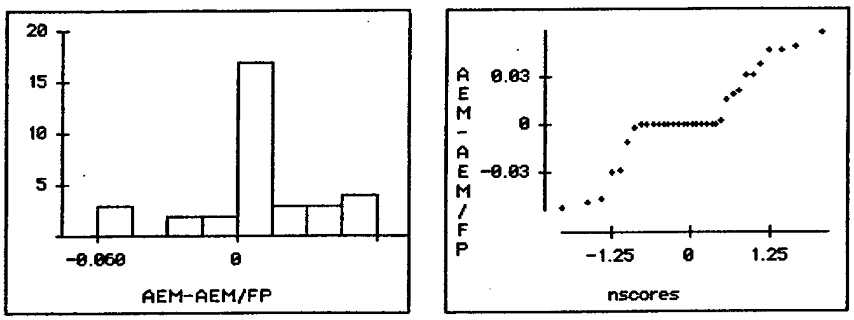



```
Paired t-Test of μ(1 - 2 )
No Selector
Individual Alpha Level 0.0250
Ho: μ(1 - 2 ) =  0 Ha:  μ(1 - 2 ) > 0

Adj Self  -  Adj Self/Fit:
Test Ho: μ(Adj Self-Adj Self/Fit) = 0 vs Ha: μ(Adj Self-Adj Self/Fit) > 0
Mean of Paired Differences = 0.0056682647 t-Statistic = 0.9035 w/33 df
Fail to reject Ho at Alpha = 0.0250
p = 0.1864
```

Figure 4.6 Paired t-Test for Adjusted Self-Measurement Errors

Expert measurement and expert measurement plus fit preference error rates generated by the adjusted size prediction model gave similar paired t-test results as self-measurement for the adjusted size prediction model. The paired t-test failed to reject the null hypothesis at an alpha level of 0.025 (see Figure 4.7). It is also improbable that fit preference adjusted size predictions for expert measurement in the adjusted size prediction model are better predictors of optimum test short size than expert measurements alone. The large p-value of 0.1815 indicates the same high probability that expert measurement and expert measurement plus fit preference predictions from the adjusted size prediction model are equivalent. The difference between error rates for expert measurement and expert measurement plus fit preference appear to follow a normal distribution.



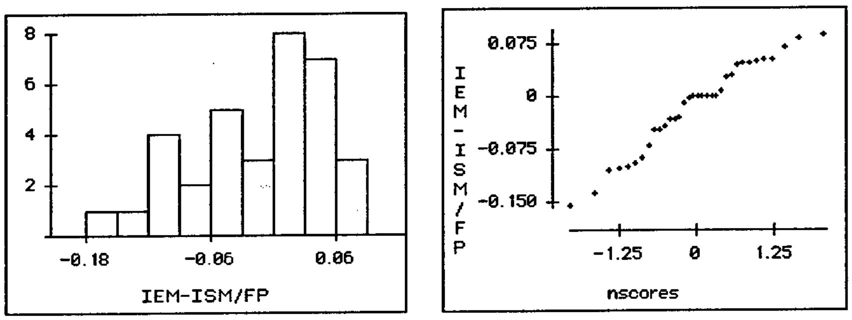
Paired t-Test of μ(1 - 2)
No Selector
Individual Alpha Level 0.0250
Ho: μ(1 - 2) = 0 Ha: μ(1 - 2) > 0

Adj Exp - Adj Exp/Fit:
Test Ho: μ(Adj Exp-Adj Exp/Fit) = 0 vs Ha: μ(Adj Exp-Adj Exp/Fit) > 0
Mean of Paired Differences = 0.0042114118 t-Statistic = 0.9223 w/33 df
Fail to reject Ho at Alpha = 0.0250
p = 0.1815

Figure 4.7 Paired t-Test for Adjusted Expert Measurement Errors

There was support for hypothesis A at the 0.05 level when comparing fit preference adjusted self-measurements to self-measurements in the initial model but no support in the adjusted model. However, the lack of optimization in the initial size prediction model may decrease the relative importance of fit preference adjustments in better prediction of optimum size.

Hypothesis B proposes that an apparel ordering model that includes fit preference and self-measurement predicts optimum short size better than expert measurement alone. In order to test this hypothesis a paired t-test was again used with an alpha level of 0.025. For the initial size prediction model this test for expert measurement and self-measurement plus fit preference error rates revealed a failure to reject the null hypothesis (see Figure 4.8). A very large p-value of 0.8885 was found indicating a high probability that self-measurement plus fit preference did not provide improved selection of optimum short size over expert measurement.



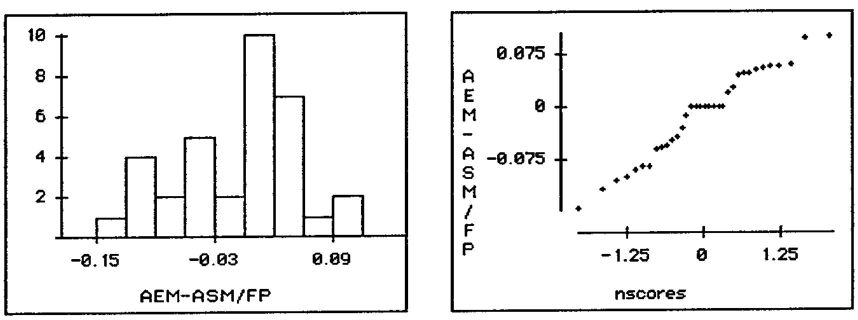

```
Paired t-Test of μ(1 - 2 )
No Selector
Individual Alpha Level 0.0250
Ho: μ(1 - 2 ) =  0  Ha:  μ(1 - 2 ) > 0

In Exp  -  In Self/Fit:
Test Ho: μ(In Exp-In Self/Fit) = 0 vs Ha: μ(In Exp-In Self/Fit) > 0
Mean of Paired Differences = -0.013626353 t-Statistic = -1.242 w/33 df
Fail to reject Ho at Alpha = 0.0250
p = 0.8885
```

Figure 4.8 Paired t-Test for Initial Size Prediction Model Errors

As indicated by the histogram in Figure 4.8 there were eight instances where the difference in error rates between expert measurement and self-measurement plus fit preference predictions was greater than 9%. All these occurrences were negative which means expert measurement predictions were significantly better in achieving optimum short sizes for these test subjects. These results were also the primary reason why overall self-measurement plus fit preference appears to be a less accurate predictor of optimum test short size.

The paired t-test results for expert measurement and self-measurement plus fit preference in the adjusted size prediction model yielded results similar to those of the initial size prediction model. Again there was a failure to reject the null hypothesis and a very large p-value of 0.8195 (see Figure 4.9).



Paired t-Test of μ(1 - 2)
No Selector
Individual Alpha Level 0.0250
Ho: μ(1 - 2) = 0 Ha: μ(1 - 2) > 0

Adj Exp - Adj Self/Fit:
Test Ho: μ(Adj Exp-Adj Self/Fit) = 0 vs Ha: μ(Adj Exp-Adj Self/Fit) > 0
Mean of Paired Differences = -0.010173735 t-Statistic = -0.9263 w/33 df
Fail to reject Ho at Alpha = 0.0250
p = 0.8195

Figure 4.9 Paired t-Test for Adjusted Size Prediction Model Errors

In the case of the adjusted size prediction model there were seven instances where the difference in error rates between expert measurement and self-measurement plus fit preference predictions was greater than 9%. Five of these occurrences were negative which means expert measurement predictions were significantly better in achieving optimum short sizes for these test subjects. Again these results appear to be the primary reason why overall self-measurement plus fit preference appears to be a less accurate predictor of optimum test short size.

Large differences in self and expert measurements for approximately 15% of test subjects appear to have limited the accuracy of the self-measurement plus fit preference predictions in both the initial and adjusted size prediction models. Adjustments to self-measurement procedures and the standardization of garments worn while self-measurements are taken may reduce the range of variations between self and expert measurements and provide a better indication of the importance of fit preference adjustments.

There was limited statistical support for Hypothesis A in this research project and no support for Hypothesis B. Since expert measurements were taken under controlled conditions with standard garments there should have been much less variance in expert measurement findings than self-measurements. Self-measurements were taken in a variety of self-selected garments with a range of measuring devices. I believe this fact rather than the importance of fit preference adjustments caused the failure to reject the null hypothesis in paired t-testing for Hypothesis B.

4.5 Measurement Accuracy

Results from self and expert measurements were compared to determine the accuracy of self-measurements at various locations on the lower body. These locations include waist circumference at the omphalion, waist circumference at the preferred waistline, seat circumference, and crotch length. Waist circumference at the omphalion was called girth on the Internet website and the preferred waist measurement was simply waist. Results for all measurements were taken over different garments for expert and self-measurements. It was anticipated that in addition to measurement errors, garment variations would impact measurement results. The girth measurement was taken directly over the skin during expert measurement procedures. Website measuring instructions were unclear on whether to take this measurement over or under garments. Test participants reported using both methods to obtain self-measurements. Girth is a circumference measurement taken horizontally around the body at the navel height (see Appendix F, p 222).

Of all the measurements the girth measurement resulted in the smallest variance between self and expert measurement. Using absolute values, the total differences between self and expert measurements were 33.88 inches or an average of 1 inch per subject (see Table 4.6). Consequently, there is a 3.1% difference between self and expert girth measurements. Considering the misreporting of self-measurements for girth, the average error was -0.73 inches per test participant. This means that on average, test participants reported girth measurements 0.73 inches larger than expert measurements. Differences between self and expert measured girth circumferences ranged from 1.25 inches to -2.5 inches.

Nine test participants reported girth measurements equal to or smaller than expert measurements (see Table 4.7). Four of these test participants had exact measurements. Another group of four test subjects had girth measurements more than two inches smaller than expert measurements. These participants were asked to complete a discrepancy question form (see Appendix E, p 211). The discrepancy form asked two questions on measurement instructions, two questions on measuring devices, and a final question on actual apparel purchasing issues. For girth measurements all test participants with discrepancies reported using tape measures. They also stated that they would have spent more time verifying their measurements if they were actually purchasing a pair of shorts (see Appendix C, p 194). This implies that in addition to common measurement errors the lack of attention to detail on the part of the test participants may be a reason for large measurement errors.

Table 4.6 Girth Measurement Variances

Subj #	Self Girth	Expert Girth	Change (in)	Total (in)	% Change	% Total
A50	31.5	31	(0.50)	0.50	(1.6%)	1.6%
B51	29	29.75	0.75	0.75	2.5%	2.5%
A52	33	32	(1.00)	1.00	(3.1%)	3.1%
A54	33	31.5	(1.50)	1.50	(4.8%)	4.8%
A56	31.5	30	(1.50)	1.50	(5.0%)	5.0%
B57	32	30.5	(1.50)	1.50	(4.9%)	4.9%
A58	30	31	1.00	1.00	3.2%	3.2%
B59	34.5	34	(0.50)	0.50	(1.5%)	1.5%
A60	31	31	0.00	0.00	0.0%	0.0%
B61	32	30.75	(1.25)	1.25	(4.1%)	4.1%
B63	33	31	[illegible]	[illegible]	(6.5%)	6.5%
A64	34.5	34	(0.50)	0.50	(1.5%)	1.5%
B65	32	30.5	(1.50)	1.50	(4.9%)	4.9%
A66	38	35.5	[illegible]	[illegible]	(7.0%)	7.0%
B67	38	37	(1.00)	1.00	(2.7%)	2.7%
A68	32.75	32.5	(0.25)	0.25	(0.8%)	0.8%
B69	32.5	30.5	[illegible]	[illegible]	(6.6%)	6.6%
A70	34.5	32.75	(1.75)	1.75	(5.3%)	5.3%
B71	32	31.5	(0.50)	0.50	(1.6%)	1.6%
B73	32	30.5	(1.50)	1.50	(4.9%)	4.9%
A74	34.5	35.75	1.25	1.25	3.5%	3.5%
B75	32.5	32.75	0.25	0.25	0.8%	0.8%
A76	35	35	0.00	0.00	0.0%	0.0%
B77	31.5	31	(0.50)	0.50	(1.6%)	1.6%
A78	31	30	(1.00)	1.00	(3.3%)	3.3%
B79	31.5	31.5	0.00	0.00	0.0%	0.0%
A80	36	36	0.00	0.00	0.0%	0.0%
B81	35	36.25	1.25	1.25	3.4%	3.4%
A82	32	31.5	(0.50)	0.50	(1.6%)	1.6%
B83	33.5	32.5	(1.00)	1.00	(3.1%)	3.1%
A84	31.875	31	(0.88)	0.88	(2.8%)	2.8%
B85	32	31	(1.00)	1.00	(3.2%)	3.2%
A86	36	34	[illegible]	[illegible]	(5.9%)	5.9%
B87	36	34.75	(1.25)	1.25	(3.6%)	3.6%

	Change (in)	Total (in)	% Change	% Total
Total	(24.88)	33.88	(78.4%)	105.3%
Avg	(0.73)	1.00	(2.3%)	3.1%

%
Smaller Self-Measurements

Greater than 2-inch Error

%
Exact Measurements

(#)
Negative Result

The waist measurement resulted in the second largest variance between self and expert measurement for the four measurements compared. The total differences between self and expert measurements were 45.25 inches or an average of 1.33 inches per test participant (see Appendix D, p 201). This results in an average 4.1% difference between self and expert waist measurements. Waist measurement differences ranged from 4 inches to -2 inches. Test participants reported waist measurements an average of 0.73 inches smaller than expert measurements. This finding is consistent with the results for self-measurements taken for girth and provided the basis for adjustments made to sizing charts in the size prediction model after the conclusion of the fit testing sessions.

Twelve test participants had self-measured waist measurements equal to or less than expert measurement findings (see Table 4.7). Two of these subjects reported waist measurements exactly equal to expert measurements. Of the remaining test participants eleven reported waist measurements more than two inches different from expert measurements. Eight of these individuals reported waist measurements two to four inches larger than expert measurements while the remaining three participants reported measurements two inches smaller. On the discrepancy question form participants with inaccurate waist measurements reported using a variety of measurement devices. These implements ranged from electrical cords and marked strings to tape measures. About 80% of the test participants that used rulers and flexible strings or cords to take self-measurements reported distrust in the accuracy of their devices.

Since waist measurements at the preferred waist are contingent upon accurately determining the preferred waistline, increased error rates were anticipated for both the waist and crotch measurement. On the self-measurement pages in the Internet website subjects were instructed to take their waist measurement over clothing that fits them well (see Appendix G, p 250). In contrast, expert waist measurements taken during the fit testing sessions were taken over compression shorts. Test participants shifted the waistband of the compression short to duplicate the height and angle of their preferred waistline during expert measurement procedures. It is improbable that test participants were able to accurately determine the preferred waistline for a garment without wearing it while making the determination. Variances in waist height determined by preferred clothing or compression shorts certainly contributed to the overall measurement errors found in self and expert measurement comparisons.

Seat self-measurements were also taken directly over individually selected garments while expert measurements were taken over compression shorts (see Figure 4.10). Seat circumference is determined by finding the largest circumference around the buttocks region. This is a very difficult measurement to duplicate accurately since there are no clearly distinguishable landmarks on the body from which to base the measurement. Additionally, many makeshift measuring devices used by test participants may not take accurate measurements when they are slid up and down across the buttocks region to determine the widest measurement.

No self-measured seat circumferences matched expert measurements. The total difference between self and expert seat measurements for the sample was 49.88 inches resulting in an average error of 1.47 inches per test participant (see Appendix D, p 202). This equals to a 3.8% error rate for self-measurement. While test participants understated their seat self-measurement by an average of only -0.25 inches, there was a wide range of measurement errors from 10 inches smaller to 3.5 inches larger than expert measurements.

Expert Seat Measurement (Front View)

Seat Self-Measurement (Back View)

Figure 4.10 Seat Self and Expert Measurement Procedures

Ten test participants reported seat measurements an average of 2.1 inches smaller than expert measurements (see Table 4.7). If the student with the 10-inch error is removed from the data as an outlier, the average error drops to 1.2 inches per subject.

Eight test participants reported waist measurements greater than two inches away from expert measurements (see Table 4.7). Two of these participants reported smaller measurements and six test reported measurements as large as 3.5 inches above expert measurements. On the discrepancy question form these participants reported using a variety of measurement devices that ranged from electrical cords and marked strings to tape measures. About 80% of the test participants that used rulers and flexible strings or cords to take self-measurements reported distrust in the accuracy of their devices.

Crotch self-measurements had the highest error rates of any measurements. Reported crotch lengths averaged 1.81 inches away from expert measurement findings (see Appendix D, p 202). This equals a 7.81% error rate. Nineteen test participants reported crotch lengths larger than expert measurements. Eleven reported measurements less than expert findings and four had exact measurements. Responses ranged from 3.65 inches below to 4.5 inches above expert measurement findings. Fourteen test participants had self-measurements two inches or more away from expert measurements (see Table 4.7). Of these 14, 10 reported crotch lengths two inches or more above expert measurements and four reported measurements an average of 3.19 inches below expert measurements.

The primary reasons for inaccuracies in self-measured crotch length determination appear to be waist-height related issues and styling factors present in self-selected garments. Shorts or pants with extremely large crotch lengths and low waist heights are currently fashionable. Test participants that wore these types of garments during self-measurement may tend to overstate their measurements. This supposition is supported by the large number of students reporting bigger measurements than expert measurements.

Waist height variations in highly stylized garments can also create large errors in measured crotch lengths. During expert measurement procedures crotch length was measured from the bottom of the waistband on the compression shorts in both the front and the rear. The fit of the compression short generally required the wearer to position the waistband higher on the body than they might normally wear their pants or shorts. This may have been due to the tighter elastic sewn in the waistband of the compression shorts. While a higher waist height generally increases measured crotch lengths, the form fitting characteristics of the compression shorts allowed a much less restricted measurement of the crotch and may have counteracted the effects of a higher waist.

Table 4.7 Self-Measurement Error Frequencies

Error (in)	Girth Frequency	Waist Frequency	Seat Frequency	Crotch Frequency
10.00	0	0	1	0
-	-	-	-	-
4.00	0	0	0	1
3.75	0	0	0	1
3.50	0	0	0	0
3.25	0	0	0	0
3.00	0	0	0	0
2.75	0	0	0	1
2.50	0	0	2	0
2.25	0	0	0	1
2.00	0	3	0	0
1.75	0	0	1	0
1.50	0	0	0	0
1.25	2	1	0	0
1.00	1	1	1	2
0.75	1	1	2	1
0.50	0	1	2	2
0.25	1	3	1	2
0.00	4	2	0	4
-0.25	1	1	1	1
-0.50	6	4	8	0
-0.75	1	0	2	0
-1.00	5	4	2	4
-1.25	2	2	5	0
-1.50	5	2	1	4
-1.75	1	1	0	0
-2.00	3	4	0	1
-2.25	0	0	1	0
-2.50	1	0	2	1
-2.75	0	0	0	1
-3.00	0	2	1	2
-3.25	0	0	0	0
-3.50	0	1	1	0
-3.75	0	0	0	0
-4.00	0	1	0	3
-4.25	0	0	0	1
-4.50	0	0	0	1
Total	**34**	**34**	**34**	**34**

Overall, self and expert measurements averaged greater than one inch difference. Results may have been skewed toward larger self-measurements due primarily to the form fitting characteristics of the compression shorts used during expert measurements. Corrections were made to the adjusted size prediction model to reflect these findings and adjust for larger self-measurements. The wide variance seen in measurement results casts doubt on the accuracy levels that size prediction models can attain with self-measurement. It would appear that standardized garments and different measurement instructions are needed to obtain more accurate results.

Some test participants reported that self-measurement instructions were too lengthy and that ordering required too many steps (see Appendix C, p 193). These subjects stressed the need for simplifying the ordering process to facilitate more impulse buying and improving the enjoyment level of ordering. In terms of measurement accuracy, girth measurements seemed to provide the most promise. Insuring repeatability by taking the measurement against the skin, the girth measurement may provide a good basis for determining garment waist sizes if a correlation can be drawn between preferred waist circumference and girth. Crotch measurement repeatability may also improve if this measurement is taken from the landmarks for girth measurements. However, additional research needs to be conducted to correlate standardized girth measurements and adjusted crotch length measurements with optimized short size selections.

If girth measurements have the greatest accuracy and lowest error rates then additional research should be conducted to determine if this body measurement can be used to accurately predict garment sizes. By using the navel as the landmark for a waist measurement some advantages may be gained in terms of ease in taking the measure and repeatability. However, the anatomical location of the navel can vary widely between individuals. This fact may provide additional problems in using the girth measurement for size determination. If the vertical distance between the navel and the preferred waistline were included in ordering information it may assist in determining a more accurate crotch length. However, waist circumference would still be difficult to determine for subjects with disproportionate girth and preferred waist measurements. This may be especially true in the population as a whole in contrast to the limited range of body types tested in this study.

4.6 Fit Testing Analysis

Test participants rated all test shorts worn during the fit testing sessions on satisfaction of fit. Verbal questioning and a five point scale were used to gather information. Evaluators circled responses on the fit evaluation form and listed additional comments as needed. A rating of five on the satisfaction of fit scale corresponded to fully satisfied while a rating of one was equivalent to unsatisfied. Participants rated shorts in a total of five categories; waist, crotch, seat, thigh, and overall.

Short presentation was randomized as much as practical for predicted test short sizes and ordered for additional test short sizes if required (see Table 4.8). Subjects selected their top pick from the predicted shorts and their final choice from all shorts. Due to the fact that expert measurements were taken at the fit test it was not possible to have shorts predicted by expert measurements at the beginning of the fit test. Rather than have idle time for test participants while size predictions for expert measurement were made subjects were given either the self-measurement or self-measurement plus fit preference predicted short. Therefore expert measurement predicted test shorts were generally presented third in order to test participants.

Table 4.8 Test Short Presentation Order and Final Selections

Subj #	E	S	F	D1	D2	D3	TOP	FINAL
A50	3	1	2	4	5		S	D1
B51	3	2	1	4			S	D1
A52	3	2	1	4	5		E	E
A54	3	1	2	4	5		F	F
A56	2	1	3	4	5	6	S	D1
B57	1	3	2	4			F	F
A58	2	1	1	3	4	5	E	D2
B59	2	1	1	3	4		E	D2
A60	3	2	1	4	5	6	F	D3
B61	3	2	1	4	5		F	F
B63	2	1	1	3	4	5	E	D3
A64	3	1	2	4	5		E	E
B65	3	2	1	4	5	6	E	D3
A66	3	1	2	4	5		E	E
B67	2	1	1	3	4		S/F	D2
A68	3	1	2	4	5		F	D2
B69	2	1	1	3	4	5	E	E
A70	1	3	2	4	5	6	S	D3
B71	3	2	1	4			E	E
B73	1	2	1	3	4		E/F	D2
A74	3	1	2	4			E	D1
B75	3	2	1	4	5		E	D1
A76	2	1	1	3	4	5	E	E
B77	1	2	3	4	5		F	F
A78	2	1	1	3	4	5	E	D1
B79	1	1	2	3	4		E/S	E/S
A80	3	2	1	4	5		F	D2
B81	3	2	1	4	5		E	D2
A82	3	1	2	4	5		E	E
B83	2	1	1	3	4	5	E	D2
A84	3	2	1	4	5		E	D2
B85	3	2	1	4	5	6	S	D2
A86	3	2	1	4	5	6	S	D1
B87	3	2	1	4	5	6	E	D2

E - Expert Measurement
S - Self-Measurement
F - SM plus Fit Preference
D1 - Alternate Short #1
D2 - Alternate Short #2
D3 - Alternate Short #3

Out of 34 fit sessions, expert shorts were presented first five times, second nine times, and third 20 times (see Table 4.8). Twenty out of 34 times test participants selected the expert measurement predicted shorts as their top choice. Eight of these shorts were also the test participants' final selections. There were two instances where either self-measurement or self-measurement plus fit preference predicted the same short size as expert measurement. In both cases the shorts were evaluated once and the results recorded in each associated measurement category.

Self-measurement predicted test shorts were presented first in order 17 times, second 15 times, and third twice. Eight times self-measurement predicted shorts were selected as the top choice for predicted shorts and nine times self-measurement plus fit preference or expert measurement findings predicted the same size test shorts. One of the initial top selections for self-measurement predicted shorts was also a final choice.

Self-measurement plus fit preference predicted test shorts generated by the initial size prediction model were presented first in order 22 times, second ten times, and third two times. Nine times fit preference predicted shorts were the top choice of the first three test shorts. Four of predicted sizes were also the test participants' final selections.

These results reveal that test participants preferred the fit of expert measurement predicted test shorts and rated them with a higher satisfaction of fit than self-measurement and self-measurement plus fit preference predictions combined. This rating was equivalent to a 55.9% selection rate for top predicted shorts from expert measurement, 23.5% from self-measurement, and 26.5% from self-measurement plus fit preference. Since the presentation sequence of expert measurement predicted test shorts was not randomized successfully, selection rate comparisons for presentation order may be somewhat misleading.

In all five evaluation categories the third predicted short presented had the highest satisfaction of fit response level. The average response for all five categories for the third predicted short was 4.29. The corresponding value for the second predicted short presented was 4.09 and 3.96 for the first predicted short presented. Additionally, the first predicted short presented scored lowest in four of the five evaluation categories. The only exception was scoring 0.03 higher than the second short presented in seat evaluation. The third predicted short presented scored the highest in all five categories.

Due to the ordered presentation of alternate shorts after the predicted short evaluations, test participants may have had the perception that satisfaction of fit for test shorts improved as the evaluator attempted to refine the fit to achieve an optimum size selection. Eleven times the last short presented was selected as the final choice and another six times the second to last short in presentation order was selected as the final short selection. Depending upon individual responses an effort was made to have participants try on one additional short in a different size to verify optimum selection. For example if a test participant stated that the fourth short presented was fully satisfactory in fit, a fifth short was generally presented one size larger or smaller in waist or crotch length to verify these results. This testing anomaly explains why shorts second to last in presentation order were often selected as the optimum fitting test shorts.

When optimum shorts were selected last in presentation order it may also have been due to testing procedures. If the maximum of six short selections had been presented to the test participant the fit session was concluded and the best fitting short was selected. Since alternate shorts generally improved in fit characteristics for test participants along with the presentation order, it is easy to see why the largest number of optimum short selections occurred last in the presentation order.

4.7 Fit Preference Findings

In general fit preference responses appear to improve the accuracy of test short size predictions. To determine the extent of these improvements waist and crotch size predictions had to be evaluated separately. Fit preference changes to predicted waist size accuracy were measured by determining the changes between predicted short sizes and the optimized short size. These differences were then compared with each other to determine the relative change between measurement generated predictions and predictions made with the addition of fit preference adjustments. Predicted crotch lengths for self and expert measurements and those predicted with fit preference adjustments were recalculated using the waist sizes for the optimized test shorts. The results were then compared to determine accuracy rates for crotch sizes.

29.4% of self-measurement waist sizes predicted with the initial size prediction model improved in accuracy with the addition of fit preference adjustments (see Table 4.9). The majority (64.7%) of these predictions remained the same and 5.9% decreased in accuracy. For the adjusted size prediction model the percentage of waist size predictions determined by self-measurement plus fit preference that improved in accuracy was 23.5%. Again the majority (67.6%) of predicted waist sizes remained the same and the remaining 8.8% decreased in accuracy. The fit preference adjustments for expert measurement waist sizes resulted in the same accuracy percentages as self-measurement findings.

Table 4.9 Fit Preference Adjusted Waist Size Accuracy

Change	ISM-ISM/FP	EM-EM/FP	SM-SM/FP
Same	64.7%	67.6%	67.6%
Better	29.4%	23.5%	23.5%
Worse	5.9%	8.8%	8.8%

ISM - Initial Self-Measurement
ISM/FP - ISM plus Fit Preference
EM - Expert Measurement
EM/FP - EM plus Fit preference
SM - Self-Measurement
SM/FP - SM plus Fit Preference

Fit preference adjustments resulted in only marginal improvements for predicted crotch size accuracy with the adjusted size prediction model. Crotch size accuracy actually decreased with fit preference adjustments using the initial size prediction model. 17.6% of self-measurement crotch sizes predicted with the initial size prediction model improved in accuracy with the addition of fit preference adjustments (see Table 4.10). The majority (52.9%) of these predictions remained the same and 29.4% decreased in accuracy.

Table 4.10 Fit Preference Adjusted Crotch Size Accuracy

Change	ISM-ISM/FP	EM-EM/FP	SM-SM/FP
Same	52.9%	64.7%	55.9%
Better	17.6%	17.6%	23.5%
Worse	29.4%	17.6%	20.6%

ISM - Initial Self-Measurement
ISM/FP - ISM plus Fit Preference
EM - Expert Measurement
EM/FP - EM plus Fit preference
SM - Self-Measurement
SM/FP - SM plus Fit Preference

For the adjusted model the percentage of crotch size predictions determined by self-measurement plus fit preference that improved in accuracy was 23.5%. Again the majority (55.9%) of predicted waist sizes remained the same and the remaining 20.6% decreased in accuracy. The fit preference adjustments for expert measurement crotch sizes resulted in 17.6% of the crotch size predictions improving in accuracy. The majority (64.7%) remained the same and 17.6% decreased in accuracy.

Since overall accuracy for size predictions improved with the addition of fit preference responses, accuracy rates for individual crotch and waist size improvements seem contradictory. It is reasonable to conclude that predicted sizes already close to optimum short sizes improved more than predicted sizes that were farther away from the optimum sizes. In other words, predicted short sizes with larger errors benefited less from the addition of fit preference responses than short sizes already close to the optimum sizes.

Since accuracy improvement results were consistent across both self and expert measurement findings, measurement errors may not be the major cause of these discrepancies. Additionally, errors in fit preference accuracy are fairly consistent across both the initial and the adjusted size prediction models. There was a marginal increase in accuracy rates for crotch size determinations in the adjusted model but waist size prediction accuracy decreased. It would also appear that fit preference responses from test participants were not consistent with their actual fit preferences as indicated by their optimum short selections. The question becomes how to improve the accuracy of fit preference responses and whether consumers can provide accurate fit preference responses without trying on a particular garment.

Certainly fit preference adjustments may need greater weighting in order to shift predicted short sizes more in line with optimum short size selections. If measurement errors are eliminated as the primary cause for predicted short size inaccuracies then we can assume that fit preference and garment positioning may be the primary determinants of optimum short size. It seems extremely difficult to determine garment positioning and waist height for consumers without having them try on clothing first. Variations in the style and fit characteristics of different garments and the interplay of crotch and waist sizes mean that individuals may not be capable of predicting accurate preferences without trying on garments first. Therefore, accurate fit preference responses may be difficult to obtain.

Improvements in predicted crotch size accuracy with the addition of fit preference were encouraging. An argument can be made that garment dimensions like waist circumference are less dependent on fit preference than crotch length. Waist size determines the positioning of shorts on the body while increases or decreases in crotch length relate more to comfort ease factors. Further research is certainly needed to find the importance of waist and crotch fit preference adjustments in relation to comfort ease and overall garment fit.

Since the majority of predicted short sizes did not change with the addition of fit preferences, a more robust weighting of fit preference adjustment values may be needed in future size prediction models. Garment positioning on the body may also be a critical factor that needs further examination. Aside from body dimensions, waist height appeared to be the major determinant of both waist and crotch size. Several subjects that indicated a low waist height preference and had small crotch length measurements for both self and expert measurement actually preferred a higher waist height when they tried on test shorts. As a result waist size was decreased and crotch size increased. Similarly subjects that indicated a high waist height preference but selected a low waist height for optimum shorts had significant shifts in waist and crotch sizes from model predictions.

In the initial size prediction model a total of 35.3% of test participants had short sizes predicted from expert measurement with larger waist and smaller crotch sizes or smaller waist and larger crotch sizes than their optimum shorts. These prediction discrepancies appear primarily due to waist height issues (see Table 4.11).

Table 4.11 Waist Height Prediction Errors

Initial Size Prediction Model

Predicted	EM	SM	SM/FP
Larger Waist/ Shorter Crotch	23.5%	17.6%	26.5%
Smaller Waist/ Larger Crotch	11.8%	11.8%	8.8%

Adjusted Size Prediction Model

Predicted	EM	EM/FP	SM	SM/FP
Larger Waist/ Shorter Crotch	17.6%	8.8%	17.6%	11.8%
Smaller Waist/ Larger Crotch	14.7%	5.9%	11.8%	11.8%

EM - Expert Measurement
EM/FP - EM plus Fit preference
SM - Self-Measurement
SM/FP - SM plus Fit Preference

Regardless of measurement method or fit preference adjustment there was a greater tendency to have predicted sizes with larger waist sizes and smaller crotch sizes. This meant test subjects selected optimum shorts with a higher waist height than was indicated by both self and expert measurement and fit preference responses (see Appendix C, p 156). The higher waist height led to a smaller waist size and a longer crotch length in the optimum short. The addition of fit preference adjustments in the adjusted size prediction model did improve a moderate percentage predicted short sizes. However, these benefits were not seen in the initial size prediction model. Since the initial model did not include adjustments for waist height fit preference this result may indicate that the inclusion of a waist height fit preference response in ordering models may help improve the accuracy of the predicted short sizes.

Inconsistencies in fit preference responses may still cause a major problem in the accuracy of predicted short sizes. These inconsistencies need to be identified early in the ordering process. Fit preference responses that indicate a tight seat preference with a very loose waist should raise questions about the accuracy of orders and related fit preferences. Increased weighting of fit preference factors will only serve to magnify these errors and produce shorts that will not achieve an acceptable level of fit satisfaction for consumers. Changes to the format of fit preference questions may help improve customer response accuracy but it is difficult to determine whether accurate fit preference results can be obtained when consumers do not have the opportunity to try on a particular garment. General responses may not be able to compensate for the styling and fit characteristics of clothing.

CHAPTER FIVE
MAJOR FINDINGS AND CONCLUSIONS

5.1 Major Findings

The addition of fit preference adjustments to self-measurements in the initial size prediction model significantly improved the accuracy of size predictions for optimized test shorts for male Cornell University students with waist circumference ranges between 30 and 35 inches. This fact was supported by paired t-test analysis using an alpha level of 0.05. The results supported the hypothesis that the addition of fit preference responses to an apparel ordering model better predicts optimum size. It is important to note that self-measurement alone in the initial size prediction model was not a statistically good predictor of optimum short size. If the measurement errors found in self-measurement are consistent with errors that occur in actual apparel ordering then fit preference responses may provide a viable solution to improve customer satisfaction and improve garment fit.

When the size prediction model was adjusted to improve the accuracy of size predictions for all measurement methods, the addition of fit preference adjustments to self and expert measurement predictions did not significantly improve size prediction accuracy. While the overall numbers of exact or acceptable fit size predictions improved with the addition of fit preference responses in the adjusted size prediction model, these results did not prove to be statistically significant. Several factors including the inexperience of test subjects in apparel purchasing, apparent style variations in garments used for self-measurement, the resolution level of test short sizing, waist height variations, measurement errors, inaccurate fit preference reporting, and the degree of weighting for fit preference responses may have contributed to the inadequacy of the adjusted size prediction model.

Experience in retail apparel shopping and self-purchasing appears to improve the accuracy of fit preference and self-measurement reporting in mass customized apparel ordering. Subjects that had limited retail shopping experience and reported purchasing a lower percentage of clothing items themselves were more apt to report self-measurements and fit preferences that did not accurately predict optimum short size selections. In order to overcome these limitations apparel ordering procedures may need to be tailored to the purchasing experience level of the customer. Interactive measurement and fit preference instructions presented over Internet websites may prove to be a useful mechanism to accomplish this goal.

In terms of self-measurement procedures, allowing the customer to select their own garments to wear while taking self-measurements may result in increased variance in the overall accuracy of self-measurements. Standardized garments used for self-measurement may reduce these variations but hamper the predictive accuracy of the resulting self-measurements. Standardizing self-measurement garments may include taking self-measurements in underwear or against the skin. The intent of selecting good fitting clothing to take self-measurements was to incorporate proven fit preferences in the apparel ordering model. Unfortunately significant style variations in these clothing items as compared with the mass customized garment may cause increased errors in the accuracy rates of size predictions. If style variations can be reduced then the use of garments with preferred fit characteristics may still prove a better technique than standardization.

Along with style variations in selected self-measurement garments higher resolution in sizes in the size prediction model appears to significantly limit the accuracy of optimum size predictions regardless of the measurement method employed. Measurement methods either with or without the addition of fit preference adjustments had low probabilities of predicting accurate short sizes when compared with short sizes determined through actually fitting garments. A proven baseline sizing chart for expert measurement may provide a better starting point for evaluating the significance of self-measurement and fit preference adjustment than an unproven model for all measurement predictions.

In order to achieve statistical significance for any measurement method in a size prediction model the resolution in sizing categories may need to be reduced. If size category resolution is decreased then the complexity of ordering requirements may also be lessened. However, decreasing the number of sizes may also impact the level of fit satisfaction achievable by mass customization. The goal of improving fit over mass production sizing systems must be tempered with the realistic shortfalls of ordering customized apparel without actually fitting garments on the body.

In terms of exact size prediction this study revealed a 30% improvement for expert measurement plus fit preference with 20 shorts predicted accurately or one size off in either crotch or waist size compared to 14 shorts predicted accurately for expert measurement alone. Self-measurement plus fit preference resulted in a 20% improvement for accurate size predictions when comparing the results for the initial and adjusted size prediction models together. These are sizable gains in accuracy over self and expert measurement predictions alone. I would contend that mass customization can be effective if consistent gains in accuracy at these levels can be achieved.

Of the four self-measurements taken, the girth measurement resulted in the smallest differences between self and expert measurements. If correlation between girth measurement and optimum size can be found girth measurements may provide a better basis for determining size predictions than preferred waist self-measurements. Since girth measurements were not dependent on the preferred waist location determined by selected self-measurement garments and based on a finite landmark at the subject's navel, repeatability of girth self-measurement may be greatly improved. In addition, basing crotch length measurements at girth landmarks may improve the repeatability and accuracy of self-measured crotch lengths.

Since self-measurements based at girth (omphalion) landmarks do not address waist height related sizing issues, significant fit preference based adjustments or additional body measurements may be needed to determine the position of mass customized garments on the body. Measuring the vertical distance between the preferred waist and the omphalion may provide the needed information to correct crotch lengths but preferred waist circumferences will be difficult to predict unless a strong correlation is found between girth and waist circumference (preferred).

Waist height variations identified in fit analysis may explain much of the high error rates found in self and expert measurement size predictions. Wide disparities between predicted sizes and optimum sizes may have resulted from dramatic shifts in waist height from self-measurement garments to mass customized garments. These changes in waist height may come from garment style characteristics, fit preferences, and crotch length variations. In the case of style characteristics and fit preference it may be difficult to quantify these factors in a size prediction model. Both appear highly dependent on the actual feel and positioning of a garment on the body. Conversely, limiting the range of crotch length offerings may reduce some variation in waist height and provide improved waist size prediction results for all measurement methods. By limiting crotch length choices, subjects should be more restricted in the waist height positioning possible for a garment. However, this may limit the level of fit optimization that can be achieved with mass customization.

Without tactile input fit preference reporting can be difficult to accomplish accurately. Improvements in fit preference question formats and the use of visual imaging with interactive instructions may improve the accuracy of fit preference responses. However, variations in the style characteristics of purchased garments need to be accurately communicated to the consumer before accurate fit preference reporting can be accomplished. While it is improbable that a size prediction model can attain the same sizing results as actually fitting a garment, improvements in interactive ordering procedures may be accomplished.

Since the majority of fit preference adjusted size predictions did not change from base measurement predictions more robust weighting and adjustment values may be needed for fit preference responses. This may be especially true for crotch length fit preference adjustments. Potential waist size adjustments appear more limited in scope due to their direct relationship with body dimensions and functional significance. Crotch length adjustments can include a large amount of comfort ease that can be varied according to individual fit preferences. Certainly, fit preference responses more consistent with those demonstrated when subjects select optimum size by fitting garments needs to be obtained in the ordering process. If accurate fit preference responses are not obtained then increased weighting for fit preference crotch length adjustments will only serve to magnify error rates for predicted short sizes.

I believe eliminating the availability of a neutral fit preference response and providing a larger range of response selections for fit preference questions would increase the accuracy of fit preference adjustments. With the five-point Likert response scale used in this study a large percentage of test subjects reported no quantifiable fit preferences. By providing an even number of response selections for fit preference questions subjects would be forced to choose between loose or tight fit preferences and allow adjustments to be made for all orders. Increasing the range of response selections would also help refine the size adjustments made for each customer order and allow further modifications to be made to optimize a fit preference based size prediction model.

Hypothesis B stated that self-measurement plus fit preference predicts satisfaction of fit better than expert measurement alone. In paired t-testing for this hypothesis no statistical significance was found to support this claim. Besides the prediction shortfalls previously mentioned large errors in reported self-measurements for approximately 20% of test participants appear to limit the effectiveness of fit preference adjusted self-measurement predictions as compared with expert measurement predictions. Unless these types of measurement errors can be reduced or eliminated for consumers in the apparel ordering process the accuracy of self-measurement based size predictions will continue to suffer.

5.2 Summary and Conclusions

Due to the inaccuracies of short sizes predicted by self and expert measurement with and without the fit preference adjustments as determined in this study it is apparent that additional variables may exist in the ordering process that can improve the accuracy of optimized short size predictions. Identifying and quantifying these variables can improve the optimum size selection for apparel customers. Variables such as waist height, garment positioning, and the interplay of garment style and fit characteristics with individual fit preferences may be the essential elements missing or miscalculated in this ordering process.

As seen in garment fit sessions, fit preference plays a critical role in the determination of optimized short sizing. The question this study was unable to answer is whether these fit preferences can be quantified and added to self or expert measurements to determine the appropriate size of men's shorts without garment fitting. Certainly achieving a satisfactory customized fit without garment fitting is a difficult process. Garment fitting generally involves a trial and error process where intermediate sizing adjustments are made. These adjustments can be maintained or further refined as additional dimensions in the garment are changed. Internet and mail-order apparel purchasing do not allow this type of adjustment process. Consequently, greater compromises may be needed in the style, ease, and sizing of the garments by the manufacturer in order to achieve an acceptable level of fit satisfaction for the consumer. This may mean simplifying patterns and styles that are available for customized fit and increasing the amount of comfort ease to fit a wider range of body types.

Manufacturers must decide what level of size optimization they want to compete on. This decision should guide the development of ordering and sizing issues as well as manufacturing efforts. Aligning customer fit requirements with a range of specially graded sizes is one technique used by mass customizers to accomplish this goal. Another technique involves the development of unique patterns for individual customers. Both techniques have advantages and disadvantages that manufacturers must examine in their decisions for manufacturing and merchandising plans.

I contend that predicting optimized sizes determined by garment fit sessions may not be attainable to the degree of resolution attempted in this study. However, further refinement to a system of fit preference adjustments especially for garment regions with a considerable amount of comfort ease may greatly improve satisfaction of fit for consumers and reduce return rates for garment manufacturers.

Mass customization has given US apparel manufacturers a competitive advantage over foreign manufacturers. However, unless US manufacturers can improve ordering and size predictions mass customization for fit without trying on a garment may prove to be an extremely difficult if not impracticable process. Technological advances like whole-body scanning may eliminate the need for self and expert measurements and improve mass customized apparel ordering. If apparel sizing concerns can be accommodated in the processing of body scan data this system may prove to be a viable alternative to expert measurements. However, fit preference adjustments are not currently addressed in body scanning sizing procedures. The combination of self-measurement and fit preference may still provide the most practicable method of size determination for mass customized mail-order or Internet apparel purchases.

5.3 Recommendations for Future Research

If mass customization is going to be effective in providing an acceptable customized fit for consumers using Internet or mail-order purchasing, improved methods for size determination may be needed. Recent advances in body scanning may provide more accurate reporting of body measurements but adjustments for garment style characteristics, waist height, fit preference, and comfort ease need additional investigation and refinement to provide an accurate system of size prediction or pattern development.

The importance of fit preference adjustments for achieving a higher level of fit satisfaction with the initial size selected was not addressed in this study. Further research is needed to determine if fit preference adjustments can improve satisfaction of fit from predicted garment sizes on a statistically significant basis. Fit preference factors also need to be examined for a wider range of body types. Many consumers in the big, tall, plus, and petite size categories may be more inclined to purchase clothing mass customized for fit than the subjects tested in this research project. The lack of availability and style selections in garments for these target groups may make them prime candidates for apparel mass customized for fit.

Big, tall, plus, and petite size consumer groups may have disproportionate body dimensions when compared with average apparel sizes and common grading rules. These anomalies may require significant variations in fit preference reporting and related size adjustments. Further research is needed to determine what fit preference related adjustments are needed for these types of consumers.

It is also important to determine consumer tolerances for satisfaction of fit and acceptance ranges for garment sizes. Rather than optimizing fit for individual customers, apparel mass customization firms may be more concerned with the level at which satisfactory fit can be achieved. This level may differ significantly from the satisfaction of fit provided by an optimized garment. Retail buyers of mass produced clothing may have developed relatively low standards for fit satisfaction and be accustomed to making significant compromises in fit to obtain desired garments based on style, price, and availability. Small improvements in sizing and garment fit may provide enough incentive for consumers to purchase mass customized apparel. Therefore the question becomes how much improvement in fit is needed to generate demand for mass customized clothing and what range of garment sizes will meet this requirement for the average customer.

Research is needed to determine what range of garment sizes and fit average consumers will deem acceptable. Once this range is determined, manufacturers can more easily choose the level of fit they want to use as a production goal. This goal will help firms determine ordering requirements, garment designs, manufacturing tolerances, and related sizing issues. If kinesthetic after effects can be overcome repeated blind testing of a series of closely sized test shorts may provide the data needed to determine this acceptability range. Wear testing may also be needed to determine if satisfaction of fit levels change over time and shift the acceptance range for garment sizing.

Variations in waist height and related sizing concerns also require further research. Several subjects in this study were found to be equally satisfied with the fit of test shorts with smaller waists with longer crotch lengths and larger waists with shorter crotch lengths. This anomaly indicates the importance of waist height determination and garment positioning. The perception of fit for these two types of garment sizes may be very closely related. Research is needed to determine if two optimum size selections are possible for consumers and what adjustments are needed to ordering models to facilitate the distinction between low and high waist heights for garments. I believe there may be an optimum ratio of waist to crotch sizes as opposed to a single optimum size for garments. If this is true then ordering models need to be developed to determine this ratio and waist height should then be utilized as the final determinant of garment size.

Further testing of the accuracy rates for fit preference responses using a variety fit preference reporting formats and presentation models may also be needed. If reporting formats can be found that significantly improve the accuracy of fit preference responses then the predictive ability of all measurement methods in an ordering model may be greatly improved. This may be particularly important in the application of body scanning to generate individualized garment patterns or size selections.

Along with accuracy testing for fit preference responses the accuracy of self-measurement procedures requires additional research. A comparison of standardized procedures with procedures that include measurements taken over garments with preferred fit characteristics may help to determine the best format for mass customized apparel ordering. Self-measurement needs further comparison with expert measurement to identify consumer tendencies to overstate or understate body measurements.

Finally, I believe the interplay of additional body dimensions with waist and crotch sizing requires additional research. Varying garment sizes to compensate for disproportionate body dimensions in other areas besides the waist and crotch may be impractical for standard or mass customization sizing systems. However, the impact of these variations on accurately predicting short sizes needs to be examined. Identifying potential problem areas for disproportionate body measurements using a ratio comparison with waist and crotch dimensions may help to increase the accuracy of size predictions in the mass customized ordering process. By establishing benchmark ratios, a comparison of customer measurements can identify orders that may require additional pattern manipulation or size adjustments. In addition, a review of these ratios can be used to establish a self-validating order system that queries customers providing unlikely or out of tolerance measurements or fit preference responses.

APPENDIX A

MAIL-ORDER CATALOG AND SIZING REVIEW

MAIL-ORDER CATALOG MEASUREMENT INSTRUCTION AND SIZE CHART REVIEW

1. **Eastbay** (sports shoes and limited sports apparel) - no measurement instructions or sizing chart

2. **L. L. Bean Outdoors** (outdoor apparel and gear)

3. **Performance Bicycle** (bicycling apparel) - list body size measurements in the following format:

	XS	S	M	L	XL
Waist	28-30	32-34	36-38	40-42	44-46
Hips	35-37	39-41	42-44	45-47	48-50
Inseam	31	32	33	34	35

   Add a note about cycling apparel fitting differently than normal clothing. No other measurement instructions given.

4. **Bike Nashbar** (cycling apparel) - no measurement instructions or sizing charts

5. **Peruvian Connection** (knitwear) - no measurement instructions. Sizing chart shows no lower body measurements for men but also no pants or shorts are sold.

6. **Paul Fredrick Menstyle** (shirts only) - excellent measurement instructions and sizing chart

7. **DeSantis Collection** (shirts only) - ask for sleeve and collar size on the order but give no measurement instructions or sizing charts

8. **J. Crew** (menswear) - asks for waist and inseam measurements for men's pants but not hips. Instructions include:

   Waist: Measure with the tape a bit loose
   Inseam: Needed only if ordering "finished" rather than "unfinished." Using pants that fit well, measure from the crotch seam. Specify cuff or no cuff.
   Shrinkage: Do not order a larger size than usual except as recommended for a specific item in the catalog (items are cut to allow for shrinkage).

   Sizing chart lists:

	XS	S	M	L	XL
Waist	24-26	28-30	32-34	36-38	40-42

9. **Patagonia** - give special sizing instruction for certain garments and detailed general instructions

   Shrinkage: Approximate shrinkage percentages are shown throughout this catalog. Because clothes do almost all of their shrinking in length, use these to estimate how much length-loss will occur. We test all of our clothes for shrinkage before they are manufactured in quantity. If we expect 6% shrinkage or more, we build in an allowance for shrinkage, and we state this in the copy.

   Waist: Measure loosely around waist at the height you prefer to wear the waistband.
   Inseam: Take a pair of pants that fit you well and measure from the crotch to the bottom of leg.
   Hips: Stand, feet together, and measure around the largest circumference at hips.

   Unisex sizing chart given as:

	XS	S	M	L	XL	XXL
Waist	26-27	28-30	31-33	34-36	37-39	41-44
Inseam	NA	33	33-34	34-35	35	NA

10. **Travel Smith** (outdoor clothing) - pictures of measurements, instructions and sizing charts

    Waist - Measure around the waist, over body (not over shirt or slacks) at the height you normally wear your pants. Keep one finger between the tape and your body.
    Inseam: Measure similar pants that fit you well. Lay them flat, with the front and back creased smooth. Measure from the crotch to the bottom of the leg hem along the inseam.
    Hips: Stand with feet together and measure around the fullest part.

	S	M	L	XL	XXL
Waist	28-30	32-34	36-38	40-42	44-46

11. **Deerskin** (leather) - no measurement instructions are sizing charts. Small selection of pants listed in waist sizes and unhemmed.

12. **Colorado Cyclist** (bicycle clothing) - no measurement or sizing instructions. Extensive cycling wear listed in sizes XS-XL.

13. **Brett Menswear** (menswear) - sizing charts only, leans toward big & tall but regular sizes listed:

	M	L	XL	2XL
Waist	32-34	36-38	40-42	44-46

14. **The Sportsman Guide** (outdoor clothing) - no measurement instructions. Sizing chart up to 5XL:

	S	M	L	XL	2XL
Waist	28-30	32-34	36-38	40-42	44-46

15. **REI** (menswear) - measurement instructions and sizing charts.

    Waist: Measure around waist where you normally wear your pants.
    Hip/seat: Standing with feet together, measure around the fullest point of seat
    Inseam: Measure a pair of good fitting pants along seam from crotch to bottom of leg

	S	M	L	XL	XXL
Waist	28-30	31-33	34-36	38-40	42-44
Hip	35-37	38-40	41-43	44-46	47-49
Inseam	31.5	32	32.5	33	33.5

16. **Orvis** (menswear) - Measurement instructions and sizing charts but no charts for pants or shorts which are sold by waist and inseam.

    Waist: Place tape around your waist - where you want to wear your pants (usually just above your hip bone). Hold tape snug, but not tight. (FIT TIP - another way is to take one of your belts and measure from the buckle to the hole you use. This is also your waist size.)
    Inseam: Take a pair of your own pants where the legs are the length you like and measure the inseam (from crotch to bottom)

17. **Bachrach** (menswear) - waist measurement instructions but no chart for pants

    Waist: Measure around waist, over body (not over shirt or slacks) at the height you normally wear your slacks. Keep one finger between tape and body. Number of inches = size.

18. **Willis & Geiger** (menswear) - measurement instructions along with chart and explanation that company sizes their product more generously than most manufacturers

    Waist: Measure around your natural waist where you normally wear your pants. Keep one finger between the tape and the body.

Inseam - Use a well-fitting, similarly styled pair of pants. Lay pants flat with seam on seam. Fold one leg back and measure along the inseam from crotch down to the bottom of hem.

	S	**M**	**L**	**XL**	**XXL**
Waist	28-30	32-34	36-38	40-42	44-46

19. **Brooks Brothers** (menswear) - no size chart or measurement instructions for men.

20. **Cobbler & Tailor** (menswear) - no sizing charts or measurement instructions

21. **Repp** (big & tall) - have charts, measurement instructions, and demonstration pictures.

Waist: Measure over your shirt only at the point where slacks are normally worn.
Inseam: Take a pair of well-fitting slacks that are a similar style. Lay them flat across a hard surface or table. Measure along the bottom of the slacks, from crotch seam to bottom.

22. **Early Winters** (menswear) - give unisex measurement instructions and men's sizing chart.

Waist: Measure at the narrowest part, near the belly button.
Hips: With feet together, measure at the fullest point.
Inseam: Wearing a comfortable pair of pants, measure from crotch to bottom hem along the inside seam.

Men's sizes:

	S	**M**	**L**	**XL**	**XXL**
Waist	28-30	32-34	36-38	40-42	44-46

Unisex sizes:

	XS	**S**	**M**	**L**	**XL**	**XXL**
Waist	24-26	28-30	32-34	36-38	40-42	44-46

23. **Eddy Bauer** (menswear) - No measurement instructions but extensive sizing charts.

Long rise - All men's pants are available in Long Rise sizes, meaning 1-1/2" extra in the rise, with inseam lengths to 37".

	XS	**S**	**M**	**L**	**XL**	**XXL**	**XXXL**
Waist	26-27	28-31	32-35	36-39	40-43	44-46	47-50

24. **Lands' End** (menswear) - have an entire book on fit!

Waist - Measure around waist, over body (not over shirt or slacks)

25. **L. L. Bean** - use sizing charts, measurement instructions, and diagrams.

Waist: Measure around your natural waistline.
Hips: Measure around fullest point of seat while standing.
Inseam: Measure similar pants that fit you well. Lay them flat, with the front and the back creased smooth. Measure along the inseam from the crotch to the bottom of the leg hem

Men's sizes:

	S	**M**	**L**	**XL**	**XXL**
Waist	28-30	32-34	36-38	40-42	44-46
Height	Regular: 5'8" - 6'1"				
	Tall: 6'1-1/2" - 6'4"				

Mail-Order Catalog Sizing Charts for Waist, Hip, and Inseam

(All Measurements in Inches)

	XS		S		M		L		XL		XXL		XXXL	
3 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
8 Waist	24.0	26.0	**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**				
9 Waist	**26.0**	**27.0**	**28.0**	**30.0**	31.0	33.0	34.0	36.0	37.0	39.0	41.0	44.0		
10 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
13 Waist					**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
14 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
15 Waist			**28.0**	**30.0**	31.0	33.0	34.0	36.0	38.0	40.0	42.0	44.0		
18 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
22 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
23 Waist	**26.0**	**27.0**	28.0	31.0	32.0	35.0	36.0	39.0	40.0	43.0	**44.0**	**46.0**	47.0	50.0
24 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	40.0	44.0	46.0	48.0	50.0	52.0
25 Waist			**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
Avg	25.3	26.7	28.0	30.1	31.8	33.9	35.7	37.8	39.6	41.8	43.7	45.8	48.5	51.0
Mode	**26.0**	**27.0**	**28.0**	**30.0**	**32.0**	**34.0**	**36.0**	**38.0**	**40.0**	**42.0**	**44.0**	**46.0**		
%	67%	67%	91%	91%	75%	75%	75%	75%	67%	67%	73%	73%		

	XS		S		M		L		XL		XXL		XXXL	
3 Hip			**35.0**	**37.0**	39.0	41.0	**42.0**	**44.0**	45.0	47.0	48.0	50.0		
15 Hip			**35.0**	**37.0**	**38.0**	**40.0**	41.0	43.0	44.0	46.0	47.0	49.0		
24 Hip			34.0	36.0	**38.0**	**40.0**	**42.0**	**44.0**	45.5	48.5	50.3	51.8	53.3	54.8
Avg			34.7	36.7	38.3	40.3	41.7	43.7	44.8	47.2	48.4	50.3	53.3	54.8
Mode			**35.0**	**37.0**	**38.0**	**40.0**	**42.0**	**44.0**						
%			67%	67%	67%	67%	67%	67%						

	XS		S		M		L		XL		XXL		XXXL	
3 Inseam			31.0	31.0	**32.0**	**32.0**	33.0	33.0	34.0	34.0	35.0	35.0		
9 Inseam			33.0	33.0	33.0	34.0	34.0	35.0	35.0	35.0				
15 Inseam			31.5	31.5	**32.0**	**32.0**	32.5	32.5	33.0	33.0	33.5	33.5		
Avg			31.8	31.8	32.3	32.7	33.2	33.5	34.0	34.0	34.3	34.3		
Mode					**32.0**	**32.0**								
%					67%	67%								

	XS		S		M		L		XL		XXL		XXXL	
3 Waist			28.0	30.0	32.0	34.0	36.0	38.0	40.0	42.0	44.0	46.0		
3 Hip			35.0	37.0	39.0	41.0	42.0	44.0	45.0	47.0	48.0	50.0		
Ratio			**80%**	**81%**	**82%**	**83%**	**86%**	**86%**	**89%**	**89%**	**92%**	**92%**		
15 Waist			28.0	30.0	31.0	33.0	34.0	36.0	38.0	40.0	42.0	44.0		
15 Hip			35.0	37.0	38.0	40.0	41.0	43.0	44.0	46.0	47.0	49.0		
Ratio			**80%**	**81%**	**82%**	**83%**	**83%**	**84%**	**86%**	**87%**	**89%**	**90%**		
24 Waist			28.0	30.0	32.0	34.0	36.0	38.0	40.0	44.0	46.0	48.0	50.0	52.0
24 Hip			34.0	36.0	38.0	40.0	42.0	44.0	45.5	48.5	50.3	51.8	53.3	54.8
Ratio			**82%**	**83%**	**84%**	**85%**	**86%**	**86%**	**88%**	**91%**	**92%**	**93%**	**94%**	**95%**
Avg			**81%**	**82%**	**83%**	**83%**	**85%**	**85%**	**88%**	**89%**	**91%**	**92%**	**94%**	**95%**

Common Industry Body Measurement Ranges for Pant Sizing (Cooklin, 1992)

(All Measurements in Inches)

		29		30		31		32		33		34		36		38	
Men's Regular	Waist			27.5	29.0	29.5	32.0	32.5	33.0	33.5	35.0						
	Hips			34.0	35.5	36.0	37.5	38.0	39.5	40.0	41.5						
	Crotch Depth			9.8		10.0		10.3		10.5							
Men's Regular	Waist	27.0	28.5	29.0	30.5	31.0	32.5			33.0	34.5			35.0	36.5		
	Hips	33.0	34.3	35.0	36.5	37.0	38.5			39.0	40.5			41.0	42.5		
	Crotch Depth	9.6		9.9		10.1				10.4				10.6			
Men's Short	Waist	28.5	30.0	30.5	32.0			32.5	34.0			34.5	36.0			36.5	38.0
	Hips	35.5	37.0	37.5	39.0			39.5	41.0			41.5	43.0			43.5	44.0
	Crotch Depth	9.5		9.8				10.0				10.3				10.5	
Men's Short	Waist	28.5	29.0	29.5	31.0	31.5	33.0			33.5	35.0			35.5	37.0		
	Hips	35.5	36.0	36.5	38.0	38.5	40.0			40.5	42.0			42.5	44.0		
	Crotch Depth	9.6		9.9		10.1				10.4				10.6			
Men's Long	Waist	27.5	28.0	28.5	29.5	30.0	31.5										
	Hips	34.5	35.0	35.5	36.0	36.5	38.0										
	Crotch Depth	10.3		10.5		10.8											
Men's Long	Waist	27.0	28.0	28.5	29.0	29.5	31.0			31.5	33.0			33.5	35.0		
	Hips	34.5	35.0	35.5	36.0	36.5	38.0			38.5	40.0			40.5	41.5		
	Crotch Depth	10.1		10.4		10.6				10.9				11.1			

		29	30	31	32	33	34	35	36
Average	Waist	28.2	29.5	31.2	33.0	33.6	35.3	35.4	37.3
	Hips	35	36.3	37.7	39.5	40.3	42.3	42.0	43.8
	Crotch Depth	9.83	10.0	10.3	10.1	10.5	10.3	10.8	10.5

	30	31	32	33	34	35
Army	30.1	31.3	32.5	33.7	34.9	36.1

Common Industry Body Measurement Ratios & 1/2 Waist Sizes (Cooklin, 1992)

(All Measurements in Inches)

		29		30		31		32		33		34		35		36	
Men's Regular	Waist/Hips			0.81	0.82	0.82	0.85	0.86	0.84	0.84	0.84						
	Waist/Crotch			2.90		3.08		3.20		3.26							
	Hips/Crotch			3.56		3.68		3.78		3.88							
Men's Regular	Waist/Hips	0.82	0.83	0.83	0.84	0.84	0.84			0.85	0.85			0.85	0.86		
	Waist/Crotch	2.88		3.01		3.14				3.25				3.36			
	Hips/Crotch	3.49		3.62		3.73				3.83				3.93			
Men's Short	Waist/Hips	0.80	0.81	0.81	0.82			0.82	0.83			0.83	0.84			0.84	0.86
	Waist/Crotch	3.08		3.21				3.33				3.44				3.55	
	Hips/Crotch	3.82		3.92				4.03				4.12				4.17	
Men's Short	Waist/Hips	0.80	0.81	0.81	0.82	0.82	0.83			0.83	0.83			0.84	0.84		
	Waist/Crotch	2.99		3.06		3.19				3.30				3.41			
	Hips/Crotch	3.71		3.77		3.88				3.98				4.07			
Men's Long	Waist/Hips	0.80	0.80	0.80	0.82	0.82	0.83										
	Waist/Crotch	2.71		2.76		2.86											
	Hips/Crotch	3.39		3.40		3.47											
Men's Long	Waist/Hips	0.78	0.80	0.80	0.81	0.81	0.82			0.82	0.83			0.83	0.84		
	Waist/Crotch	2.72		2.77		2.85				2.97				3.08			
	Hips/Crotch	3.43		3.45		3.51				3.61				3.69			

		29	30	31	32	33	34	35	36
Average	Waist/Hips	0.81	0.81	0.83	0.84	0.84	0.83	0.84	0.85
	Waist/Crotch	2.87	2.95	3.02	3.26	3.19	3.44	3.28	3.55
	Hips/Crotch	3.56	3.62	3.65	3.90	3.82	4.12	3.89	4.17

	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0
1/2 Waist Sz	29.5	30.3	31.2	32.1	33.0	33.3	33.6	34.4	35.3	35.3	35.4

APPENDIX B

TEST SHORT AND SIZE RANGE ANALYSIS

ANSUR (30 & Under) Test Measures

(All Measurements in Centimeters and Kilograms)

Summary of Waist (OM)		**Summary of Thigh**	
Count	1234	Count	1234
Mean	844.45	Mean	593.97
Median	836	Median	593
MidRange	892.5	MidRange	611
StdDev	79.73	StdDev	49.32
Range	477	Range	294
IntQRange	109	IntQRange	68
Summary of Buttocks		**Summary of Crotch (OM)**	
Count	1234	Count	1234
Mean	977.19	Mean	757.99
Median	976	Median	754
MidRange	990	MidRange	771.5
StdDev	60.84	StdDev	52.64
Range	370	Range	341
IntQRange	87	IntQRange	70
Summary of Weight		**Summary of Height**	
Count	1234	Count	1234
Mean	773.74	Mean	1757.54
Median	766	Median	1756
MidRange	859.5	MidRange	1801
StdDev	105.75	StdDev	66.42
Range	767	Range	482
IntQRange	142	IntQRange	90

ANSUR (30 & Under) Correlation and Regression

Pearson Product-Moment Correlation

	Waist	Butt	Weight	Thigh	Crotch	Height
Waist (OM)	1.00					
Buttocks	0.86	1.00				
Weight	0.85	0.94	1.00			
Thigh	0.83	0.94	0.90	1.00		
Crotch (OM)	0.81	0.82	0.81	0.79	1.00	
Height	0.30	0.41	0.56	0.28	0.40	1.00

Dependent variable is: Waist (OM)
R squared = 80.9% R squared (adjusted) = 80.9%
s = 34.89 with 1234-6 = 1228 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	6.34e6	5	1.27e6	1.04e3
Residual	1.49e6	1228	1216.96	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	422.483	51.04	8.28	0.0001
Buttocks	0.439	0.060	7.33	0.0001
Weight	0.458	0.035	13	0.0001
Thigh	-0.301	0.068	-4.47	0.0001
Crotch (OM)	0.430	0.034	12.7	0.0001
Height	-0.289	0.022	-12.9	0.0001

ANSUR (Complete) Test Measures

(All Measurements in Centimeters and Kilograms)

Summary of Waist (OM)

Count	1774
Mean	862.42
Median	856
MidRange	919.5
StdDev	86.40
Range	531
IntQRange	122

Summary of Thigh

Count	1774
Mean	596.51
Median	596
MidRange	622.5
StdDev	49.28
Range	329
IntQRange	66

Summary of Buttocks

Count	1774
Mean	983.67
Median	982
MidRange	1022
StdDev	62.18
Range	434
IntQRange	86

Summary of Crotch (OM)

Count	1774
Mean	766.67
Median	763
MidRange	791.5
StdDev	55.55
Range	381
IntQRange	75

Summary of Weight

Count	1774
Mean	784.87
Median	777
MidRange	877
StdDev	111.06
Range	802
IntQRange	145

Summary of Height

Count	1774
Mean	1755.81
Median	1755.5
MidRange	1769.5
StdDev	66.81
Range	545
IntQRange	91

ANSUR (Complete) Correlation and Regression

Pearson Product-Moment Correlation

	Waist	Butt	Weight	Thigh	Crotch	Height
Waist (OM)	1.00					
Buttocks	0.86	1.00				
Weight	0.85	0.94	1.00			
Thigh	0.80	0.93	0.90	1.00		
Crotch (OM)	0.81	0.81	0.81	0.76	1.00	
Height	0.28	0.40	0.55	0.29	0.38	1.00

Dependent variable is: Waist (OM)
R squared = 82.3% R squared (adjusted) = 82.3%
s = 36.36 with 1774 - 6 = 1768 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	1.090e7	5	2.180e6	1.65e3
Residual	2.337e6	1768	1321.88	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	523.8	43.39	12.1	0.0001
Buttocks	0.544	0.051	10.7	0.0001
Weight	0.534	0.029	18.7	0.0001
Thigh	-0.571	0.055	-10.4	0.0001
Crotch (OM)	0.461	0.027	16.8	0.0001
Height	-0.358	0.018	-19.5	0.0001

Ten Size Waist Determination and Waist Ranges

(All Measurements as Listed in Inches and Centimeters)

WAIST CIRCUMFERENCE (OMPHALION)

	MEAN	SD	(-1SD)	(+1SD)	RANGE
CM	84.4	8.0	76.5	92.4	15.9
IN	33.2	3.1	30.1	36.4	6.3

TEN SIZE

CM	IN
76.5	30.1
78.1	30.7
79.7	31.4
81.3	32.0
82.9	32.6
84.4	33.2
86.0	33.9
87.6	34.5
89.2	35.1
90.8	35.8
92.4	36.4

WAIST RANGES

CM	IN
765-780	30-1/2 to 31
781-796	31 to 31-1/2
797-812	31-1/2 to 32
813-828	32 to 32-1/2
829-843	32-1/2 to 33
844-859	33 to 33-1/2
860-875	33-1/2 to 34
876-891	34 to 34-1/2
892-907	34-1/2 to 35
908-923	35 to 35-1/2

TEN SIZE (ADJ)

CM	IN
76.5	30.1
78.1	30.7
79.7	31.4
81.3	32.0
82.9	32.6
84.4	33.2
86.0	33.9
87.6	34.5
89.2	35.1
90.8	35.8

TEN SIZE with 1/2" SIZING

CM	IN	SIZE
76.4720	30.1	30.5
78.0666	30.7	31
79.6611	31.4	31.5
81.2556	32.0	32
82.8502	32.6	32.5
84.4447	33.2	33
86.0392	33.9	33.5
87.6338	34.5	34
89.2283	35.1	34.5
90.8228	35.8	35

Waist Circumference and Crotch Length Statistical Measures for 30 & Under ANSUR Subjects

(All Measurements in Centimeters)

CROTCH COUNT	DIFF	CROTCH MEAN	DIFF	CROTCH MEDIAN	DIFF	CROTCH SD	DIFF	CROTCH RANGE	DIFF	CROTCH IQRANGE	DIFF
101		74.1		74.0		2.8		13.8		3.3	
91	-10	74.6	0.5	74.5	0.5	3.2	0.4	16.2	2.4	4.6	1.3
99	8	74.9	0.2	74.7	0.2	3.1	-0.1	14.3	-1.9	4.6	0.0
80	-19	75.8	0.9	75.6	0.8	3.1	-0.1	15.0	0.7	4.5	-0.1
102	22	76.9	1.1	76.8	1.2	3.2	0.1	18.3	3.3	4.1	-0.4
105	3	76.6	-0.3	76.5	-0.3	3.0	-0.2	13.9	-4.4	4.2	0.1
97	-8	77.7	1.1	77.0	0.5	3.2	0.2	14.9	1.0	4.6	0.4
73	-24	78.1	0.5	77.6	0.6	3.0	-0.2	16.1	1.2	3.9	-0.7
76	3	78.7	0.6	78.9	1.3	3.7	0.7	14.9	-1.2	5.6	1.6
74	-2	79.8	1.1	79.7	0.8	3.2	-0.5	15.4	0.5	4.5	-1.1
90	Avg	76.7	Avg	76.5	Avg	3.2	Avg	15.3	Avg	4.4	Avg

WAIST COUNT	DIFF	WAIST MEAN	DIFF	WAIST MEDIAN	DIFF	WAIST SD	DIFF	WAIST RANGE	DIFF	WAIST IQRANGE	DIFF
101		80.6		80.6		0.4		1.1		0.7	
91	-10	81.8	1.2	81.8	1.2	0.4	0.0	1.1	0.0	0.6	-0.1
99	8	83.1	1.3	83.1	1.3	0.4	0.0	1.2	0.1	0.6	0.0
80	-19	84.4	1.3	84.4	1.3	0.3	-0.1	1.1	-0.1	0.5	-0.1
102	22	85.5	1.2	85.5	1.1	0.3	0.0	1.1	0.0	0.6	0.1
105	3	86.8	1.2	86.7	1.2	0.4	0.0	1.2	0.1	0.7	0.1
97	-8	88.1	1.3	88.1	1.4	0.3	-0.1	1.1	-0.1	0.5	-0.2
73	-24	89.3	1.2	89.3	1.2	0.3	0.0	1.1	0.0	0.6	0.1
76	3	90.5	1.2	90.5	1.2	0.4	0.1	1.2	0.1	0.8	0.2
74	-2	91.7	1.3	91.7	1.3	0.4	-0.1	1.1	-0.1	0.5	-0.3
90	Avg	86.2	Avg	86.2	Avg	0.4	Avg	1.1	Avg	0.6	Avg

ANSUR Size Range Statistical Analysis

Segment 1: 76.5 to 78.0 cm (30.5 to 31.0 in)

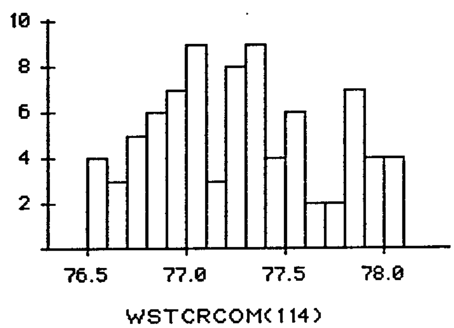
(All Measurements in Centimeters)

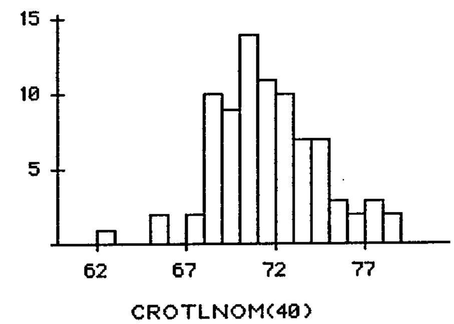
Summary of **WSTCRCOM(114)**
No Selector

Count	83
Mean	77.2217
Median	77.2
MidRange	77.25
StdDev	0.425999
Range	1.5
IntQRange	0.6

Summary of **CROTLNOM(40)**
No Selector

Count	83
Mean	71.5614
Median	71.2
MidRange	70.65
StdDev	2.97583
Range	15.7
IntQRange	4.05

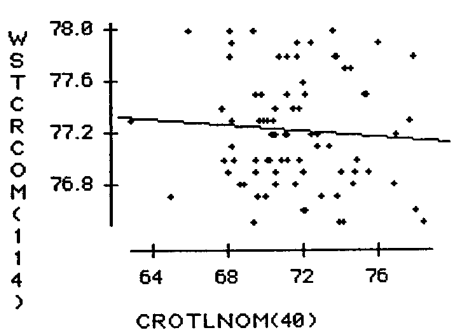




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 0.6%   R squared (adjusted) = -0.6%
s = 0.4273 with 83 - 2 = 81 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.093063	1	0.093063	0.51
Residual	14.7879	81	0.182567	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	78.0318	1.136	68.7	≤ 0.0001
CROTLNOM...	-0.0113207	0.01586	-0.714	0.4773



ANSUR Size Range Statistical Analysis

Segment 2: 78.1 to 79.6 cm (31.0 to 31.5 in)

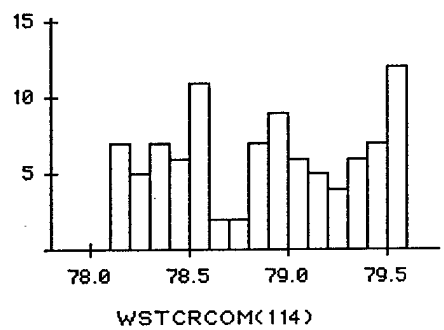
(All Measurements in Centimeters)

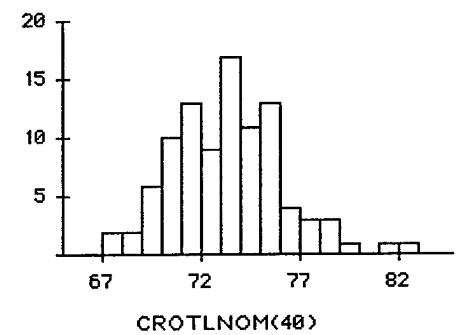
Summary of **WSTCRCOM(114)**
No Selector

Count	96
Mean	78.8385
Median	78.9
MidRange	78.85
StdDev	0.471363
Range	1.5
IntQRange	0.9

Summary of **CROTLNOM(40)**
No Selector

Count	96
Mean	73.3021
Median	73.35
MidRange	74.65
StdDev	2.87464
Range	14.9
IntQRange	3.85

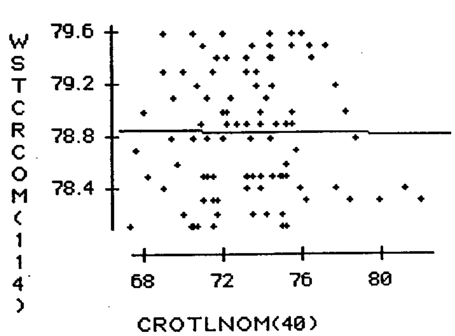




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 0%   R squared (adjusted) = -1.1%
s = 0.4738 with 96 - 2 = 94 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.00191999	1	0.00191999	0.00855
Residual	21.1055	94	0.224526	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	78.9532	1.241	63.6	≤ 0.0001
CROTLNOM...	-0.00156388	0.01691	-0.0925	0.9265



ANSUR Size Range Statistical Analysis

Segment 3: 79.7 to 81.2 cm (31.5 to 32.0 in)

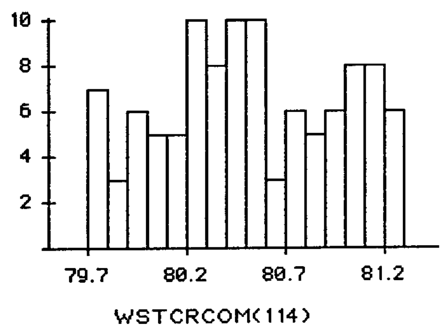
(All Measurements in Centimeters)

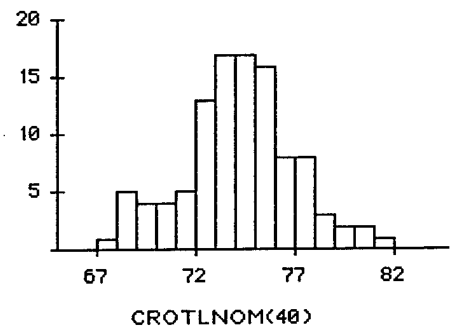
Summary of **WSTCRCOM(114)**
No Selector

Count	106
Mean	80.4717
Median	80.4
MidRange	80.45
StdDev	0.446095
Range	1.5
IntQRange	0.7

Summary of **CROTLNOM(40)**
No Selector

Count	106
Mean	74.0547
Median	74.05
MidRange	74.5
StdDev	2.82085
Range	14.6
IntQRange	3.6

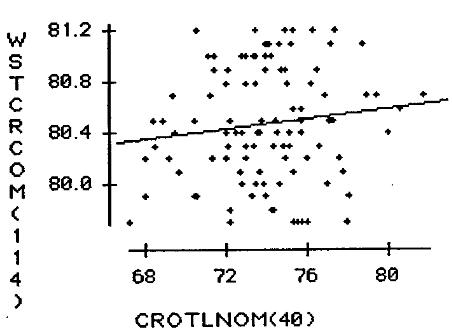




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 1.6%   R squared (adjusted) = 0.7%
s = 0.4446 with 106 - 2 = 104 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.333965	1	0.333965	1.69
Residual	20.5611	104	0.197703	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	78.9911	1.14	69.3	≤ 0.0001
CROTLNOM...	0.0199929	0.01538	1.3	0.1966



ANSUR Size Range Statistical Analysis

Segment 4: 81.3 to 82.8 cm (32.0 to 32.5 in)

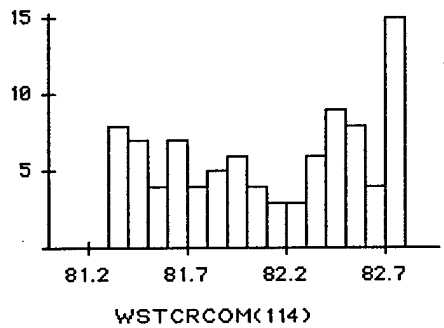
(All Measurements in Centimeters)

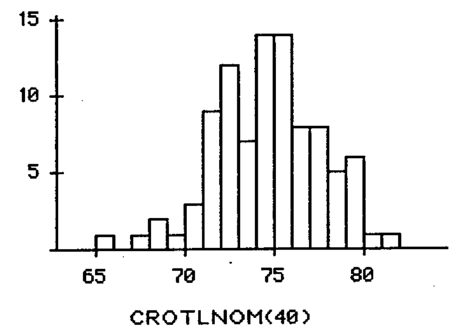
Summary of **WSTCRCOM(114)**
No Selector

Count	93
Mean	82.072
Median	82.1
MidRange	82.05
StdDev	0.499645
Range	1.5
IntQRange	0.9

Summary of **CROTLNOM(40)**
No Selector

Count	93
Mean	74.5398
Median	74.5
MidRange	73.65
StdDev	2.99986
Range	16.1
IntQRange	3.95

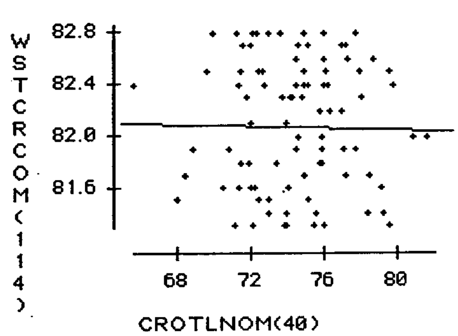




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 0% R squared (adjusted) = -1.1%
s = 0.5023 with 93 - 2 = 91 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.00771026	1	0.00771026	0.0306
Residual	22.9596	91	0.252303	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	82.2995	1.302	63.2	≤ 0.0001
CROTLNOM...	-0.00305168	0.01746	-0.175	0.8616



ANSUR Size Range Statistical Analysis

Segment 5: 82.9 to 84.3 cm (32.5 to 33.0 in)

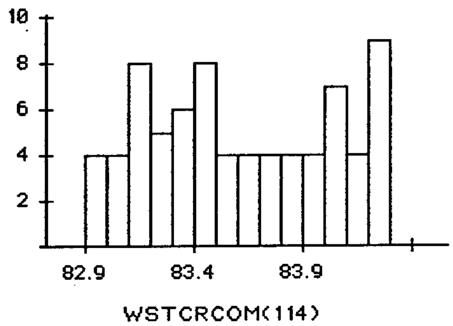
(All Measurements in Centimeters)

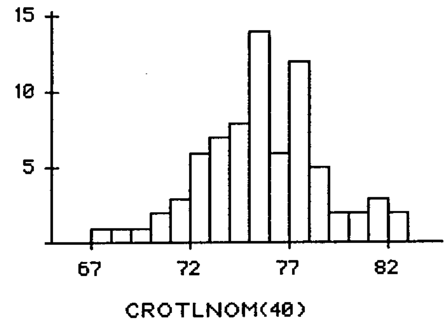
Summary of WSTCRCOM(114)
No Selector

Count	75
Mean	83.5733
Median	83.5
MidRange	83.6
StdDev	0.42691
Range	1.4
IntQRange	0.8

Summary of CROTLNOM(40)
No Selector

Count	75
Mean	75.664
Median	75.5
MidRange	75.25
StdDev	3.11204
Range	15.1
IntQRange	3.975

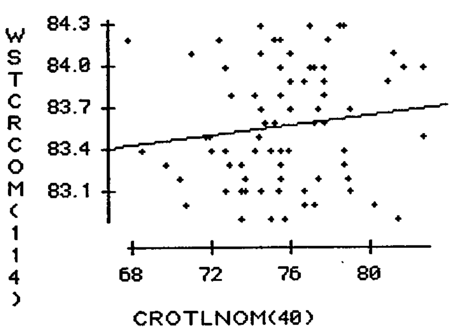




Dependent variable is: WSTCRCOM(114)
No Selector
R squared = 1.7% R squared (adjusted) = 0.3%
s = 0.4262 with 75 - 2 = 73 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	0.226047	1	0.226047	1.24
Residual	13.2606	73	0.181652	

Variable	Coefficient	s.e. of Coeff	t-ratio	prob
Constant	82.2296	1.206	68.2	≤ 0.0001
CROTLNOM...	0.0177598	0.01592	1.12	0.2683



ANSUR Size Range Statistical Analysis

Segment 6: 84.4 to 85.9 cm (33.0 to 33.5 in)

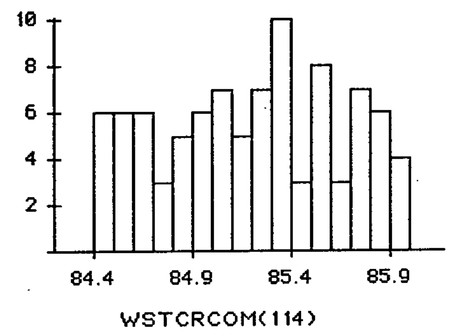
(All Measurements in Centimeters)

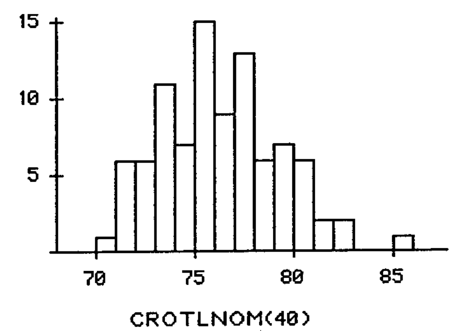
Summary of **WSTCRCOM(114)**
No Selector

Count	92
Mean	85.1489
Median	85.2
MidRange	85.15
StdDev	0.449785
Range	1.5
IntQRange	0.7

Summary of **CROTLNOM(40)**
No Selector

Count	92
Mean	76.1891
Median	75.95
MidRange	78
StdDev	3.03827
Range	15.6
IntQRange	4.15

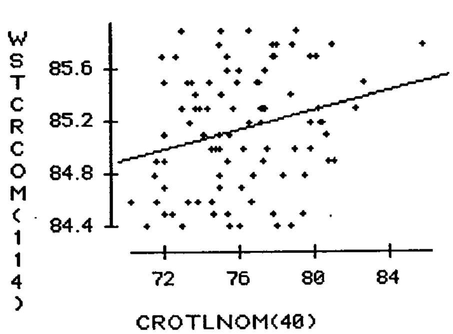




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 6.2% R squared (adjusted) = 5.1%
s = 0.4381 with 92 - 2 = 90 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	1.13877	1	1.13877	5.93
Residual	17.2711	90	0.191901	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	82.3437	1.152	71.5	≤ 0.0001
CROTLNOM...	0.0368189	0.01511	2.44	0.0168



ANSUR Size Range Statistical Analysis

Segment 7: 86.0 to 87.5 cm (33.5 to 34.0 in)

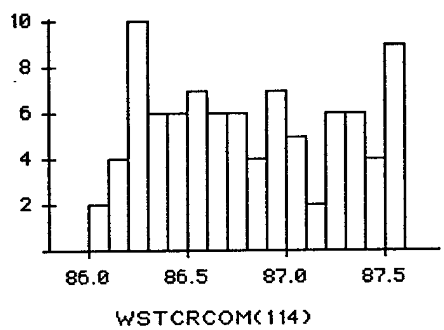
(All Measurements in Centimeters)

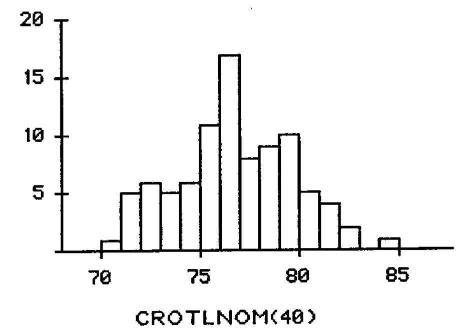
Summary of **WSTCRCOM(114)**
No Selector

Count	90
Mean	86.7633
Median	86.7
MidRange	86.75
StdDev	0.460447
Range	1.5
IntQRange	0.8

Summary of **CROTLNOM(40)**
No Selector

Count	90
Mean	76.6622
Median	76.6
MidRange	77.85
StdDev	2.94163
Range	13.9
IntQRange	4

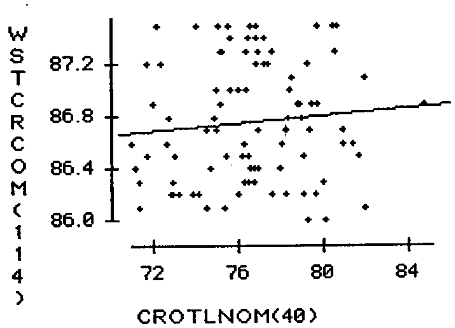




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 0.9% R squared (adjusted) = -0.2%
s = 0.461 with 90 - 2 = 88 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.166253	1	0.166253	0.782
Residual	18.7027	88	0.212531	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	85.637	1.274	67.2	≤ 0.0001
CROTLNOM...	0.0146927	0.01661	0.884	0.3789



ANSUR Size Range Statistical Analysis

Segment 8: 87.6 to 89.1 cm (34.0 to 34.5 in)

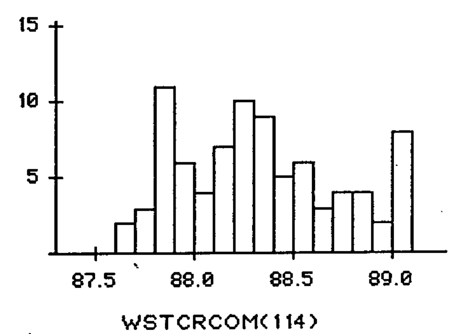
(All Measurements in Centimeters)

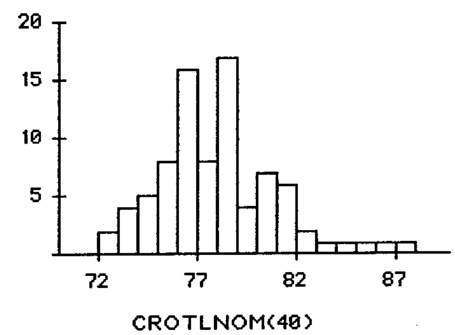
Summary of **WSTCRCOM(114)**
No Selector

Count	84
Mean	88.2821
Median	88.2
MidRange	88.35
StdDev	0.405136
Range	1.5
IntQRange	0.65

Summary of **CROTLNOM(40)**
No Selector

Count	84
Mean	78.0179
Median	77.8
MidRange	80.15
StdDev	3.00711
Range	15.5
IntQRange	3.4

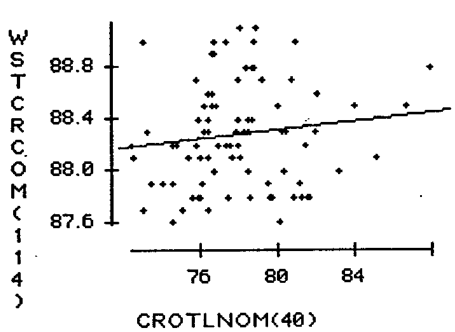




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 1.5% R squared (adjusted) = 0.3%
s = 0.4045 with 84 - 2 = 82 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.20542	1	0.20542	1.26
Residual	13.4178	82	0.163632	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	86.9914	1.153	75.5	≤ 0.0001
CROTLNOM...	0.0165437	0.01477	1.12	0.2658



ANSUR Size Range Statistical Analysis

Segment 9: 89.2 to 90.7 cm (34.5 to 35.0 in)

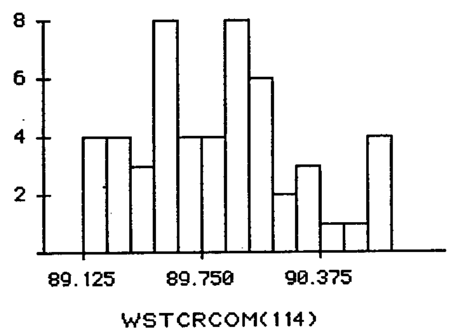
(All Measurements in Centimeters)

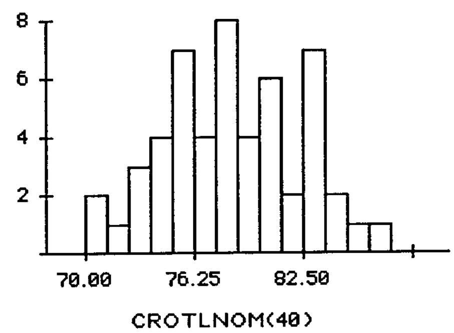
Summary of **WSTCRCOM(114)**
No Selector

Count	52
Mean	89.8327
Median	89.8
MidRange	89.95
StdDev	0.423673
Range	1.5
IntQRange	0.6

Summary of **CROTLNOM(40)**
No Selector

Count	52
Mean	78.4712
Median	78.35
MidRange	78.35
StdDev	3.93154
Range	15.9
IntQRange	6.15

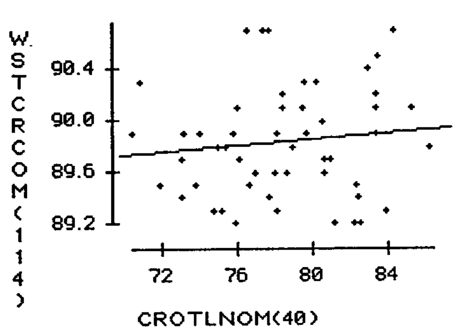




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 1.2%   R squared (adjusted) = -0.8%
s = 0.4253 with 52 - 2 = 50 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	0.108987	1	0.108987	0.602
Residual	9.04544	50	0.180909	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	88.91	1.19	74.7	≤ 0.0001
CROTLNOM...	0.0117582	0.01515	0.776	0.4413



ANSUR Size Range Statistical Analysis

Segment 10: 90.8 to 92.3 cm (35.0 to 35.5 in)

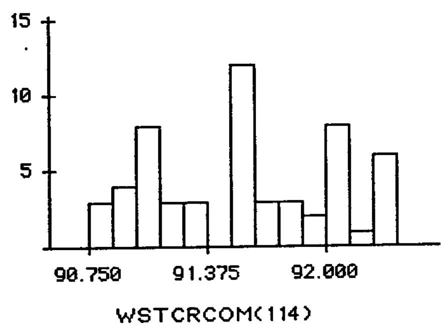
(All Measurements in Centimeters)

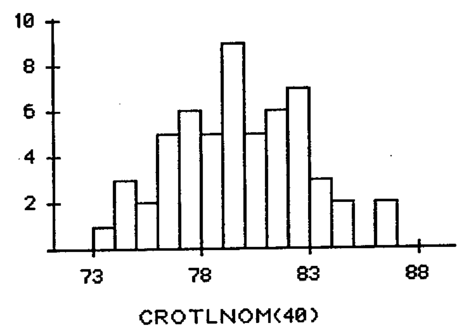
Summary of **WSTCRCOM(114)**
No Selector

Count	56
Mean	91.5554
Median	91.6
MidRange	91.55
StdDev	0.470945
Range	1.5
IntQRange	0.9

Summary of **CROTLNOM(40)**
No Selector

Count	56
Mean	79.7214
Median	79.7
MidRange	80
StdDev	3.00761
Range	13.4
IntQRange	4.35

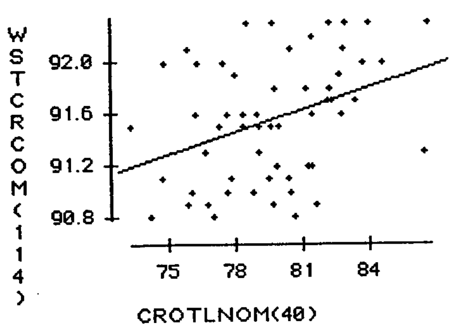




Dependent variable is: **WSTCRCOM(114)**
No Selector
R squared = 13.2% R squared (adjusted) = 11.6%
s = 0.4428 with 56 - 2 = 54 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	1.60905	1	1.60905	8.21
Residual	10.5893	54	0.196099	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	**prob**
Constant	87.0216	1.584	54.9	≤ 0.0001
CROTLNOM...	0.0568699	0.01985	2.86	0.0059



Original Pattern and ANSUR Crotch Length Data Comparison

(All Measurements in Centimeters)

Size	ANSUR Mean	Change	Pattern Front	Change	Pattern Back	Change	Pattern Total	Change	Adjust
30.0			27.51	0.16	40.74	0.15	68.25	0.31	0.59
30.5	71.56	1.74	27.67	0.16	40.89	0.15	68.56	0.31	0.59
31.0	73.30	0.75	27.83	0.16	41.04	0.16	68.87	0.32	0.59
31.5	74.05	0.49	27.99	0.16	41.20	0.15	69.19	0.31	0.59
32.0	74.54	1.12	28.15	0.15	41.35	0.15	69.50	0.30	0.59
32.5	75.66	0.53	28.30	0.15	41.50	0.15	69.80	0.30	0.59
33.0	76.19	0.47	28.45	0.16	41.65	0.16	70.10	0.32	0.59
33.5	76.66	1.36	28.61	0.16	41.81	0.16	70.42	0.32	0.59
34.0	78.02	0.45	28.77	0.16	41.97	0.15	70.74	0.31	0.59
34.5	78.47	1.25	28.93	0.16	42.12	0.16	71.05	0.32	0.59
35.0	79.72		29.09		42.28		71.37		

Sum	8.16
Avg	0.91

Sum	3.12
Avg	0.31

ANSUR Std Dev

(In Centimeters)

Size	SD
30.0	2.98
30.5	2.87
31.0	2.82
31.5	3.00
32.0	3.11
32.5	3.04
33.0	2.94
33.5	3.01
34.0	3.93
34.5	3.01
35.0	

Sum	30.71
Avg	3.07

Original and Adjusted Pattern Crotch Seam Lengths

(All Measurements in Centimeters)

Size	Adjust Front	Change	Adjust Back	Change	Adjust Total	Original Total	Change
30.0	25.73	0.45	38.93	0.45	64.66	68.25	-3.59
30.5	26.18	0.45	39.38	0.45	65.57	68.56	-2.99
31.0	26.64	0.45	39.84	0.45	66.47	68.87	-2.40
31.5	27.09	0.45	40.29	0.45	67.38	69.19	-1.81
32.0	27.54	0.45	40.74	0.45	68.29	69.50	-1.21
32.5	28.00	0.45	41.20	0.45	69.19	69.80	-0.61
33.0	28.45	0.45	41.65	0.45	70.10	70.10	0.00
33.5	28.90	0.45	42.10	0.45	71.01	70.42	0.59
34.0	29.36	0.45	42.56	0.45	71.91	70.74	1.17
34.5	29.81	0.45	43.01	0.45	72.82	71.05	1.77
35.0	30.26		43.46		73.73	71.37	2.36

Final Pattern Crotch Lengths

(All Measurements in Centimeters)

Size	- 1SD	Base	+ 1SD	+ 2SD
30.0	61.59	64.66	67.73	70.80
30.5	62.50	65.57	68.64	71.71
31.0	63.40	66.47	69.54	72.62
31.5	64.31	67.38	70.45	73.52
32.0	65.22	68.29	71.36	74.43
32.5	66.12	69.19	72.26	75.34
33.0	67.03	70.10	73.17	76.24
33.5	67.94	71.01	74.08	77.15
34.0	68.84	71.91	74.98	78.06
34.5	69.75	72.82	75.89	78.96
35.0	70.66	73.73	76.80	79.87

- 1SD Front, Back, & Total Crotch Seam Lengths
(All Measurements in Centimeters)

Size	- 1SD Front	Change	- 1SD Back	Change	- 1SD Total
30.0	24.51	0.45	37.08	0.45	61.59
30.5	24.96	0.45	37.54	0.45	62.50
31.0	25.41	0.45	38.00	0.45	63.40
31.5	25.86	0.45	38.45	0.45	64.31
32.0	26.30	0.45	38.91	0.45	65.22
32.5	26.75	0.45	39.37	0.45	66.12
33.0	27.20	0.45	39.83	0.45	67.03
33.5	27.65	0.45	40.28	0.45	67.94
34.0	28.10	0.45	40.74	0.45	68.84
34.5	28.55	0.45	41.20	0.45	69.75
35.0	29.00		41.65		70.66

+ 1SD Front, Back, & Total Crotch Seam Lengths
(All Measurements in Centimeters)

Size	+ 1SD Front	Change	+ 1SD Back	Change	+ 1SD Total
30.0	26.95	0.45	40.78	0.45	67.73
30.5	27.41	0.45	41.23	0.45	68.64
31.0	27.87	0.45	41.68	0.45	69.54
31.5	28.32	0.45	42.13	0.45	70.45
32.0	28.78	0.45	42.58	0.45	71.36
32.5	29.24	0.45	43.03	0.45	72.26
33.0	29.70	0.45	43.47	0.45	73.17
33.5	30.15	0.45	43.92	0.45	74.08
34.0	30.61	0.45	44.37	0.45	74.98
34.5	31.07	0.45	44.82	0.45	75.89
35.0	31.52		45.27		76.80

+ 2SD Front, Back, & Total Crotch Seam Lengths
(All Measurements in Centimeters)

Size	+ 2SD Front	Change	+ 2SD Back	Change	+ 2SD Total
30.0	28.17	0.45	42.63	0.45	70.80
30.5	28.64	0.45	43.07	0.45	71.71
31.0	29.10	0.45	43.52	0.45	72.62
31.5	29.56	0.45	43.96	0.45	73.52
32.0	30.02	0.45	44.41	0.45	74.43
32.5	30.48	0.45	44.85	0.45	75.34
33.0	30.94	0.45	45.30	0.45	76.24
33.5	31.40	0.45	45.75	0.45	77.15
34.0	31.86	0.45	46.19	0.45	78.06
34.5	32.32	0.45	46.64	0.45	78.96
35.0	32.78		47.08		79.87

Ease Adjusted Final Pattern Measurements
(All Measurements in Centimeters)

Size	- 1SD	Base	+ 1SD	+ 2SD
30.0	54.49	57.56	60.63	63.70
30.5	55.40	58.47	61.54	64.61
31.0	56.30	59.37	62.44	65.52
31.5	57.21	60.28	63.35	66.42
32.0	58.12	61.19	64.26	67.33
32.5	59.02	62.09	65.16	68.24
33.0	59.93	63.00	66.07	69.14
33.5	60.84	63.91	66.98	70.05
34.0	61.74	64.81	67.88	70.96
34.5	62.65	65.72	68.79	71.86
35.0	63.56	66.63	69.70	72.77

Original Pattern Ease Adjustments
(All Measurements in Inches and Centimeters)

Size	Pattern	Crotch (In)	Ease	Final (In)	Final (cm)
30.0	68.25	26.87	-2.80	24.07	61.15
30.5	68.56	26.99	-2.80	24.20	61.46
31.0	68.87	27.11	-2.80	24.32	61.77
31.5	69.19	27.24	-2.80	24.44	62.09
32.0	69.50	27.36	-2.80	24.57	62.40
32.5	69.80	27.48	-2.80	24.69	62.70
33.0	70.10	27.60	-2.80	24.80	63.00
33.5	70.42	27.72	-2.80	24.93	63.32
34.0	70.74	27.85	-2.80	25.06	63.64
34.5	71.05	27.97	-2.80	25.18	63.95
35.0	71.37	28.10	-2.80	25.30	64.27

Original Pattern/ANSUR Comparison
(All Measurements in Centimeters)

Size	Pattern Final	ANSUR Mean	Change
30.0	61.15	70.65	9.50
30.5	61.46	71.56	10.10
31.0	61.77	73.30	11.53
31.5	62.09	74.05	11.96
32.0	62.40	74.54	12.14
32.5	62.70	75.66	12.96
33.0	63.00	76.19	13.19
33.5	63.32	76.66	13.34
34.0	63.64	78.02	14.38
34.5	63.95	78.47	14.52
35.0	64.27	79.72	15.45

Final Pattern (Base) Ease Adjustments
(All Measurements in Inches and Centimeters)

Size	Pattern Base	Crotch (In)	Ease	Base (In)	Base (cm)
30.0	64.66	25.46	-2.80	22.66	57.56
30.5	65.57	25.81	-2.80	23.02	58.47
31.0	66.47	26.17	-2.80	23.38	59.37
31.5	67.38	26.53	-2.80	23.73	60.28
32.0	68.29	26.88	-2.80	24.09	61.19
32.5	69.19	27.24	-2.80	24.45	62.09
33.0	70.10	27.60	-2.80	24.80	63.00
33.5	71.01	27.96	-2.80	25.16	63.91
34.0	71.91	28.31	-2.80	25.52	64.81
34.5	72.82	28.67	-2.80	25.87	65.72
35.0	73.73	29.03	-2.80	26.23	66.63

Final (Base)/ANSUR Comparison
(All Measurements in Centimeters)

Size	Base Final	ANSUR Mean	Change
30.0	57.56	70.65	13.09
30.5	58.47	71.56	13.09
31.0	59.37	73.30	13.93
31.5	60.28	74.05	13.77
32.0	61.19	74.54	13.35
32.5	62.09	75.66	13.57
33.0	63.00	76.19	13.19
33.5	63.91	76.66	12.76
34.0	64.81	78.02	13.20
34.5	65.72	78.47	12.75
35.0	66.63	79.72	13.09

Expert Measurement Crotch Ranges
(All Measurements in Centimeters)

Size	- 2Sd	- 1Sd	Base	+ 1Sd	+ 2Sd
30.0	51.4	54.5	57.6	60.6	63.7
30.5	52.3	55.4	58.5	61.5	64.6
31.0	53.2	56.3	59.4	62.4	65.5
31.5	54.1	57.2	60.3	63.4	66.4
32.0	55.0	58.1	61.2	64.3	67.3
32.5	55.9	59.0	62.1	65.2	68.2
33.0	56.8	59.9	63.0	66.1	69.1
33.5	57.7	60.8	63.9	67.0	70.0
34.0	58.6	61.7	64.8	67.9	71.0
34.5	59.5	62.6	65.7	68.8	71.9
35.0	60.5	63.6	66.6	69.7	72.8

Expert Measurement Crotch Ranges
(All Measurements in Inches)

Size	- 2Sd	- 1Sd	Base	+ 1Sd	+ 2Sd
30.0	20.2	21.5	22.7	23.9	25.1
30.5	20.6	21.8	23.0	24.2	25.4
31.0	20.9	22.2	23.4	24.6	25.8
31.5	21.3	22.5	23.7	24.9	26.2
32.0	21.7	22.9	24.1	25.3	26.5
32.5	22.0	23.2	24.4	25.7	26.9
33.0	22.4	23.6	24.8	26.0	27.2
33.5	22.7	24.0	25.2	26.4	27.6
34.0	23.1	24.3	25.5	26.7	27.9
34.5	23.4	24.7	25.9	27.1	28.3
35.0	23.8	25.0	26.2	27.4	28.6

Expert Measurement Adjustments:
- Waist adjusted + 1/2"
- Crotch adjusted -3.1cm

Self Measurement Crotch Ranges
(All Measurements in Centimeters)

Size	- 2Sd	- 1Sd	Base	+ 1Sd	+ 2Sd
30.0	54.5	57.6	60.7	63.7	66.8
30.5	55.4	58.5	61.6	64.6	67.7
31.0	56.3	59.4	62.5	65.5	68.6
31.5	57.2	60.3	63.4	66.5	69.5
32.0	58.1	61.2	64.3	67.4	70.4
32.5	59.0	62.1	65.2	68.3	71.3
33.0	59.9	63.0	66.1	69.2	72.2
33.5	60.8	63.9	67.0	70.1	73.1
34.0	61.7	64.8	67.9	71.0	74.1
34.5	62.6	65.7	68.8	71.9	75.0
35.0	63.6	66.7	69.7	72.8	75.9

Self-Measurement Crotch Ranges
(All Measurements in Inches)

Size	- 2Sd	- 1Sd	Base	+ 1Sd	+ 2Sd
30.0	21.5	22.7	23.9	25.1	26.3
30.5	21.8	23.0	24.2	25.4	26.7
31.0	22.2	23.4	24.6	25.8	27.0
31.5	22.5	23.7	25.0	26.2	27.4
32.0	22.9	24.1	25.3	26.5	27.7
32.5	23.2	24.5	25.7	26.9	28.1
33.0	23.6	24.8	26.0	27.2	28.4
33.5	24.0	25.2	26.4	27.6	28.8
34.0	24.3	25.5	26.7	27.9	29.2
34.5	24.7	25.9	27.1	28.3	29.5
35.0	25.0	26.2	27.5	28.7	29.9

Self Measurement Adjustments:
- Waist adjusted + 1"
- Crotch no adjustment

Test Short Size Validation for Waist Measurement

(All Measurements in Centimeters)

	Short		Medium		Long		X-Long		Avg
30.0	41.2	0.4	41.7	-0.1	41.6	0.0	41.8	-0.2	41.6
	0.9	-0.2	0.7	0.0	0.4	0.3	0.8	-0.1	0.7
30.5	42.1	0.2	42.4	-0.1	42	0.3	42.6	-0.3	42.3
	0.7	0.0	0.2	0.5	1.1	-0.4	0.8	-0.1	0.7
31.0	42.8	0.2	42.6	0.4	43.1	-0.1	43.4	-0.4	43.0
	0.7	0.1	0.7	0.1	1.1	-0.3	0.7	0.1	0.8
31.5	43.5	0.3	43.3	0.5	44.2	-0.4	44.1	-0.3	43.8
	0.6	-0.1	1.2	-0.6	0.1	0.4	0.3	0.2	0.5
32.0	44.1	0.2	44.5	-0.2	44.3	0.0	44.4	-0.1	44.3
	0.9	-0.1	0.5	0.3	0.7	0.1	1	-0.2	0.8
32.5	45	0.1	45	0.1	45	0.1	45.4	-0.3	45.1
	0.5	0.0	0.8	-0.3	0.4	0.1	0.3	0.2	0.5
33.0	45.5	0.1	45.8	-0.2	45.4	0.2	45.7	-0.1	45.6
	0.5	0.3	0.6	0.1	1	-0.2	0.9	-0.2	0.8
33.5	46	0.4	46.4	-0.1	46.4	-0.1	46.6	-0.3	46.4
	1	-0.4	0.9	-0.3	0.4	0.2	0.2	0.4	0.6
34.0	47	0.0	47.3	-0.3	46.8	0.2	46.8	0.2	47.0
	0.7	0.3	0.9	0.1	1	0.0	1.3	-0.3	1.0
34.5	47.7	0.3	48.2	-0.3	47.8	0.1	48.1	-0.1	48.0
	0.7	-0.2	0.7	-0.2	0.3	0.2	0.4	0.1	0.5
35.0	48.4	0.1	48.9	-0.4	48.1	0.4	48.5	0.0	48.5

#	Change between sizes
#	Changes outside tolerances
#	Waist Measurement on Test Apparatus

Test Short Size Validation for Crotch Measurement

(All Measurements in Centimeters)

	Short		Medium		Long		X-Long	
30.0	36.4	0.5	37.8	0.5	39.4	0.5	40.5	0.5
	0.5	0.0	0.3	-0.1	0.5	0.0	0.9	0.4
	0.5	0.0	0.3	-0.1	0.5	0.0	0.9	0.4
30.5	36.9	1.0	38.1	0.9	39.9	1.0	41.4	1.0
	0.4	-0.1	0.5	0.1	0.4	-0.1	0.6	0.1
	0.9	-0.1	0.8	-0.1	0.9	-0.1	1.5	0.5
31.0	37.3	1.4	38.6	1.4	40.3	1.5	42	1.5
	0.3	-0.2	0.5	0.1	0.4	-0.1	0.4	-0.1
	1.2	-0.2	1.3	0.0	1.3	-0.2	1.9	0.4
31.5	37.6	1.9	39.1	1.8	40.7	2.0	42.4	2.0
	0.5	0.0	1.2	0.7	0.4	-0.1	0.3	-0.2
	1.7	-0.2	2.5	0.7	1.7	-0.3	2.2	0.2
32.0	38.1	2.4	40.3	2.3	41.1	2.5	42.7	2.5
	0.4	-0.1	0.5	0.1	0.5	0.0	0.8	0.3
	2.1	-0.3	3.0	0.8	2.2	-0.3	3.0	0.5
32.5	38.5	2.9	40.8	2.7	41.6	3.0	43.5	3.0
	0.4	-0.1	0.3	-0.1	0.7	0.2	0.3	-0.2
	2.5	-0.4	3.3	0.6	2.9	-0.1	3.3	0.3
33.0	38.9	3.4	41.1	3.2	42.3	3.5	43.8	3.5
	0.6	0.1	0.3	-0.2	0.4	-0.1	0.6	0.1
	3.1	-0.3	3.6	0.5	3.3	-0.2	3.9	0.4
33.5	39.5	3.8	41.4	3.6	42.7	4.0	44.4	4.0
	0.8	0.3	-0.2	-0.6	0.7	0.2	0.5	0.0
	3.9	0.1	3.4	-0.2	4.0	0.0	4.4	0.4
34.0	40.3	4.3	41.2	4.1	43.4	4.5	44.9	4.5
	0.5	0.0	0.7	0.2	0.5	0.0	0.2	-0.3
	4.4	0.1	4.1	0.1	4.5	0.0	4.6	0.1
34.5	40.8	4.8	41.9	4.5	43.9	5.0	45.1	5.0
	0.4	-0.1	0.4	-0.1	0.5	0.0	0.4	-0.1
	4.8	0.0	4.5	0.0	5.0	0.0	5.0	0.0
35.0	41.2	NA	42.3	NA	44.4	NA	45.5	NA

# (black)	Changes between sizes
# (dark shaded)	Changes outside of tolerances
# (light shaded)	Crotch Length on Test Apparatus

APPENDIX C

SURVEY AND MEASUREMENT DATA

Test Subject Self-Measurement and Fit Preference Responses

(All Measurements in Inches and Pounds)

Subj	Height	Weight	S(girth)	S(waist)	S(seat)	S(crotch)	FP(w)	FP(wh)	FP(s)	FP(c)
A50	67.00	145	31.50	31.50	37.75	23.50	2	3	3	3
B51	66.75	132	29.00	31.25	36.00	26.00	3	3	4	3
A52	66.50	153	33.00	34.00	39.00	25.00	3	3	2	3
A54	67.75	138	33.00	32.00	37.00	30.00	4	4	4	4
A56	74.00	160	31.50	36.00	38.50	27.00	4	4	4	4
B57	70.50	155	32.00	34.00	38.50	27.00	4	2	3	4
A58	66.25	146	30.00	32.00	41.00	26.00	3	4	3	3
B59	69.00	165	34.50	35.50	40.50	28.00	3	3	3	3
A60	74.00	169	31.00	35.00	39.00	27.00	5	5	4	4
B61	73.25	165	32.00	34.00	37.00	27.00	4	3	5	5
B63	69.50	176	33.00	33.50	40.25	25.50	3	3	3	3
A64	70.00	176	34.50	36.00	40.50	30.00	4	2	3	3
B65	65.00	134	32.00	33.50	38.00	24.00	4	2	3	3
A66	70.00	192	38.00	36.00	38.00	28.50	4	2	4	1
B67	71.50	188	38.00	36.00	41.00	26.00	3	4	3	4
A68	70.00	175	32.75	33.50	38.50	25.50	4	4	5	5
B69	66.50	150	32.50	31.50	39.50	26.50	4	3	4	4
A70	66.00	148	34.50	37.00	39.00	25.00	2	3	4	4
B71	65.50	139	32.00	31.75	38.25	25.25	3	2	3	4
B73	72.00	156	32.00	32.50	38.00	24.00	3	3	4	4
A74	69.00	172	34.50	32.00	36.00	26.00	1	3	2	3
B75	70.75	162	32.50	33.50	41.50	25.75	3	3	5	4
A76	69.00	175	35.00	35.50	44.00	24.00	3	3	3	4
B77	64.00	134	31.50	31.50	38.50	25.00	3	4	3	2
A78	68.75	138	31.00	32.50	37.50	28.50	4	4	3	4
B79	67.00	140	31.50	32.50	36.50	26.50	4	4	5	5
A80	72.25	175	36.00	33.00	38.00	27.00	4	3	3	3
B81	66.00	165	35.00	33.00	30.00	25.00	3	5	3	3
A82	66.00	125	32.00	32.00	34.00	20.00	4	4	4	4
B83	67.00	164	33.50	35.50	40.50	27.00	3	3	3	4
A84	66.00	136	31.88	31.75	35.63	23.13	4	4	4	5
B85	71.50	158	32.00	33.00	39.00	28.00	2	4	4	3
A86	64.75	149	36.00	33.00	37.00	23.00	3	4	4	3
B87	69.75	178	36.00	37.00	42.00	27.00	2	3	3	4

Test Subject Expert Measurements and Initial Size Prediction Model Sizes

(All Measurements and Sizes in Inches)

Subj	E(girth)	E(waist)	E(g-w)	E(seat)	E(thigh)	E(crotch)	IEM(w)	IEM(c)	ISM(w)	ISM(c)	ISF(w)	ISF(c)
A50	31.00	31.75	2.50	37.00	21.00	26.25	31.0	4	30.5	2	30.5	2
B51	29.75	32.00	3.00	35.75	20.75	23.50	31.5	2	30.5	4	30.5	4
A52	32.00	33.00	3.00	37.75	22.25	20.75	32.0	1	32.5	2	32.5	1
A54	31.50	34.00	2.75	36.50	20.00	26.00	33.0	3	31.0	4	31.5	4
A56	30.00	34.00	2.50	38.75	22.00	24.00	33.0	2	34.0	3	34.5	3
B57	30.50	34.00	4.00	37.75	20.50	24.00	33.0	2	32.5	3	33.0	4
A58	31.00	31.50	2.25	37.50	20.50	26.00	31.0	4	31.0	3	31.0	3
B59	34.00	33.50	3.00	39.50	20.25	26.00	32.5	4	34.0	3	34.0	3
A60	31.00	33.00	3.50	38.00	21.00	25.50	32.0	3	33.5	3	34.0	4
B61	30.75	32.25	3.00	38.00	21.50	26.00	31.5	4	32.5	3	33.0	4
B63	31.00	32.00	3.00	39.00	22.50	27.75	31.5	4	32.0	2	32.0	2
A64	34.00	35.75	4.50	40.00	22.50	26.00	34.5	2	34.0	4	34.5	4
B65	30.50	30.50	2.00	37.50	20.50	24.75	30.0	4	32.0	1	32.5	1
A66	35.50	35.00	3.00	40.50	22.00	27.00	34.0	3	34.0	4	34.5	2
B67	37.00	36.00	2.50	40.50	23.00	26.00	34.5	2	34.0	2	34.0	2
A68	32.50	31.50	4.00	38.00	22.50	26.00	31.0	4	32.0	2	32.5	4
B69	30.50	31.00	3.00	38.00	21.00	25.00	30.5	4	30.5	4	31.0	4
A70	32.75	34.00	4.00	38.50	21.50	24.00	33.0	2	35.0	1	35.0	1
B71	31.50	30.75	2.00	37.00	21.00	25.50	30.5	4	30.5	3	30.5	4
B73	30.50	32.00	3.50	37.50	22.00	24.50	31.5	3	31.5	2	31.5	3
A74	35.75	34.00	2.50	38.50	21.00	27.00	33.0	4	31.0	3	30.5	4
B75	32.75	34.00	3.25	39.25	23.50	25.50	33.0	3	32.0	3	32.5	4
A76	35.00	34.00	3.00	41.50	25.00	27.75	33.0	4	34.0	1	34.0	1
B77	31.00	30.25	3.25	38.00	21.25	23.50	30.0	3	30.5	3	30.5	2
A78	30.00	33.50	3.75	36.25	20.25	24.00	32.5	2	31.5	4	31.5	4
B79	31.50	32.00	3.00	37.00	20.75	25.50	31.5	4	31.5	4	31.5	4
A80	36.00	35.00	4.00	38.75	21.25	24.25	34.0	1	31.5	4	32.0	4
B81	36.25	34.25	4.25	40.00	22.00	25.00	33.0	2	31.5	2	31.5	2
A82	31.50	31.00	3.00	35.75	20.25	24.00	30.5	3	31.0	1	31.5	1
B83	32.50	32.00	3.00	37.50	22.00	26.00	31.5	4	34.0	3	34.0	3
A84	31.00	32.00	4.00	36.50	19.75	23.50	31.5	2	30.5	1	31.0	3
B85	31.00	33.25	3.50	37.75	20.50	24.00	32.5	2	31.5	4	31.5	4
A86	34.00	31.75	2.25	37.50	21.00	24.00	31.0	3	31.5	1	32.0	1
B87	34.75	33.00	2.75	39.50	23.00	27.00	32.0	4	35.0	2	35.0	3

Adjusted Size Prediction Model, Alternate, and Final Test Short Sizes

(All Sizes in Inches)

Subj	EM(w)	EM(c)	EF(w)	EF(c)	SM(w)	SM(c)	SF(w)	SF(c)	D1(w)	D1(c)	D2(w)	D2(c)	D3(w)	D3(c)	Fin(w)	Fin(c)
A50	31.0	4	30.5	4	30.5	3	30.0	3	30.5	4	30.5	3	30.0	3	30.5	3
B51	31.5	2	31.0	2	30.5	4	30.0	4	30.5	2	NA	NA	NA	NA	30.5	2
A52	32.0	1	32.0	1	32.5	3	32.0	2	31.5	1	31.5	2	NA	NA	32.0	1
A54	33.0	4	33.0	4	31.0	4	31.0	4	32.0	1	31.5	3	32.0	3	31.5	4
A56	33.0	2	33.5	2	34.0	3	34.5	4	32.0	1	32.0	3	32.5	4	32.0	3
B57	33.0	2	33.0	2	32.5	4	32.5	4	32.5	4	NA	NA	NA	NA	33.0	4
A58	31.0	4	31.0	4	31.0	4	31.0	4	30.5	2	31.0	2	30.5	3	31.0	2
B59	32.5	4	32.5	3	34.0	4	33.5	4	33.0	2	33.0	3	NA	NA	33.0	3
A60	32.0	4	33.0	4	33.5	4	34.0	4	32.0	4	32.5	3	33.0	3	33.0	3
B61	31.5	4	31.5	4	32.5	4	32.5	4	33.5	4	33.0	3	NA	NA	33.0	4
B63	31.5	4	31.5	4	32.0	3	32.0	3	32.0	4	32.5	4	32.0	3	32.0	3
A64	34.5	3	34.5	2	34.0	4	34.0	4	34.5	3	35.0	2	NA	NA	34.5	2
B65	30.0	4	30.0	4	32.0	2	32.0	2	31.5	4	30.5	4	30.0	4	30.0	4
A66	34.0	4	33.5	2	34.0	4	34.0	3	33.5	4	34.0	2	NA	NA	34.0	3
B67	34.5	3	34.5	3	34.0	3	34.0	3	33.5	3	34.0	3	NA	NA	34.0	3
A68	31.0	4	31.0	4	32.0	3	32.0	4	32.0	3	32.0	4	NA	NA	32.0	4
B69	30.5	4	30.5	4	30.5	4	30.5	4	31.0	3	31.5	3	31.0	4	30.5	4
A70	33.0	2	32.5	3	35.0	1	34.5	2	34.0	2	34.0	3	34.0	4	34.0	4
B71	30.0	4	30.0	4	30.5	4	30.0	4	30.0	3	NA	NA	NA	NA	30.0	4
B73	31.5	3	31.0	4	31.5	2	31.0	3	32.0	2	32.0	1	NA	NA	32.0	1
A74	33.0	4	32.0	4	31.0	4	30.0	4	32.0	4	NA	NA	NA	NA	32.0	4
B75	33.0	3	32.5	4	32.0	4	31.5	4	32.5	4	32.5	3	NA	NA	32.5	4
A76	33.0	4	33.0	4	34.0	1	33.5	2	33.0	3	33.5	4	34.0	4	33.0	4
B77	30.0	3	30.0	2	30.5	4	30.5	3	30.5	4	30.0	2	NA	NA	30.5	2
A78	32.5	2	33.0	3	31.5	4	31.5	4	32.0	3	32.5	3	32.0	2	32.0	3
B79	31.5	4	31.5	4	31.5	4	31.5	4	31.0	3	31.0	4	NA	NA	31.5	4
A80	34.0	2	34.0	1	31.5	4	31.5	4	32.5	4	32.5	3	NA	NA	32.5	3
B81	33.0	3	33.5	3	31.5	3	31.5	3	32.5	4	33.0	3	NA	NA	33.0	3
A82	30.5	3	30.5	4	31.0	1	31.0	1	31.0	3	30.5	4	NA	NA	30.5	3
B83	31.5	4	31.5	4	34.0	3	33.5	4	32.0	3	31.5	4	32.0	2	31.5	4
A84	31.5	2	31.5	4	30.5	2	30.5	4	30.5	3	30.5	4	NA	NA	30.5	4
B85	32.5	2	32.0	3	31.5	4	31.0	4	31.0	3	31.0	4	31.5	3	31.0	4
A86	31.0	3	31.0	3	31.5	2	31.5	2	31.0	2	31.5	2	31.0	1	31.0	2
B87	32.0	4	32.0	4	35.0	3	34.5	4	33.0	4	32.5	4	33.0	3	32.5	4

Subject Responses to Final Questionnaire

Subj	1	4	5a	6a	6b	6c	6d	7	8	9	10	11a	11b	11c	11d	11e	11f
A50	1	31	4	2	3	3	1	2	4	2	95	90	0	10	0	0	0
B51	1	18	4	2	3	NA	NA	2	5	2	60	40	40	20	0	0	0
A52	1	19	4	3	4	4	1	2	5	3	95	75	0	20	5	0	0
A54	1	19	3	NA	5	5	NA	1	4	1	95	75	15	5	0	0	10
A56	1	20	4	NA	7	7	2	2	5	1	90	60	30	10	0	0	0
B57	1	18	3	3	7	7	3	1	5	2	100	80	0	10	0	10	0
A58	2	18	4	NA	5	4	1	2	4	2	80	35	35	20	10	0	0
B59	1	29	4	4	6	4	NA	2	2	2	NA	60	40	0	0	0	0
A60	1	20	4	4	6	5	NA	1	5	2	90	10	10	10	40	10	10
B61	1	18	1	4	7	9	3	1	5	2	100	35	35	15	15	0	0
B63	1	25	6	NA	7	9	3	1	4	2	90	40	40	20	0	0	0
A64	1	19	4	NA	7	6	NA	1	4	2	95	70	5	20	5	0	0
B65	1	20	4	NA	3	3	1	2	5	3	90	85	10	5	0	0	0
A66	2	33	1	NA	7	NA	3	1	3	1	90	65	20	0	0	0	15
B67	1	35	4	4	7	7	NA	2	4	3	80	80	20	0	0	0	0
A68	1	19	4	NA	6	6	NA	1	4	2	90	45	15	10	0	30	0
B69	1	18	4	3	3	4	1	2	5	2	60	65	10	20	5	0	0
A70	1	19	4	4	6	NA	NA	1	4	2	95	95	4	1	0	0	0
B71	1	19	3	NA	5	5	1	1	5	2	50	10	20	10	5	5	50
B73	1	19	4	4	5	6	2	2	4	2	25	60	10	30	0	0	0
A74	1	19	5	NA	5	7	3	1	4	1	95	30	40	20	0	0	0
B75	1	18	3	4	7	7	2	1	5	1	95	100	0	0	0	0	0
A76	1	18	4	3	7	NA	NA	2	4	1	75	30	50	10	10	0	0
B77	1	18	4	NA	4	3	2	2	5	2	75	50	30	15	0	0	5
A78	1	18	4	NA	5	6	2	1	4	2	100	70	10	0	0	0	20
B79	1	18	4	3	5	5	NA	2	5	2	90	90	0	0	0	0	10
A80	1	27	4	3	7	5	NA	3	5	2	80	30	20	35	15	0	0
B81	1	17	4	NA	6	5	3	2	4	3	50	80	0	5	5	10	0
A82	2	19	3	3	3	NA	NA	2	5	2	90	80	10	0	0	0	10
B83	1	18	4	NA	5	5	NA	1	4	1	60	10	30	20	10	0	30
A84	1	18	3	3	7	3	3	1	4	1	90	80	5	15	0	0	0
B85	1	24	4	3	5	6	2	3	4	3	90	40	30	20	10	0	0
A86	2	29	3	NA	3	3	1	1	3	1	100	90	5	5	0	0	0
B87	2	21	4	4	9	5	NA	1	4	3	100	95	2	1	1	1	0

Subject Responses to Final Questionnaire (cont)

Subj	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29	30
A50	1	2	5	1	3	3	4	4	3	3	4	4	4	3	2	4	5	4
B51	3	3	5	2	3	4	4	4	4	3	4	2	4	5	4	5	3	4
A52	4	4	2	1	3	2	4	5	2	2	4	4	3	3	2	4	4	4
A54	2	4	NA	1	5	4	5	3	4	4	5	4	5	5	4	5	5	5
A56	4	3	5	2	4	4	4	5	5	2	5	4	5	4	3	4	4	5
B57	1	5	5	1	4	4	5	5	5	4	5	3	3	5	5	4	4	4
A58	2	3	4	2	3	3	2	3	4	4	4	3	3	2	2	4	4	5
B59	4	4	5	1	3	3	4	5	3	3	5	4	4	4	4	5	5	5
A60	2	2	3	1	4	3	5	5	3	5	5	4	4	3	3	5	5	3
B61	1	4	3	1	4	4	5	3	3	4	5	3	3	3	3	5	5	5
B63	1	2	5	1	2	2	5	4	4	4	4	4	4	4	2	4	4	4
A64	2	4	5	1	3	4	5	5	4	3	5	4	5	5	4	4	5	5
B65	5	5	5	2	4	3	4	5	4	4	5	3	5	3	3	3	4	3
A66	1	1	3	3	5	5	5	5	3	5	5	4	3	2	3	4	3	2
B67	1	3	5	3	4	3	3	4	5	4	4	4	5	5	4	NA	NA	NA
A68	1	3	5	4	4	4	5	5	3	3	5	3	5	4	4	3	3	3
B69	3	3	5	2	3	4	5	3	3	2	5	3	3	2	3	4	3	4
A70	4	3	5	1	3	4	5	4	3	4	4	4	4	3	3	4	5	5
B71	4	4	3	3	3	3	5	3	3	3	5	5	5	4	4	5	5	5
B73	3	2	2	1	4	3	5	4	3	3	5	2	4	3	2	5	5	4
A74	1	1	3	1	2	3	4	5	5	4	5	4	5	3	3	4	5	4
B75	5	5	5	1	4	5	4	5	3	3	5	4	4	3	5	5	5	5
A76	3	3	3	2	3	3	5	4	2	2	5	3	3	5	4	5	5	4
B77	3	3	5	4	4	3	5	4	4	3	3	2	5	4	4	4	4	4
A78	4	5	5	1	3	4	5	4	3	2	5	4	3	4	4	4	4	5
B79	3	3	5	1	4	4	5	5	4	2	5	4	5	4	4	4	4	4
A80	3	3	2	2	4	4	4	4	4	2	5	2	4	4	4	4	4	3
B81	5	5	4	2	4	4	4	4	3	4	3	3	2	5	5	5	4	5
A82	1	5	5	1	4	4	5	5	5	4	5	4	5	4	3	4	3	3
B83	5	5	3	3	3	3	5	3	5	4	5	3	5	5	5	5	5	5
A84	5	3	5	2	5	4	4	4	4	3	5	3	4	5	3	4	4	4
B85	2	3	4	3	4	4	4	4	5	4	4	3	5	5	5	4	5	5
A86	5	5	5	1	3	3	3	2	4	3	2	3	2	3	3	4	5	4
B87	1	5	5	1	4	4	5	5	4	3	5	3	4	3	4	5	5	3

Final Questionnaire Responses for Short Answer Questions

Subj	2	3
A50	FELT THE BEST	NO
B51	FIT VERY WELL	NOTHING, THEY FIT WELL
A52	IF I WANTED THIS TYPE OF SHORTS, FIT GOOD	STYLE, LEGS WIDER
A54	THEY FIT WELL	MAKE THEM A LITTLE LONGER
A56	COMFORTABLE AND LOOK NICE	NO CHANGE, SUPPOSED TO BE DRESS SHORTS
B57	FITS WELL AND FEELS COMFORTABLE	MAKE THE SHORTS A BIT LONGER
A58	THEY WERE SHORT IN LENGTH	LENGTHEN AND CHANGE COLOR
B59	LOOK GOOD IN IT AND COMFORTABLE	NO CHANGE
A60	FIT WELL IN WAIST AND NOT TOO BAGGY	LONGER IN THE LEG
B61	FELL RIGHT AND JUST FELT THE BEST	LONGER LEGS BUT FIT WAS PERFECT
B63	FITS VERY WELL AND COMFORTABLE	SMALLER THIGH AND LITTLE SMALLER CROTCH
A64	PRETTY COMFORTABLE	NONE
B65	COMFORTABLE AND THEY FIT	NONE
A66	WANT SHORTS SLIGHTLY LONGER	LENGTH TO THE KNEES
B67	FEEL GOOD	PLEATS TO ADD ROOM
A68	FIT WELL ALL AROUND	NONE
B69	FIT WAS VERY COMFORTABLE	INCREASE LENGTH SOME
A70	FEEL GOOD, LOOK LIKE SHORTS I OWN	LENGTH SHORTER, EVERYTHING ELSE GOOD
B71	VERY COMFORTABLE	LITTLE TIGHTER WAIST OTHERWISE GREAT
B73	COMFORTABLE TO MOVE IN, FIT WELL	LOOSEN EVERYTHING A BIT FOR BIGGER SHIRT
A74	FIT FOR ALL AREAS & LEGS WERE GREAT	COLOR & DETAILS, VARIETY GOOD IN SHORTS
B75	LOOSE AND TIGHT IN RIGHT PLACES	DECREASE WAIST SIZE, LIKE TIGHTER
A76	LOOSE ENOUGH TO MOVE & NOT TOO LOOSE	WOULDN'T MAKE ANY CHANGES
B77	COMFORTABLE	MAKE SLIGHTLY TIGHTER
A78	ALL THINGS I LOOK FOR WERE IN FIT SESSION	NONE, THOUGHT SHORTS FIT VERY WELL
B79	COMFORTABLE AND APPEALING	CROTCH & SEAT A LITTLE LOWER FOR SITTING
A80	ALL SEEM TO FIT GOOD	NO CHANGES NEEDED
B81	RIGHT LOOSENESS, COMFORTABLE, NOT HANG	LOWER HEMLINE TO KNEES
A82	TOO PLAIN	LONGER
B83	COMFORTABLE AND FIT WELL	NONE, HAPPY WITH THE FINAL FIT
A84	GOOD COMFORT	LONGER SHORTS TO MID KNEE PREFERRED
B85	FIT WELL ENOUGH SO I WAS COMFORTABLE	MORE ROOM IN THIGH AND PLEATS
A86	LOOK FOR COLOR THEN SIZE	IT'S PERFECT
B87	NEEDS LOOSER CROTCH/THIGHS	

Final Questionnaire Responses for Short Answer Questions (cont)

Subj	5b	6e	11g
A50			
B51			
A52			
A54	INDIA		SPECIALTY STORES
A56			
B57		WIDE	
A58			
B59			
A60			SPECIALTY STORES
B61			
B63	GERMAN		
A64			
B65			
A66			
B67			OUTLETS
A68			
B69		30 & 31 WAIST/31& 32 INSEAM	
A70			
B71			GIFTS
B73		SOMETIMES 33 OR 34 INSEAM	
A74		SOMETIMES 34 OR 35 INSEAM	
B75			
A76			
B77			MAIL ORDER & NET ONCE
A78			USED CLOTHING
B79		MED/LGE, 31-33W, 32-33INS	OUTLETS
A80	CAN BE MEDIUM OR LARGE		
B81			
A82			
B83			LOCAL FARM STORE
A84			
B85			
A86			
B87		34 TO 36 WAIST	

Final Questionnaire Responses for Short Answer Questions (cont)

Subj	27	31
A50	SIZE UNAVAILABLE, MUCH VARIATION	NO
B51	PANTS OFTEN TOO TIGHT FOR MY SIZE	SELF MEASUREMENT HARD WITH NO MATERIAL
A52	LENGTH & WAIST IN PANTS HARD TO GET	MISLEADING MEASURING OVER CLOTHING
A54		PUT IN A THIGH MEASUREMENT
A56	LEGS TOO SHORT ON PANTS SOMETIMES	ALL EASY, I MESSED UP SELF MEASUREMENTS
B57	CAN'T FIND THE PERFECT FIT	GET RID OF PROCEDURES, TRYING ON IS BEST
A58	WAIST NOT MATCH LOOSENESS IN THIGH	SELF MEASURE NOT RELIABLE, NEED EXPERT
B59	THERE IS NOT ALWAYS A FITTING ROOM	NO CHANGE
A60	SIZE SELLS QUICKLY, PLAIN STYLE HARD FIND	ADD REFERENCE FOR FIT QUESTIONING
B61	SMALL WAIST WITH LONG LEGS HARD TO GET	NONE
B63	INSEAM TOO SMALL, CROTCH DOESN'T FIT	MORE VARIETY IN SELECTIONS OF SHORTS
A64	CROTCH SIZE GENERALLY OFF	HAVE ONE PAGE WITH ALL MEASUREMENTS
B65	TOO BIG	HARD TO MEASURE WITHOUT TAPE MEASURE
A66	HARDLY GET RIGHT LENGTH	ALL MEASUREMENT INSTRUCTIONS ONE PAGE
B67	PANT LENGTH TOO LONG	
A68	PRICE NOT REASONABLE FOR STUDENT	PUT PROCEDURES ALL ON ONE PAGE
B69	USUALLY TIGHT AT HIPS, BAGGY AT THIGHS	PEOPLE HAVE DIFFERENT OPINIONS ON STYLE
A70	MY BUTT IS BIG AND LEGS SHORT	EASY ONCE I HAD A TAPE MEASURE
B71	TRY ON MANY SIZES WITH DIFFERENT MAKERS	ALL VERY EASY TO UNDERSTAND
B73	I'M BETWEEN NORMAL SIZES AND LONG LEGS	MAKE LOOSER/TIGHTER MORE SPECIFIC
A74	LENGTH AND SEAT OF PANTS	USE SHORTS FROM OTHER FABRICS
B75	HARD TO GET LOOSE THIGH AND TIGHT WAIST	IT IS PRETTY GOOD
A76	THIGHS TIGHT SOMETIMES	FIT PREFERENCE TOO VAGUE
B77	PRICE, COMFORT	NOT USED TO THIS SORT OF THING
A78	PANTS TEND TO BE TOO LONG	PANTS WORN IMPACTED CROTCH SIZE
B79	UNCOMFORTABLE SIT SOMETIMES	OVERALL GOOD, NOTHING TO CHANGE
A80	FEW, NOT THAT PICKY ABOUT DETAILS	TOO MUCH DETAIL, HAMPERS IMPULSE BUY
B81	MOST PANTS A BIT LONG FOR MY LEGS	NEED MORE TIME SPENT ON MEASURING
A82	TOO LONG IN PANTS	GOOD
B83	OFTEN GET MAKER WITH WEIRD SIZING	
A84	INSEAM TOO LONG	TOO WORDY & TOO MANY "NEXT" CLICKS
B85	LENGTH & WAIST HARD TO GET RIGHT	
A86	NOT MANY CHOICES IN SIZE	COLOR CHOICE FIRST, IMPROVE WEB SITE
B87	SOMETIMES IN BETWEEN WAIST SIZES	SELF MEASUREMENT LONG AND TEDIOUS

Discrepancy Form Answers for Test Subjects with Greater than 2-inch Measurement Variations

Subj	1	2	3
A52	AS WELL AS I COULD	HARD GETTING ALL THE MEASUREMENTS IN RIGHT SPOT	PLASTIC STRING/CORD
A54	YES	NO	EXTENSION CORD
A56	YES	NO, INACCURATE IN MY CALCULATIONS	STRING AND 12" RULER
A66	YES	OKAY	TAPE MEASURE
A76	YES	NOT CONFUSING/SEAT MEASUREMENT HARD TO TAKE	THIN TAPE MEASURE
A78	YES	NOT AT ALL	STRING AND YARDSTICK
A80	AS BEST AS POSSIBLE	NO	MARKED STRING
B81	YES, BUT I MEASURED TOO LOW	UNSURE WHERE SEAT WAS TO BE	STRING
B83	YES	NO	STRING AND RULER
B85	MEASURED CROTCH TO OMPH	NO, JUST MISREAD THEM	MEASURING TAPE
B87	YES	NO	TAPE MEASURE

Subj	4	5
A52	YES	NO
A54	YES	UNLIKELY, BUT I NEVER PURCHASE INTERNET CLOTHING
A56	HAD LARGE MARGIN OF ERROR	NO, I WOULD RETURN FOR CORRECT SIZE OR USE A BELT
A66	YES	YES, WOULD SPEND TIME TO GET GOOD MEASUREMENTS
A76	YES	NO, (WEARING SHORTS, DIDN'T PULL TIGHT ENOUGH)
A78	YES, TOOK 3 TIMES	YES, WOULD GET CLARIFICATION ON WHAT TO WEAR
A80	CONFUSING ON CROTCH	PERHAPS BUT ASKS FOR TOO MUCH DETAIL
B81	NOT PERFECT BUT NO PROBLEM	I WOULD HAVE BEEN MORE CAREFUL AND REMEASURED
B83	NO	YES, WOULD HAVE ORDERED SIZE I CURRENTLY WEAR
B85	YES	NO
B87	YES	NO

APPENDIX D

DATA AND STATISTICAL ANALYSIS

Test Short Presentation Order Matrix with Satisfaction of Fit Responses

Subj	W EM	S EM	C EM	I EM	O EM	W SM	S SM	C SM	I SM	O SM	W FP	S FP	C FP	I FP	O FP	W D1	S D1	C D1	I D1	O D1	W D2	S D2	C D2	I D2	O D2	W D3	S D3	C D3	I D3	O D3
A50	3	2	4	4	3	5	4	5	3	4						5	5	5	4	5	4	4.5	5	3	4					
B51	4	5	5	5	5						5	4	5	4	5	5	5	5	5	5										
A52	5	5	4.5	5	5						2	4	4	5	3	5	4	5	4	4	5	5	4	4	4					
A54	4	5	4	3	3	5	3	5	5	4						4	4.5	5	5	4	4	4.5	5	5	4					
A56						3	4	5	5	4	2	4	4	4	4	5	5	5	5	5	4	4	5	5	4	4	4	5	5	4.5
B57	5	3	4	2	4	5	5	5	3	4						5	5	5	5	4										
A58						4	5	3	5	4	4	5	3	5	4	5	3.5	5	3	4	5	5	5	4	4.5	5	5	3.5	5	4
B59						3	3	2	2	3	3	3	2	2	3	5	5	5	4	4	5	5	4	5	4					
A60	5	4	4	5	4						3	5	4	4	4	5	4	5	5	4	5	4	5	5	5	5	5	5	5	5
B61	2	4	4	4	3.5						5	5	3.5	5	5	4	5	5	5	5	5	3	3	5	3					
B63						2	4	3	4	3	2	4	3	4	3	5	5	3	4	4	2	3	3	3	3	5	4	4	4	4
A64	5	5	5	5	5	4	5	3	4	3.5						5	4.5	5	5	4.5	4.5	5	5	5	4.5					
B65	5	3	4	4	4						1	2	2	4	2	2	3	3	4	3	4	3	2	4	4	5	5	5	5	5
A66	5	5	5	5	5	4	5	5	5	4						4	5	5	5	4	5	4	4	5	4					
B67						4	4	5	4	4	4	4	5	4	4	4	4	5	5	4	5	5	5	5	5					
A68	5	5	5	3	4	5	4	4	5	4						5	5	5	4	4	5	5	5	5	5					
B69						5	2	5	5	4	5	2	5	5	4	5	3	5	5	4	3	4	3	4	3	4	3	4	4	4
A70	4	3	4	2	3	5	4	4	5	5						5	5	5	4	4	5	5	5	5	4	5	5	5	5	5
B71	5	5	5	5	5						4	5	5	5	5	5	5	5	5	5										
B73	5	4	5	4	4.5						5	4	5	4	4.5	4	5	5	5	4.5	5	5	5	5	5					
A74	4	4	4	5	5	5	4	4	5	4						5	5	5	5	5										
B75	4	5	5	4	4						3	4	4	4	4	3	5	5	5	5	5	5	4	4	4.5					
A76						4	4	5	3.5	4	4	4	5	3.5	4	4	5	5	5	5	5	5	5	4	5	5	5	4	4	4
B77	4	4	3	5	4						5	5	4	4	4	5	4	3	4	3	4	3	4	4	3					
A78						4	4	5	4	4	4	4	5	4	4	5	5	5	5	5	4	4	5	5	4	5	4.5	5	4	4.5
B79	5	4	4	5	5	5	4	4	5	5						4.5	4	4	4	4	5	4.5	4.5	5	5					
A80	2.5	4	3	3.5	3						4	5	4	4	4	5	5	5	4.5	5	5	5	4.5	5	5					
B81	5	5	4	5	4						4	5	5	3	4	5	5	4	5	5	5	5	5	5	5					
A82	5	5	5	5	5	4	3	2	3	2						4	5	3	4	4	4	5	4	5	4					
B83						1	3	4	5	3	1	3	4	5	3	5	3	4	4	4	5	5	5	5	5	5	4	5	4	4
A84	5	5	5	5	5						4	5	5	5	5	5	5	4	5	4.5	5	5	5	5	5					
B85	4	4	5	4	3.5						4	5	3	4	4	5	4	4	3	4	5	4	5	5	5	5	4.5	5	4.5	4.5
A86	5	5	3	3	4						4	5	3	3	4	5	5	4	5	4.5	5	5	4.5	5	4.5	4	5	5	5	5
B87	4.5	3	4	2	3						3	5	2	4	2	4.5	4	4	4	4	5	4	3.5	3	4.5	4.5	5	3	3	4

5 - 1st in Order; [black] - 2nd in Order; 5 - 3rd in Order; 5 - 4th in Order; 5 - 5th in Order; 5 - 6th in Order

Top Predicted and Final Short Selection Matrix with Satisfaction of Fit Responses

Subj	W EM	S EM	C EM	I EM	O EM	W SM	S SM	C SM	I SM	O SM	W FP	S FP	C FP	I FP	O FP	W D1	S D1	C D1	I D1	O D1	W D2	S D2	C D2	I D2	O D2	W D3	S D3	C D3	I D3	O D3
A50	3	2	4	4	3	5	4	5	3	4	5	4	5	3	4	5	5	5	4	5	4	4	5	3	4					
B51	4	5	5	5	5	5	4	5	5	5	5	4	5	4	5	5	5	5	5	5										
A52	5	5	4.5	5	5	4	3	5	5	4	2	4	4	5	3	5	4	5	4	4	5	5	4	4	4					
A54	4	5	4	3	3	5	3	5	5	4	5	5	5	5	5	4	4.5	5	5	4	4	4.5	5	5	4					
A56	5	2	2	2	3	3	4	5	5	4	2	4	4	4	4	5	5	5	5	5	4	4	5	5	4	4	4	5	5	4.5
B57	5	3	4	2	4	5	5	5	3	4	5	5	5	5	5	5	5	5	5	4										
A58	5	5	4	5	4.5	4	5	3	5	4	4	5	3	5	4	5	3.5	5	3	4	5	5	5	4	4.5	5	5	3.5	5	4
B59	4	4	2	4	3	3	3	2	2	3	3	3	2	2	3	5	5	5	4	4	5	5	4	5	4					
A60	5	4	4	5	4	5	5	5	5	5	3	5	4	4	4	5	4	5	5	4	5	4	5	5	5	5	5	5	5	5
B61	2	4	4	4	3.5	3	4	3	4	3.5	5	5	3.5	5	5	4	5	5	5	5	5	3	3	5	3					
B63	4	4	3	4	4	2	4	3	4	3	2	4	3	4	3	5	5	3	4	4	2	3	3	3	3	5	4	4	4	4
A64	5	5	5	5	5	4	5	3	4	3.5	5	5	4	3	4	5	4.5	5	5	4.5	4.5	5	5	5	4.5					
B65	5	3	4	4	4	2	2	3	4	3	1	2	2	4	2	2	3	3	4	3	4	3	2	4	4	5	5	5	5	5
A66	5	5	5	5	5	4	5	5	5	4	4	5	5	5	4	4	5	5	5	4	5	4	4	5	4					
B67	3	4	4	5	4	4	4	5	4	4	4	4	5	4	4	4	4	5	5	4	5	5	5	5	5					
A68	5	5	5	3	4	5	4	4	5	4	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5					
B69	5	4	4	5	5	5	2	5	5	4	5	2	5	5	4	5	3	5	5	4	3	4	3	4	3	4	3	4	4	4
A70	4	3	4	2	3	5	4	4	5	5	3	5	5	5	4	5	5	5	4	4	5	5	5	5	4	5	5	5	5	5
B71	5	5	5	5	5	4	5	5	5	5	4	5	5	5	5	5	5	5	5	5										
B73	5	4	5	4	4.5	4	5	3	4	4	5	4	5	4	4.5	4	5	5	5	4.5	5	5	5	5	5					
A74	4	4	4	5	5	5	4	4	5	4	1	2	5	4	3	5	5	5	5	5										
B75	4	5	5	4	4	4	5	3	3	3	3	4	4	4	4	3	5	5	5	5	5	5	4	4	4.5					
A76	5	5	5	5	5	4	4	5	3.5	4	4	4	5	3.5	4	4	5	5	5	5	5	5	5	4	5	5	5	4	4	4
B77	4	4	3	5	4	5	4	5	3	4	5	5	4	4	4	5	4	3	4	3	4	3	4	4	3					
A78	5	5	5	3	4	4	4	5	4	4	4	4	5	4	4	5	5	5	5	5	4	4	5	5	4	5	4.5	5	4	4.5
B79	5	4	4	5	5	5	4	4	5	5	4	3	3	5	4	4.5	4	4	4	4	5	4.5	4.5	5	5					
A80	2.5	4	3	3.5	3	3	3	4	3.5	3.5	4	5	4	4	4	5	5	5	4.5	5	5	5	4.5	5	5					
B81	5	5	4	5	4	3	4	2	4	3	4	5	5	3	4	5	5	4	5	5	5	5	5	5	5					
A82	5	5	5	5	5	4	3	2	3	2	3	2	3	3	3	4	5	3	4	4	4	5	4	5	4					
B83	4.5	4	5	2	4	1	3	4	5	3	1	3	4	5	3	5	3	4	4	4	5	5	5	5	5	5	4	5	4	4
A84	5	5	5	5	5	5	4	4	5	4	4	5	5	5	5	5	5	4	5	4.5	5	5	5	5	5					
B85	4	4	5	4	3.5	4	4	5	4	4.5	4	5	3	4	4	5	4	4	3	4	5	4	5	5	5	5	4.5	5	4.5	4.5
A86	5	5	3	3	4	5	4	5	5	4.5	4	5	3	3	4	5	5	4	5	4.5	5	5	4.5	5	4.5	4	5	5	5	5
B87	4.5	3	4	2	3	3	3	4	5	3	3	5	2	4	2	4.5	4	4	4	4	5	4	3.5	3	4.5	4.5	5	3	3	4

5 - Top Short Selected from Predicted

5 - Final Short Selected

Fit Satisfaction / Presentation Order for Predicted Shorts

Subj	W FP	S FP	C FP	T FP	O FP	W SM	S SM	C SM	T SM	O SM	W EM	S EM	C EM	T EM	O EM
A50	5	4	5	3	4	5	4	5	3	4	3	2	4	4	3
B51	5	4	5	4	5	5	4	5	5	5	4	5	5	5	5
A52	2	4	4	5	3	4	3	5	5	4	5	5	4.5	5	5
A54	5	3	5	5	4	5	5	5	5	5	4	5	4	3	3
A56	3	4	5	5	4	5	2	2	2	3	2	4	4	4	4
B57	5	3	4	2	4	5	5	5	5	5	5	5	5	3	4
A58	4	5	3	5	4	5	5	4	5	4.5					
B59	3	3	2	2	3	4	4	2	4	3					
A60	3	5	4	4	4	5	5	5	5	5	5	4	4	5	4
B61	5	5	3.5	5	5	3	4	3	4	3.5	2	4	4	4	3.5
B63	2	4	3	4	3	4	4	3	4	4					
A64	4	5	3	4	3.5	5	5	4	3	4	5	5	5	5	5
B65	1	2	2	4	2	2	2	3	4	3	5	3	4	4	4
A66	4	5	5	5	4	4	5	5	5	4	5	5	5	5	5
B67	4	4	5	4	4	3	4	4	5	4					
A68	5	4	4	5	4	5	5	5	5	5	5	5	5	3	4
B69	5	2	5	5	4	5	4	4	5	5					
A70	4	3	4	2	3	3	5	5	5	4	5	4	4	5	5
B71	4	5	5	5	5	4	5	5	5	5	5	5	5	5	5
B73	5	4	5	4	4.5	4	5	3	4	4					
A74	5	4	4	5	4	1	2	5	4	3	4	4	4	5	5
B75	3	4	4	4	4	4	5	3	3	3	4	5	5	4	4
A76	4	4	5	3.5	4	5	5	5	5	5					
B77	4	4	3	5	4	5	4	5	3	4	5	5	4	4	4
A78	4	4	5	4	4	5	5	5	3	4					
B79	5	4	4	5	5	4	3	3	5	4					
A80	4	5	4	4	4	3	3	4	3.5	3.5	2.5	4	3	3.5	3
B81	4	5	5	3	4	3	4	2	4	3	5	5	4	5	4
A82	4	3	2	3	2	3	2	3	3	3	5	5	5	5	5
B83	1	3	4	5	3	4.5	4	5	2	4					
A84	4	5	5	5	5	5	4	4	5	4	5	5	5	5	5
B85	4	5	3	4	4	4	4	5	4	4.5	4	4	5	4	3.5
A86	4	5	3	3	4	5	4	5	5	4.5	5	5	3	3	4
B87	3	5	2	4	2	3	3	4	5	3	4.5	3	4	2	3
Avg	3.9	4.1	4.0	4.1	3.8	4.1	4.0	4.1	4.2	4.0	4.3	4.4	4.4	4.2	4.2

5 - 1st in Presentation Order

5 - 2nd in Presentation Order

5 - 3rd in Presentation Order

Presentation and Selection Chart

Subj	EM	SM	FP	D1	D2	D3	TOP	FINAL
A50	3	1	2	4	5		S	D1
B51	3	2	1	4			S	D1
A52	3	2	1	4	5		E	E
A54	3	1	2	4	5		F	F
A56	2	1	3	4	5	6	S	D1
B57	1	3	2	4			F	F
A58	2	1	1	3	4	5	E	D2
B59	2	1	1	3	4		E	D2
A60	3	2	1	4	5	6	F	D3
B61	3	2	1	4	5		F	F
B63	2	1	1	3	4	5	E	D3
A64	3	1	2	4	5		E	E
B65	3	2	1	4	5	6	E	D3
A66	3	1	2	4	5		E	E
B67	2	1	1	3	4		S/F	D2
A68	3	1	2	4	5		F	D2
B69	2	1	1	3	4	5	E	E
A70	1	3	2	4	5	6	S	D3
B71	3	2	1	4			E	E
B73	1	2	1	3	4		E/F	D2
A74	3	1	2	4			E	D1
B75	3	2	1	4	5		E	D1
A76	2	1	1	3	4	5	E	E
B77	1	2	3	4	5		F	F
A78	2	1	1	3	4	5	E	D1
B79	1	1	2	3	4		E/S	E/S
A80	3	2	1	4	5		F	D2
B81	3	2	1	4	5		E	D2
A82	3	1	2	4	5		E	E
B83	2	1	1	3	4	5	E	D2
A84	3	2	1	4	5		E	D2
B85	3	2	1	4	5	6	S	D2
A86	3	2	1	4	5	6	S	D1
B87	3	2	1	4	5	6	E	D2

Satisfaction of Fit Differences Between Final and Top Shorts

Subj	TOP					FINAL					CHANGE				
A50	5	4	5	3	4	5	5	5	4	5	0	1	0	1	1
B51	5	4	5	5	5	5	5	5	5	5	0	1	0	0	0
A52	5	5	4.5	5	5	5	5	4.5	5	5	0	0	0	0	0
A54	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
A56	3	4	5	5	4	5	5	5	5	5	2	1	0	0	1
B57	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
A58	5	5	4	5	4.5	5	5	5	4	4.5	0	0	1	-1	0
B59	4	4	2	4	3	5	5	4	5	4	1	1	2	1	1
A60	3	5	4	4	4	5	5	5	5	5	2	0	1	1	1
B61	5	5	3.5	5	5	5	5	3.5	5	5	0	0	0	0	0
B63	4	4	3	4	4	5	4	4	4	4	1	0	1	0	0
A64	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B65	5	3	4	4	4	5	5	5	5	5	0	2	1	1	1
A66	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B67	4	4	5	4	4	5	5	5	5	5	1	1	0	1	1
A68	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B69	5	4	4	5	5	5	4	4	5	5	0	0	0	0	0
A70	3	5	5	5	4	5	5	5	5	5	2	0	0	0	1
B71	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B73	5	4	5	4	4.5	5	5	5	5	5	0	1	0	1	0.5
A74	4	4	4	5	5	5	5	5	5	5	1	1	1	0	0
B75	4	5	5	4	4	3	5	5	5	5	-1	0	0	1	1
A76	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B77	5	5	4	4	4	5	5	4	4	4	0	0	0	0	0
A78	5	5	5	3	4	5	5	5	5	5	0	0	0	2	1
B79	5	4	4	5	5	5	4	4	5	5	0	0	0	0	0
A80	4	5	4	4	4	5	5	4.5	5	5	1	0	0.5	1	1
B81	5	5	4	5	4	5	5	5	5	5	0	0	1	0	1
A82	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B83	4.5	4	5	2	4	5	5	5	5	5	0.5	1	0	3	1
A84	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
B85	4	4	5	4	4.5	5	4	5	5	5	1	0	0	1	0.5
A86	5	4	5	5	4.5	5	5	4	5	4.5	0	1	-1	0	0
B87	4.5	3	4	2	3	5	4	3.5	3	4.5	0.5	1	-0.5	1	1.5
Avg	4.59	4.50	4.50	4.41	4.44	4.94	4.85	4.71	4.82	4.87	0.35	0.35	0.21	0.41	0.43

Initial Model Measurement Errors from Final Shorts

(All Measurements in Inches)

Subj	Final-EM		Final-SM		Final-FP	
	Waist	Crotch	Waist	Crotch	Waist	Crotch
A50	(0.5)	(1.0)	0.0	1.0	0.0	1.0
B51	(1.0)	0.0	0.0	(2.0)	0.0	(2.0)
A52	0.0	0.0	(0.5)	(1.0)	(0.5)	0.0
A54	(1.5)	1.0	0.5	0.0	0.0	0.0
A56	(1.0)	1.0	(2.0)	0.0	(2.5)	0.0
B57	0.0	2.0	0.5	1.0	0.0	0.0
A58	0.0	(2.0)	0.0	(1.0)	0.0	(1.0)
B59	0.5	(1.0)	(1.0)	0.0	(1.0)	0.0
A60	1.0	0.0	(0.5)	0.0	(1.0)	(1.0)
B61	1.5	0.0	0.5	1.0	0.0	0.0
B63	0.5	(1.0)	0.0	1.0	0.0	1.0
A64	0.0	0.0	0.5	(2.0)	0.0	(2.0)
B65	0.0	0.0	(2.0)	3.0	(2.5)	3.0
A66	0.0	0.0	0.0	(1.0)	(0.5)	1.0
B67	(0.5)	1.0	0.0	1.0	0.0	1.0
A68	1.0	0.0	0.0	2.0	(0.5)	0.0
B69	0.0	0.0	0.0	0.0	(0.5)	0.0
A70	1.0	2.0	(1.0)	3.0	(1.0)	3.0
B71	(0.5)	0.0	(0.5)	1.0	(0.5)	0.0
B73	0.5	(2.0)	0.5	(1.0)	0.5	(2.0)
A74	(1.0)	0.0	1.0	1.0	1.5	0.0
B75	(0.5)	1.0	0.5	1.0	0.0	0.0
A76	0.0	0.0	(1.0)	3.0	(1.0)	3.0
B77	0.5	(1.0)	0.0	(1.0)	0.0	0.0
A78	(0.5)	1.0	0.5	(1.0)	0.5	(1.0)
B79	0.0	0.0	0.0	0.0	0.0	0.0
A80	(1.5)	2.0	1.0	(1.0)	0.5	(1.0)
B81	0.0	1.0	1.5	1.0	1.5	1.0
A82	0.0	0.0	(0.5)	2.0	(1.0)	2.0
B83	0.0	0.0	(2.5)	1.0	(2.5)	1.0
A84	(1.0)	2.0	0.0	3.0	(0.5)	1.0
B85	(1.5)	2.0	(0.5)	0.0	(0.5)	0.0
A86	0.0	(1.0)	(0.5)	1.0	(1.0)	1.0
B87	0.5	0.0	(2.5)	2.0	(2.5)	1.0
Avg	(0.12)	0.21	(0.24)	0.53	(0.44)	0.29

ABS Initial Model Measurement Errors

(All Measurements in Inches)

Subj	Final-EM (ABS)		Final-SM (ABS)		Final-FP (ABS)	
	Waist	Crotch	Waist	Crotch	Waist	Crotch
A50	0.5	1	0	1	0	1
B51	1	0	0	2	0	2
A52	0	0	0.5	1	0.5	0
A54	1.5	1	0.5	0	0	0
A56	1	1	2	0	2.5	0
B57	0	2	0.5	1	0	0
A58	0	2	0	1	0	1
B59	0.5	1	1	0	1	0
A60	1	0	0.5	0	1	1
B61	1.5	0	0.5	1	0	0
B63	0.5	1	0	1	0	1
A64	0	0	0.5	2	0	2
B65	0	0	2	3	2.5	3
A66	0	0	0	1	0.5	1
B67	0.5	1	0	1	0	1
A68	1	0	0	2	0.5	0
B69	0	0	0	0	0.5	0
A70	1	2	1	3	1	3
B71	0.5	0	0.5	1	0.5	0
B73	0.5	2	0.5	1	0.5	2
A74	1	0	1	1	1.5	0
B75	0.5	1	0.5	1	0	0
A76	0	0	1	3	1	3
B77	0.5	1	0	1	0	0
A78	0.5	1	0.5	1	0.5	1
B79	0	0	0	0	0	0
A80	1.5	2	1	1	0.5	1
B81	0	1	1.5	1	1.5	1
A82	0	0	0.5	2	1	2
B83	0	0	2.5	1	2.5	1
A84	1	2	0	3	0.5	1
B85	1.5	2	0.5	0	0.5	0
A86	0	1	0.5	1	1	1
B87	0.5	0	2.5	2	2.5	1
Avg	0.53	0.74	0.85	1.18	0.71	0.88

Girth Self & Expert Measurement Differences

(All Measurements in Inches)

Subj	Self Girth	Expert Girth	Change (In)	Total (In)	% Change	% Total
A50	31.50	31.00	(0.50)	0.50	(1.6%)	1.6%
B51	29.00	29.75	0.75	0.75	2.5%	2.5%
A52	33.00	32.00	(1.00)	1.00	(3.1%)	3.1%
A54	33.00	31.50	(1.50)	1.50	(4.8%)	4.8%
A56	31.50	30.00	(1.50)	1.50	(5.0%)	5.0%
B57	32.00	30.50	(1.50)	1.50	(4.9%)	4.9%
A58	30.00	31.00	1.00	1.00	3.2%	3.2%
B59	34.50	34.00	(0.50)	0.50	(1.5%)	1.5%
A60	31.00	31.00	0.00	0.00	0.0%	0.0%
B61	32.00	30.75	(1.25)	1.25	(4.1%)	4.1%
B63	33.00	31.00	(2.00)	2.00	(6.5%)	6.5%
A64	34.50	34.00	(0.50)	0.50	(1.5%)	1.5%
B65	32.00	30.50	(1.50)	1.50	(4.9%)	4.9%
A66	38.00	35.50	(2.50)	2.50	(7.0%)	7.0%
B67	38.00	37.00	(1.00)	1.00	(2.7%)	2.7%
A68	32.75	32.50	(0.25)	0.25	(0.8%)	0.8%
B69	32.50	30.50	(2.00)	2.00	(6.6%)	6.6%
A70	34.50	32.75	(1.75)	1.75	(5.3%)	5.3%
B71	32.00	31.50	(0.50)	0.50	(1.6%)	1.6%
B73	32.00	30.50	(1.50)	1.50	(4.9%)	4.9%
A74	34.50	35.75	1.25	1.25	3.5%	3.5%
B75	32.50	32.75	0.25	0.25	0.8%	0.8%
A76	35.00	35.00	0.00	0.00	0.0%	0.0%
B77	31.50	31.00	(0.50)	0.50	(1.6%)	1.6%
A78	31.00	30.00	(1.00)	1.00	(3.3%)	3.3%
B79	31.50	31.50	0.00	0.00	0.0%	0.0%
A80	36.00	36.00	0.00	0.00	0.0%	0.0%
B81	35.00	36.25	1.25	1.25	3.4%	3.4%
A82	32.00	31.50	(0.50)	0.50	(1.6%)	1.6%
B83	33.50	32.50	(1.00)	1.00	(3.1%)	3.1%
A84	31.88	31.00	(0.88)	0.88	(2.8%)	2.8%
B85	32.00	31.00	(1.00)	1.00	(3.2%)	3.2%
A86	36.00	34.00	(2.00)	2.00	(5.9%)	5.9%
B87	36.00	34.75	(1.25)	1.25	(3.6%)	3.6%
		Total	(24.88)	33.88	(78.4%)	105.3%
		Avg	(0.73)	1.00	(2.3%)	3.1%

Waist Self & Expert Measurement Differences

(All Measurements in Inches)

Subj	Self Waist	Expert Waist	Change (In)	Total (In)	% Change	% Total
A50	31.50	31.75	0.25	0.25	0.8%	0.8%
B51	31.25	32.00	0.75	0.75	2.3%	2.3%
A52	34.00	33.00	(1.00)	1.00	(3.0%)	3.0%
A54	32.00	34.00	2.00	2.00	5.9%	5.9%
A56	36.00	34.00	(2.00)	2.00	(5.9%)	5.9%
B57	34.00	34.00	0.00	0.00	0.0%	0.0%
A58	32.00	31.50	(0.50)	0.50	(1.6%)	1.6%
B59	35.50	33.50	(2.00)	2.00	(6.0%)	6.0%
A60	35.00	33.00	(2.00)	2.00	(6.1%)	6.1%
B61	34.00	32.25	(1.75)	1.75	(5.4%)	5.4%
B63	33.50	32.00	(1.50)	1.50	(4.7%)	4.7%
A64	36.00	35.75	(0.25)	0.25	(0.7%)	0.7%
B65	33.50	30.50	(3.00)	3.00	(9.8%)	9.8%
A66	36.00	35.00	(1.00)	1.00	(2.9%)	2.9%
B67	36.00	36.00	0.00	0.00	0.0%	0.0%
A68	33.50	31.50	(2.00)	2.00	(6.3%)	6.3%
B69	31.50	31.00	(0.50)	0.50	(1.6%)	1.6%
A70	37.00	34.00	(3.00)	3.00	(8.8%)	8.8%
B71	31.75	30.75	(1.00)	1.00	(3.3%)	3.3%
B73	32.50	32.00	(0.50)	0.50	(1.6%)	1.6%
A74	32.00	34.00	2.00	2.00	5.9%	5.9%
B75	33.50	34.00	0.50	0.50	1.5%	1.5%
A76	35.50	34.00	(1.50)	1.50	(4.4%)	4.4%
B77	31.50	30.25	(1.25)	1.25	(4.1%)	4.1%
A78	32.50	33.50	1.00	1.00	3.0%	3.0%
B79	32.50	32.00	(0.50)	0.50	(1.6%)	1.6%
A80	33.00	35.00	2.00	2.00	5.7%	5.7%
B81	33.00	34.25	1.25	1.25	3.6%	3.6%
A82	32.00	31.00	(1.00)	1.00	(3.2%)	3.2%
B83	35.50	32.00	(3.50)	3.50	(10.9%)	10.9%
A84	31.75	32.00	0.25	0.25	0.8%	0.8%
B85	33.00	33.25	0.25	0.25	0.8%	0.8%
A86	33.00	31.75	(1.25)	1.25	(3.9%)	3.9%
B87	37.00	33.00	(4.00)	4.00	(12.1%)	12.1%
		Total	(24.75)	45.25	(77.7%)	138.2%
		Avg	(0.73)	1.33	(2.3%)	4.1%

Seat Self & Expert Measurement Differences

(All Measurements in Inches)

Subj	Self Seat	Expert Seat	Change (in)	Total (in)	% Change	% Total
A50	37.75	37.00	(0.75)	0.75	(2.0%)	2.0%
B51	36.00	35.75	(0.25)	0.25	(0.7%)	0.7%
A52	39.00	37.75	(1.25)	1.25	(3.3%)	3.3%
A54	37.00	36.50	(0.50)	0.50	(1.4%)	1.4%
A56	38.50	38.75	0.25	0.25	0.6%	0.6%
B57	38.50	37.75	(0.75)	0.75	(2.0%)	2.0%
A58	41.00	37.50	(3.50)	3.50	(9.3%)	9.3%
B59	40.50	39.50	(1.00)	1.00	(2.5%)	2.5%
A60	39.00	38.00	(1.00)	1.00	(2.6%)	2.6%
B61	37.00	38.00	1.00	1.00	2.6%	2.6%
B63	40.25	39.00	(1.25)	1.25	(3.2%)	3.2%
A64	40.50	40.00	(0.50)	0.50	(1.3%)	1.3%
B65	38.00	37.50	(0.50)	0.50	(1.3%)	1.3%
A66	38.00	40.50	2.50	2.50	6.2%	6.2%
B67	41.00	40.50	(0.50)	0.50	(1.2%)	1.2%
A68	38.50	38.00	(0.50)	0.50	(1.3%)	1.3%
B69	39.50	38.00	(1.50)	1.50	(3.9%)	3.9%
A70	39.00	38.50	(0.50)	0.50	(1.3%)	1.3%
B71	38.25	37.00	(1.25)	1.25	(3.4%)	3.4%
B73	38.00	37.50	(0.50)	0.50	(1.3%)	1.3%
A74	36.00	38.50	2.50	2.50	6.5%	6.5%
B75	41.50	39.25	(2.25)	2.25	(5.7%)	5.7%
A76	44.00	41.50	(2.50)	2.50	(6.0%)	6.0%
B77	38.50	38.00	(0.50)	0.50	(1.3%)	1.3%
A78	37.50	36.25	(1.25)	1.25	(3.4%)	3.4%
B79	36.50	37.00	0.50	0.50	1.4%	1.4%
A80	38.00	38.75	0.75	0.75	1.9%	1.9%
B81	30.00	40.00	10.00	10.00	25.0%	25.0%
A82	34.00	35.75	1.75	1.75	4.9%	4.9%
B83	40.50	37.50	(3.00)	3.00	(8.0%)	8.0%
A84	35.63	36.50	0.88	0.88	2.4%	2.4%
B85	39.00	37.75	(1.25)	1.25	(3.3%)	3.3%
A86	37.00	37.50	0.50	0.50	1.3%	1.3%
B87	42.00	39.50	(2.50)	2.50	(6.3%)	6.3%
		Total	(8.63)	49.88	(23.5%)	129.2%
		Avg	(0.25)	1.47	(0.7%)	3.8%

Crotch Self & Expert Measurement Differences

(All Measurements in Inches)

Subj	Self Crotch	Expert Crotch	Change (In)	Total (In)	% Change	% Total
A50	23.50	26.25	2.75	2.75	10.5%	10.5%
B51	26.00	23.50	(2.50)	2.50	(10.6%)	10.6%
A52	25.00	20.75	(4.25)	4.25	(20.5%)	20.5%
A54	30.00	26.00	(4.00)	4.00	(15.4%)	15.4%
A56	27.00	24.00	(3.00)	3.00	(12.5%)	12.5%
B57	27.00	24.00	(3.00)	3.00	(12.5%)	12.5%
A58	26.00	26.00	0.00	0.00	0.0%	0.0%
B59	28.00	26.00	(2.00)	2.00	(7.7%)	7.7%
A60	27.00	25.50	(1.50)	1.50	(5.9%)	5.9%
B61	27.00	26.00	(1.00)	1.00	(3.8%)	3.8%
B63	25.50	27.75	2.25	2.25	8.1%	8.1%
A64	30.00	26.00	(4.00)	4.00	(15.4%)	15.4%
B65	24.00	24.75	0.75	0.75	3.0%	3.0%
A66	28.50	27.00	(1.50)	1.50	(5.6%)	5.6%
B67	26.00	26.00	0.00	0.00	0.0%	0.0%
A68	25.50	26.00	0.50	0.50	1.9%	1.9%
B69	26.50	25.00	(1.50)	1.50	(6.0%)	6.0%
A70	25.00	24.00	(1.00)	1.00	(4.2%)	4.2%
B71	25.25	25.50	0.25	0.25	1.0%	1.0%
B73	24.00	24.50	0.50	0.50	2.0%	2.0%
A74	26.00	27.00	1.00	1.00	3.7%	3.7%
B75	25.75	25.50	(0.25)	0.25	(1.0%)	1.0%
A76	24.00	27.75	3.75	3.75	13.5%	13.5%
B77	25.00	23.50	(1.50)	1.50	(6.4%)	6.4%
A78	28.50	24.00	(4.50)	4.50	(18.8%)	18.8%
B79	26.50	25.50	(1.00)	1.00	(3.9%)	3.9%
A80	27.00	24.25	(2.75)	2.75	(11.3%)	11.3%
B81	25.00	25.00	0.00	0.00	0.0%	0.0%
A82	20.00	24.00	4.00	4.00	16.7%	16.7%
B83	27.00	26.00	(1.00)	1.00	(3.8%)	3.8%
A84	23.13	23.50	0.38	0.38	1.6%	1.6%
B85	28.00	24.00	(4.00)	4.00	(16.7%)	16.7%
A86	23.00	24.00	1.00	1.00	4.2%	4.2%
B87	27.00	27.00	0.00	0.00	0.0%	0.0%
		Total	(27.13)	61.38	(115.7%)	248.1%
		Avg	(0.80)	1.81	(3.4%)	7.3%

Expert Measurement (Initial) Predictive Significance

```
t-Test of Individual µ's
No Selector
Individual Alpha Level 0.05
Ho: µ =  0 Ha:  µ > 0

In Exp :
Test Ho: µ(In Exp) = 0 vs Ha: µ(In Exp) > 0
Sample Mean = 0.049910235 t-Statistic = 7.54 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Self-Measurement (Initial) Predictive Significance

```
t-Test of Individual µ's
No Selector
Individual Alpha Level 0.05
Ho: µ =  0 Ha:  µ > 0

In Self :
Test Ho: µ(In Self) = 0 vs Ha: µ(In Self) > 0
Sample Mean = 0.073951647 t-Statistic = 10.78 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Self-Measurement / Fit Preference (Initial) Predictive Significance

```
t-Test of Individual µ's
No Selector
Individual Alpha Level 0.05
Ho: µ =  0 Ha:  µ > 0

In Self/Fit :
Test Ho: µ(In Self/Fit) = 0 vs Ha: µ(In Self/Fit) > 0
Sample Mean = 0.063536588 t-Statistic = 7.842 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Expert Measurement (Adjusted) Predictive Significance

```
t-Test of Individual μ's
No Selector
Individual Alpha Level 0.05
Ho: μ =  0 Ha:  μ > 0

Adj Exp :
Test Ho: μ(Adj Exp) = 0 vs Ha: μ(Adj Exp) > 0
Sample Mean = 0.049214 t-Statistic = 7.497 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Expert Measurement / Fit Preference (Adjusted) Predictive Significance

```
t-Test of Individual μ's
No Selector
Individual Alpha Level 0.05
Ho: μ =  0 Ha:  μ > 0

Adj Exp/Fit :
Test Ho: μ(Adj Exp/Fit) = 0 vs Ha: μ(Adj Exp/Fit) > 0
Sample Mean = 0.045002588 t-Statistic = 6.462 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Self-Measurement (Adjusted) Predictive Significance

```
t-Test of Individual μ's
No Selector
Individual Alpha Level 0.05
Ho: μ =  0 Ha:  μ > 0

Adj Self :
Test Ho: μ(Adj Self) = 0 vs Ha: μ(Adj Self) > 0
Sample Mean = 0.065056 t-Statistic = 8.656 w/33 df
Reject Ho at Alpha = 0.05
p ≤ 0.0001
```

Self-Measurement / Fit Preference (Adjusted) Predictive Significance

t-Test of Individual μ's

No Selector

Individual Alpha Level 0.05

Ho: $\mu = 0$ Ha: $\mu > 0$

Adj Self/Fit:

Test Ho: μ(Adj Self/Fit) = 0 vs Ha: μ(Adj Self/Fit) > 0

Sample Mean = 0.059387735 t-Statistic = 6.976 w/33 df

Reject Ho at Alpha = 0.05

$p \le 0.0001$

APPENDIX E

TEST FORMS

Clothing Research Study

CORNELL
UNIVERSITY

Textile and Apparel Department

MALE TEST PARTICIPANTS NEEDED:

- Must wear pants or shorts with a waist size between 30 and 35 inches
- Participants will:
  - Evaluate and complete website apparel ordering for men's shorts
  - Take self-measurements and try-on several pairs of shorts
  - Complete a short questionnaire
- One hour test blocks scheduled between 8:00 am and 4:00 pm *July 6*
  - Other times and dates can be arranged
- Testing is limited to 15 subjects and the sign-up deadline is *July 3*
- **Contact:** Sean Ahrens at sfa3@cornell.edu or 256-7206

FREE REFRESHMENTS PROVIDED

CONSENT FORM

We invite you to participate in this study of the fit preference and self-measurement for mass customized men's clothing. Through this study, we hope to gain a better understanding of the effects of fit preference statements along with self-measurement techniques in automated apparel ordering. Ultimately we want to help improve ordering accuracy and satisfaction of fit with men's customized clothing.

Procedures:

If you decide to participate in this study, we will have you work through an Internet ordering site for men's shorts. You will conduct self-measurement procedures and report crotch, waist, and seat circumferences. We will then ask you to respond to a series of fit preference questions and complete an ordering questionnaire that includes demographic information and purchasing questions. We will measure you and have you try on a series of shorts until you find a pair whose fit you prefer the most. Finally, we will videotape you while you try on the test shorts.

You complete the Internet ordering site, self-measurement, and fit preference section of the research on your time. The fit testing period, expert measurement and final questionnaire period will take approximately 30 minutes.

Any information obtained in connection with this study that can be identified with you will remain confidential. In all written reports and publications, no individual will be identified or identifiable and only pertinent data will be presented.

Your decision whether or not to participate in this study will not affect your future relations with Cornell University or the Department of Textiles and Apparel in any way. If you decide to participate in this study, you may withdraw at any time.

If you have any questions about this research and/or your rights as a participant, please call Dr. Susan Ashdown at (607) 255-1929, or e-mail her at spa4@cornell.edu

Agreement:

Your signature below indicates that you have read and understand the information provided and that you wish to participate in this study. You may withdraw from this study at any time without prejudice. You may have a copy of this agreement if you wish.

______________________	______________________	____________
Printed Name	Signature	Date

Signature of Investigator ______________________

ORDER FORM

Ordering information:

Style selection	AUGUSTA
Color selection	KHAKI
Short length	7 Inches

Self-measurement data:

Height (est)	______ in	Weight (est)	______ lbs
Girth	______ in	Waist	______ in
Seat	______ in	Crotch	______ in
Garment worn	____________________ (please specify)		

Fit preference responses:

What is your fit preference for casual shorts in the following areas?
(Circle your selection)
1 = Very snug **5 = Very loose**

	Snug				**Loose**
Waist	1	2	3	4	5
Seat	1	2	3	4	5
Crotch	1	2	3	4	5

Do you prefer to wear the waist of your shorts high or low?
1 = Very low **5 = Very high**

	Low				**High**
Waist height	1	2	3	4	5

THANK YOU FOR YOUR ORDER!

(Please return this Order Form to a test evaluator)

EXPERT MEASUREMENT / FIT EVALUATION FORM

Measurements : List expert measurements

Height	Weight	Waist (O)	Waist (P)	(O)-(P)	Seat	Thigh	Crotch

Fit Evaluation : Evaluate the look and feel in terms of pressure, restriction, ease of movement, and appearance

Exp (A): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Top / Final (Circle)

Self (B): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Top / Final (Circle)

Fit (C): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Top / Final (Circle)

Alt (D-1): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Final (Circle)

Alt (D-2): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Final (Circle)

Alt (D-3): ____ / ____

Waist	Seat	Crotch	Thigh	Overall	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	LOOK
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	FEEL

Remarks: ________________

________________ Final (Circle)

DISCREPANCY QUESTION FORM

For EM/SM variances greater than 2 inches:

(Circle all that apply) **GIRTH** **WAIST** **SEAT** **CROTCH**

1. Did you follow the website measuring instructions?

____

____

____

2. Did you find the measurement procedures difficult or confusing?

____

____

____

3. What type of measuring device did you use?

____

____

____

4. Do you feel that this device was accurate?

____

____

____

5. Would you follow different procedures if you were actually purchasing the shorts?

____

____

____

6. Can you demonstrate how you actually took the measurement(s) in question.

GIRTH ______________

WAIST ______________

SEAT ______________

CROTCH ______________

FIT TEST SURVEY

Part 1 Test Shorts

1. Based on fit alone, do you like the look and feel of the final shorts you selected well enough to purchase a pair?

   _____ Yes _____ No

2. Why or why not? ____

   ____

3. What changes would you make in the fit of your final shorts and why? _______

   ____

   ____

Part 2 Background Information

4. What is your age? ____________________

5. Which describes your ethnic identity? (Circle letters of all that apply)

   a. African/African American
   b. American Indian/Alaskan Native
   c. Asian/Asian American
   d. Caucasian
   e. Latino/Chicano/Hispanic American
   f. Other (Please specify) ____________________________

6. What is the most common size of pants or shorts that you normally purchase? (Circle all that apply)

   Extra Small   Small   Medium   Large   Extra Large

   (Waist) 28 29 30 31 32 33 34 35 36

   (Inseam) 28 29 30 31 32 33 34 35 36

   Short   Tall   Long

   Other (please specify) ______________________________

Part 3 Purchasing Questionnaire

Please circle your response
1 = Always 5 = Never

	Always				Never
7. The way my clothes feel on my body is important to me	1	2	3	4	5
8. I have alterations done on ready-to-wear clothing	1	2	3	4	5
9. The clothing I wear the most is also the most comfortable	1	2	3	4	5

10. What percentage of your clothing do you purchase yourself? __________ %

11. What percentage of your clothing is purchased from the following:

a. Department stores __________ %
b. Discount stores __________ %
c. Sporting goods stores __________ %
d. Mail-order catalogs __________ %
e. Internet __________ %
f. Other __________ % (Please specify) ____________

When shopping for clothes, how often do you:
1 = Always 5 = Never

	Always				Never
12. Look at manufacturer's sizing information	1	2	3	4	5
13. Follow manufacturer's sizing guidelines	1	2	3	4	5
14. Use mail-order catalog measurement instructions	1	2	3	4	5
15. Try on garments before you purchase them	1	2	3	4	5

In general, do you prefer clothing looser or tighter on your body?
1 = Very tight 5 = Very loose

	Tight				Loose
16. Shorts	1	2	3	4	5
17. Pants	1	2	3	4	5

How important are the following attributes in the shorts you purchase?
1 = Not important 5 = Very important

	Not				Very
18. Fit	1	2	3	4	5
19. Style	1	2	3	4	5
20. Durability	1	2	3	4	5
21. Features	1	2	3	4	5
22. Comfort	1	2	3	4	5
23. Fabric	1	2	3	4	5
24. Price	1	2	3	4	5

How easily can you find good fitting ready-to-wear?
1 = Difficult **5 = Easy**

	Difficult				Easy
25. Shorts	1	2	3	4	5
26. Pants	1	2	3	4	5

27. What problems do you have with fit when purchasing shorts or pants? _______

____

____

Part 4 Ordering Format

Please rate your ease in understanding and conducting the following procedures:
1 = Very difficult **5 = Very easy**

	Difficult				Easy
28. Internet site review	1	2	3	4	5
29. Self-measurement instruction	1	2	3	4	5
30. Fit preference questioning	1	2	3	4	5

31. What changes would you make to these procedures and why? _______________

____

____

This concludes your portion of testing for this research project. Please ensure that all testing materials and survey forms are returned and that you check-out with a test evaluator before departing.

THANK YOU FOR YOUR PARTICIPATION!
(Please return Survey Form to a test evaluator)

DATA CODING FOR FIT TEST QUESTIONNAIRE

1 Purchase final selection based on fit
(1) - Yes
(2) - No
2 Answer (Why or why not purchase)
3 Answer (What changes would you make)
4 Age (Years)
5a Ethnic identity
(1) African/African American
(2) American Indian/Alaskan Native
(3) Asian/Asian American
(4) Caucasian
(5) Latino/Chicano/Hispanic American
(6) Other
5b Answer (Specify other)
6a Common sizes normally purchased
(1) Extra Small
(2) Small
(3) Medium
(4) Large
(5) Extra Large
6b Common waist sizes normally purchased
(1) 28
(2) 29
(3) 30
(4) 31
(5) 32
(6) 33
(7) 34
(8) 35
(9) 36
6c Common inseam sizes normally purchased
(1) 28
(2) 29
(3) 30
(4) 31
(5) 32
(6) 33
(7) 34
(8) 35
(9) 36
6d Common additional size identifiers normally purchased
(1) Short
(2) Tall
(3) Long
(4) Other
6e Answer (Specify other)

7 The way my clothes feel on my body is important to me
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never
8 I have alterations done on ready-to-wear clothing
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never
9 The clothing I wear the most is also the most comfortable
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never
10 Clothing purchased yourself (%)
11a Clothing from department stores (%)
11b Discount stores (%)
11c Sporting goods stores (%)
11d Mail-order catalogs (%)
11e Internet (%)
11f Other (%)
11g Answer (Specify other)
12 Look at manufacturer's sizing information
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never
13 Follow manufacturer's sizing guidelines
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never
14 Use mail-order catalog measurement instructions
   (1) Always
   (2) Frequently
   (3) Occasionally
   (4) Seldom
   (5) Never

15 Try on garments before you purchase them
(1) Always
(2) Frequently
(3) Occasionally
(4) Seldom
(5) Never
16 General preference short fit
(1) Very tight
(2) Tight
(3) Average
(4) Loose
(5) Very loose
17 General preference pant fit
(1) Very tight
(2) Tight
(3) Average
(4) Loose
(5) Very loose
18 Fit
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
19 Style
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
20 Durability
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
21 Features
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
22 Comfort
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important

23 Fabric
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
24 Price
(1) Very unimportant
(2) Unimportant
(3) Indifferent
(4) Important
(5) Very important
25 Ease in finding good fitting ready-to-wear shorts
(1) Very difficult
(2) Difficult
(3) Average
(4) Easy
(5) Very easy
26 Ease in finding good fitting ready-to-wear pants
(1) Very difficult
(2) Difficult
(3) Average
(4) Easy
(5) Very easy
27 Answer (Problems with fit when purchasing shorts or pants)
28 Ease in understanding and completing internet site review
(1) Very difficult
(2) Difficult
(3) Average
(4) Easy
(5) Very easy
29 Ease in understanding and completing self-measurement instruction
(1) Very difficult
(2) Difficult
(3) Average
(4) Easy
(5) Very easy
30 Ease in understanding and completing fit preference questioning
(1) Very difficult
(2) Difficult
(3) Average
(4) Easy
(5) Very easy
31 Answer (Changes to procedures and why)

APPENDIX F

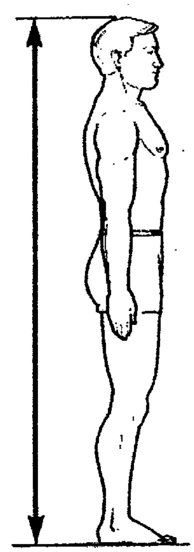
EXPERT MEASUREMENTS

STATURE

ORIGIN-TERMINATION: Standing surface -- **top of head.**

PROCEDURE: Subject is in the anthropometric standing position with the head in the Frankfort plane. Stand at one side of the subject and use an anthropometer to measure the vertical distance between the standing surface and the **top of the head.** Move the blade of the anthropometer across the top of the head to ensure measurement of the maximum distance. Use firm pressure to compress the subject's hair. The measurement is taken at the maximum point of quiet respiration.

CAUTION: Be sure that the head is in the Frankfort plane.



WEIGHT

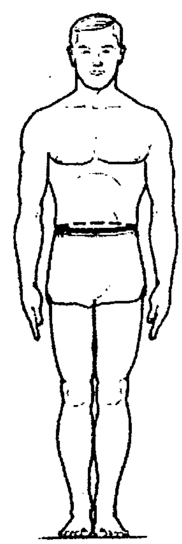
PROCEDURE: Subject stands on the footprints of the platform of the scale. Stand in front of the subject and take the weight of the subject to the nearest tenth of a kilogram.

WAIST CIRCUMFERENCE (OMPHALION)

LANDMARK(S) ENCOMPASSED: **Waist (omphalion): right and left; posterior and anterior.**

PROCEDURE: Subject is in the anthropometric standing position in front of a mirror. Stand in front of the subject and use a tape to measure the horizontal distance around the torso at the level of the center of the navel. The tape will pass over the drawn **waist (omphalion) landmarks** at the front, back and sides. Use the mirror to check the position of the tape as it crosses the subject's back. Exert only enough tension on the tape to maintain contact between the tape and the body. The measurement is made at the maximum point of quiet respiration.

CAUTION: The subject must not tense the abdominal muscles.

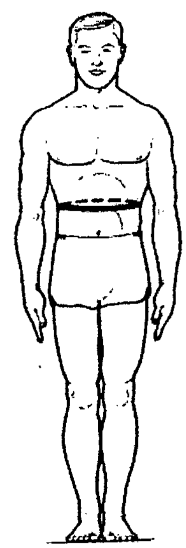


WAIST CIRCUMFERENCE (NATURAL INDENTATION)

LANDMARK(S) ENCOMPASSED: **Waist (natural indentation): right** and **left; posterior** and **anterior.**

PROCEDURE: Subject is in the anthropometric standing position in front of a mirror. Stand in front of the subject and use a tape to measure the horizontal circumference at the level of the drawn **waist (natural indentation) landmarks.** (Since all the waist landmarks are established at the level of the greatest indentation on the right side, the tape passes over both landmarks regardless of where the natural indentation on the left side may actually be.) Use the mirror to check the position of the tape as it crosses the subject's back. Exert only enough tension on the tape to maintain contact between the tape and the skin. The measurement is made at the maximum point of quiet respiration.

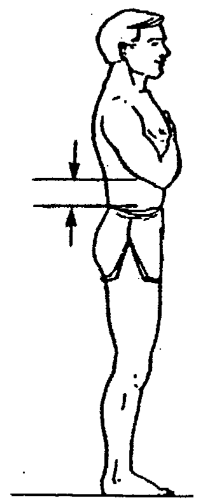
CAUTION: The subject must not tense the abdominal muscles.



WAIST (NATURAL INDENTATION) -- WAIST (OMPHALION) LENGTH

ORIGIN-TERMINATION: **Waist (natural indentation), right -- waist (omphalion), right**

PROCEDURE: Subjects stands on the table in the anthropometric standing position but with the right hand on the chest. Ask the subject to hold up the right leg of the shorts to expose the landmark. Stand at the right of the subject and use a tape to measure the surface distance between the drawn **waist (natural indentation)** and **waist (omphalion) landmarks**. Be sure the tape lies on the surface of the skin.

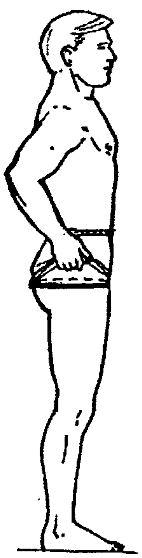


BUTTOCK CIRCUMFERENCE

LANDMARK(S) ENCOMPASSED: **Buttock point: right lateral, left lateral,** and **posterior.**

PROCEDURE: Subject stands erect on a table with heels together. Ask the subject to hold up the right leg of the shorts to expose the landmark. Stand at the subject's right and use a tape to measure the horizontal circumference of the trunk at the level of the maximum protrusion of the right buttock. The tape should pass over the **posterior buttock point** (not drawn) and the **buttock point landmarks** drawn on the right and left hips. (On the right hip this landmark is a horizontal line with a "B" drawn beside it.) If necessary, ask male subjects to adjust the genitalia so as to interfere as little as possible with the tape. Exert only enough tension on the tape to maintain contact between the tape and the skin.

CAUTION: The tape must be maintained in a horizontal plane.

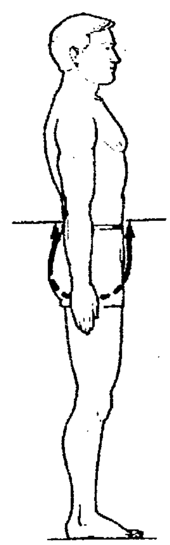


CROTCH LENGTH (OMPHALION)

ORIGIN-TERMINATION: **Waist (omphalion), anterior — waist (omphalion), posterior.**

PROCEDURE: Subject stands erect looking straight ahead with the feet sufficiently apart to allow passing a tape through the crotch. When the tape is in place, the subject brings the heels together for the measurement. Stand at the right of the subject and measure the distance between the drawn landmarks on the navel [**waist (omphalion), anterior**] and at the same waist level in back [**waist (omphalion), posterior**]. The tape passes through the crotch (on males to the right of the scrotum) and between the buttocks. The zero point of the tape is placed on the **posterior waist landmark.** After passing through the crotch the tape should be brought vertically to the **anterior waist landmark.** On men this will be somewhat to the right of the navel. Exert only enough tension on the tape to maintain contact between the tape and the surface of the body. The measurement is taken at the maximum point of quiet respiration.

CAUTION: Be sure the subject does not tense the abdominal muscles and that the tape lies on the skin.

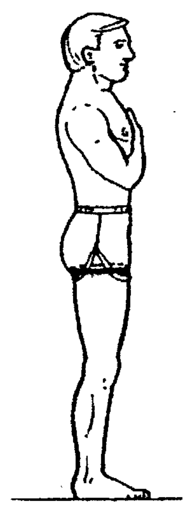


THIGH CIRCUMFERENCE

LANDMARK(S) ENCOMPASSED: **Gluteal furrow point.**

PROCEDURE: Subject stands erect on a table with the weight distributed equally on both feet. The legs are spread apart just enough so that the thighs do not touch, and the right hand is on the chest. Stand at the right of the subject and use a tape to measure the circumference of the thigh at its juncture with the buttock (drawn **gluteal furrow point**). The measurement is made perpendicular to the long axis of the thigh. Exert only enough tension on the tape to maintain contact between the tape and the skin.

CAUTION: The subject must not tense the thigh muscles. The tape must not be placed in a furrow.



APPENDIX G
RESEARCH WEBSITE

CUSTOMIZED GOLF APPAREL

RED BIRD

Welcome to the RED BIRD Golf Store

We deliver to your doorstep America's best made, best fitting men's golfwear. We custom size your selected garments to your own measurements and specifications. We provide easy-to-follow instructions on self-measurement and fit preference reporting and we guarantee you will receive the best fitting golf clothes you can buy or your money back.

Important Notice

This is a simulated web site for apparel ordering, fit preference and self-measurement research. The contact information, products, and store policies are fictional. Images and descriptions are provided to help you complete testing. Feel free to visit the entire site. However, you are only required to review the text in blue, order shorts and complete measurement and fit preference reporting before closing your session. The actual shorts you will evaluate in Stage 2 are made for sizing purposes only. If you have any questions, please contact one of the test evaluators.

Merchandise Guarantee

We will make your on-line shopping experience as pleasant, easy, and safe as digitally possible. All RED BIRD shorts are guaranteed against defects in workmanship and material for ten years from the date of purchase. We will take care of any and all problems and complaints to your satisfaction ... **Thank You!**

To Navigate Our Site

Test participants click the "NEXT" banner to continue or use the buttons at the top of the page to navigate the remainder of the RED BIRD Golf Store.

CATALOG ORDERING

CUSTOMIZED GOLF APPAREL

RED BIRD

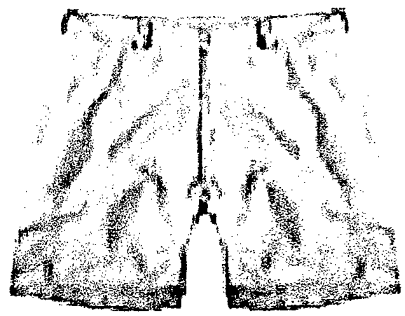
YOUR BEST SOURCE FOR GOLF!

We have the top ranking catalog order business for customized golfing apparel in the country. Please shop our on-line selections and feel free to contact us with your questions.

WE FEATURE:

Golf Shorts

Wear the same shorts as the PGA Tour professionals! We have three styles of golf shorts custom fit to meet your needs. All RED BIRD shorts are made with stonewashed cotton twill and have double stitched seams for long-life and durability. They are fade resistant and guaranteed against manufacturing defects for 10 years from the date of purchase. Please click on the menu button at the top of the page to view our golf short selections.



Golf Shirts

Look like a golf professional on and off the course! We have a full line of golf shirts with the famous RED BIRD logo. These shirts are 100% cotton with ribbed colors. We have a wide selection of colors and styles to choose from. Please click on the menu button at the top of the page to view our golf shirt selections.

Golf Caps

Complete that look with one of our signature golf caps! We have a wide variety of styles and colors to compliment your game. All our golf caps have the famous RED BIRD logo and come in a range of custom sizes. Please click on the menu button at the top of the page to view our golf cap selections.

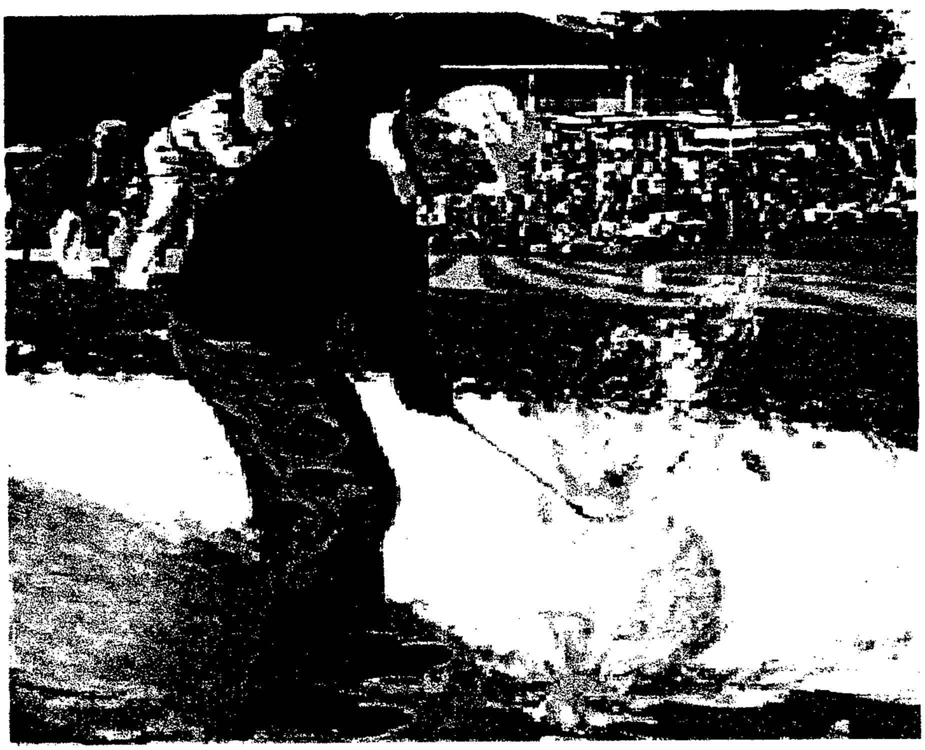
GOLF SHORTS

CUSTOMIZED GOLF APPAREL

RED BIRD

Red Bird Golf Shorts

We have three styles of shorts currently available. All RED BIRD golf shorts are made with stonewashed cotton twill and have double needle stitching for long-life and durability. They are fade and wrinkle resistant. They have the same easy care and washability of polyester but the comfort of a natural fiber that stretches and gives with every body movement. We guarantee all our clothing against defects for 10 years from your date of purchase. We may not be able to shave points off your game but we can make you look and feel great while you're on or off the course.



Red Bird Pledge

You will play and feel your best in the comfort of America's best fitting and best made golf shorts.

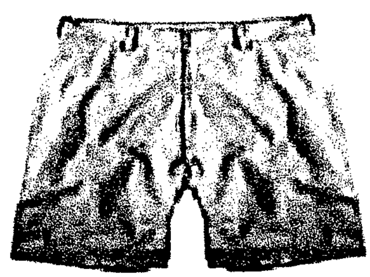
Red Bird Ordering

Custom sized and delivered to your door in only 10 business days. Call us for pricing. We give discounts for multiple orders and allow for reduced shipping costs.

Research Study

Please click the "NEXT" banner at the top of the page to move to the self-measurement and fit preference sections.

MODEL: Augusta



7" Augusta
Stonewashed cotton twill. Zip fly. Two back welt pockets with buttons. Machine wash. Plain front. $37.00

LENGTHS
Medium 7" length

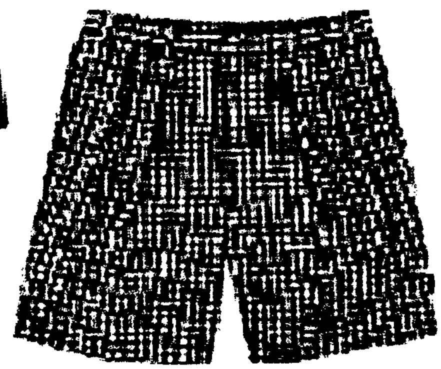
MODEL: Avenal

Avenal Classic
Lightly stonewashed cotton twill. Roomy fit. Plain front. Zip fly. Off seam pockets, back welt pockets. 8" inseam. Machine washable. $40.50

Avenal Madras
Pleated front. Zipper fly. Two back welt pockets, each with button. An 8" inseam. Machine washable. $44.50

CURRENTLY
UNAVAILABLE

MODEL: Sawgrass



Sawgrass Classic
Plain front. Stonewashed cotton twill. Soft, broken-in. Zipper fly. Has back flap pockets. A 6" inseam. Machine wash. $38.00

Sawgrass Madras
Soft, lightweight cotton. Pleated. Button fly. With two back welt pockets. 6" inseam. Machine wash. $34.00.

CURRENTLY
UNAVAILABLE

Red Bird Golf Shirts

We have three styles of golf shirts currently available. All our shirts are made with 100% American-produced cotton. They have a wrinkle resistant treatment with the easy care and washability of polyester plus the comfort of a stretchable fabric. We design our shirts to move with your body as well as provide a thermal barrier to outside playing conditions.

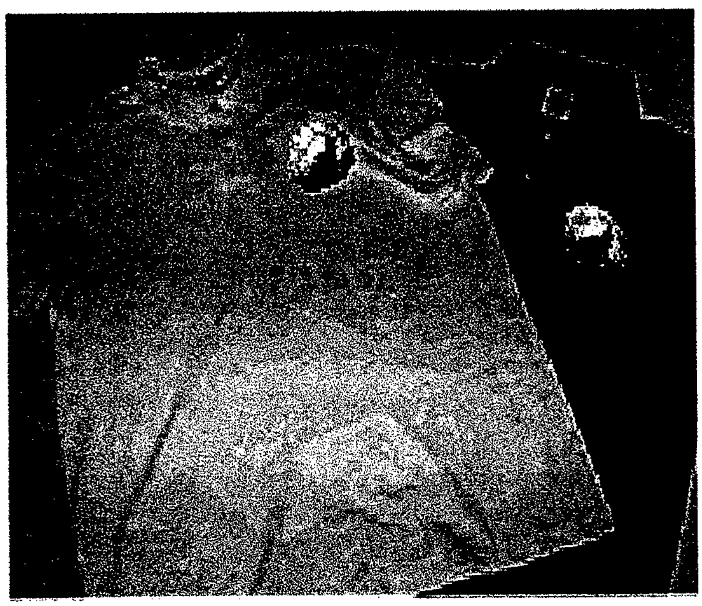
Red Bird Pledge

You will play and feel your best in the comfort of America's best fitting and best made golf shirts.

Red Bird Ordering

Customed sized and delivered to your door in only 10 business days. Buy one shirt for $35.00 plus freight. Additional shirts only $29.00 each plus reduced freight. Please specify your desired color selection, sleeve length, tail length, and body measurements when ordering.

MODEL: Caddie



100% Cotton
Uniform Tail

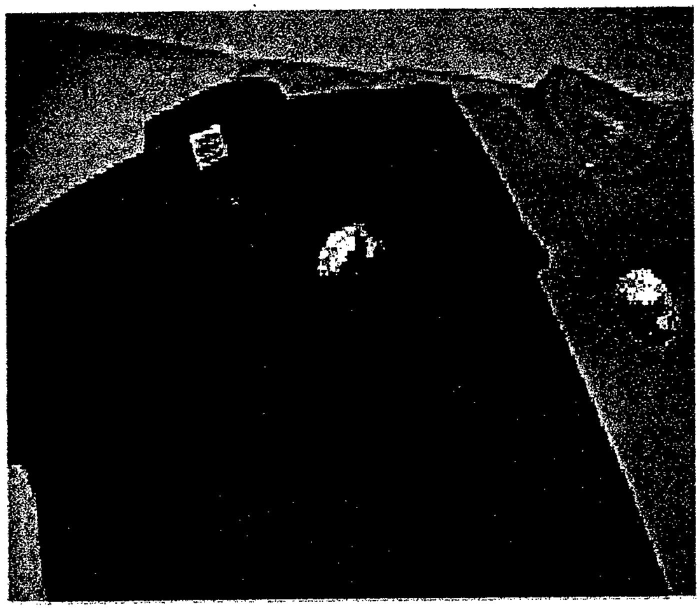
SIZES
Custom Fit

MODEL: Eagle

100% Cotton
Two Tone

SIZES
Custom Fit
Medium 8" sleeve
Long 10" sleeve

MODEL: Birdie



100% Cotton
Long Tail

SIZES
Custom Fit

Red Bird Golf Caps

We have two styles of golf caps available. All our caps are made with 100% cotton. They have water and fade resistant treatments so they will continue to look good even after heavy usage. Look and feel your best with our custom fitted golf caps.

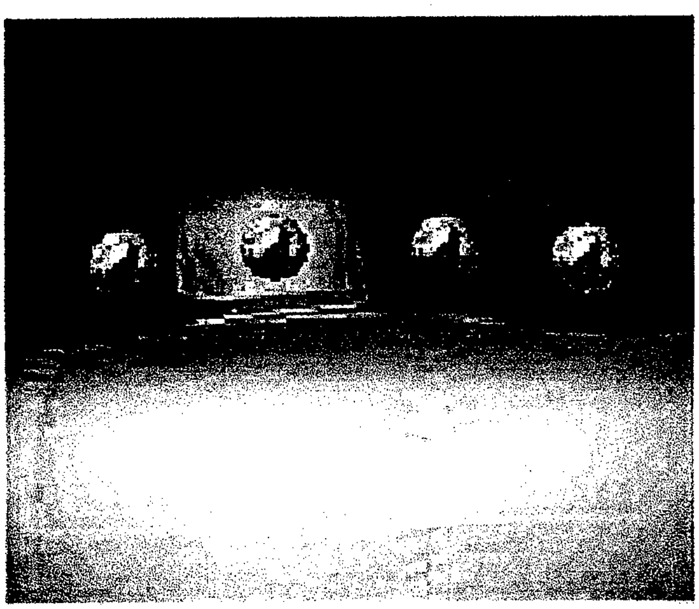
Red Bird Pledge

You will play and feel your best in the comfort of America's best fitting and best made golf caps.

Red Bird Ordering

Customed sized and delivered to your door in only 10 business days. Buy one cap for $17.50 plus freight. Additional caps only $15.00 each plus reduced freight. Please specify your desired color selection, style choice, and hat size.

MODEL: Driver



100% Cotton
Rear Ventilation

MODEL: Wedge

100% Cotton
No Ventilation

CUSTOMIZED GOLF APPAREL

Red Bird Customer Service

We will make your on-line shopping experience as pleasant, easy, and safe as digitally possible. We guarantee your satisfaction with our products and service or we will fix the problem free of charge. All RED BIRD garments are guaranteed for ten years from the date of purchase against defects in workmanship and material. We will take care of any problems or complaints quickly and to your satisfaction ...
Thank You!

If you do not trust the World Wide Web with your credit card information you can call us, e-mail us, fax us, or write to us. We will be happy to serve you in any manner you desire.

Our toll free telephone number **123-456-7890** is available from 10:00 AM to 5:00 PM Monday through Saturday.

Our fax number **123-456-7890** is available 24 hours a day.

Our e-mail address is sfa3@cornell.edu.

Our mailing address is
RED BIRD Golf Store
West 86th Street
New York, NY 12345

Please allow 2 weeks for delivery.

Return Policy

If you are not completely satisfied with your clothing for any reason or if there is a defect in the material or workmanship, we will gladly replace or repair the item for you at no charge. Please contact us immediately with any questions or concerns. We are here to make your clothing purchase as pleasant as possible.

Customized garments will be manufactured to your complete satisfaction.

RED BIRD

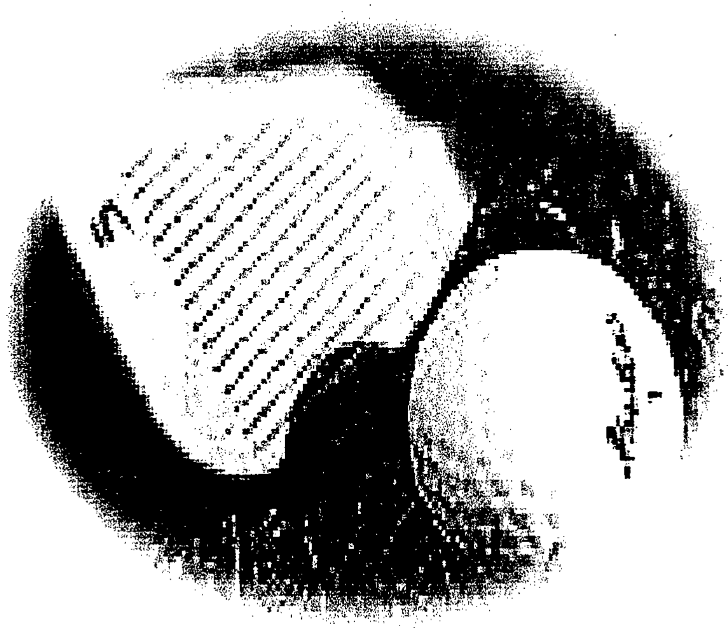
CUSTOMIZED GOLF APPAREL

YOUR BEST SOURCE FOR GOLF!

We have the top ranking catalog order business for customized golfing apparel in the country. Please shop our online selections and feel free to contact us with your questions.

Testing Assistance

Please make every effort to complete your short ordering, self measurement, and fit preference assignments without outside assistance. It is important for us to know what problems you encounter with this website. If you are stuck, please e-mail your questions using the link at the bottom of the page. If you have questions on instructions or problems with self measurement procedures, please return to the appropriate section of this website and reread the instruction several times before seeking further assistance.



SIZING

CUSTOMIZED GOLF APPAREL

RED BIRD

RED BIRD Sizing

RED BIRD golf measurements are easy to take. In fact, you will find them even easier if you closely follow the step-by-step instructions we provide. If you have any questions on this Sizing Section, please e-mail your questions using the link at the bottom of the page.

Measurement Preparation

Before you begin, you will need to gather a few things:

- A cloth tape measure or household item like a shoe lace, or a string that is long enough to fit around your body and non-stretchable
- If you're using a household item, you'll need a ruler or a yardstick to determine your final measurements
- A comfortable pair of pants or shorts that fit well
- Finally, something to write down your measurements

To Navigate Our Sizing Section

Test participants click the "NEXT" banner to continue. You can also use the buttons to move between pages. You can return to the main website using the "HOME" button. You must complete all pages in the Sizing Section.

Golf Short Sizing

Golf shorts must be both playable and comfortable. Good fit is very important in the waist and crotch. In order to custom manufacture your RED BIRD golf shorts, we must get accurate self-measurements and desired fit preferences. We strongly suggest that you take your measurements in pants or shorts that fit well. Remember to list the type of pants or shorts you wear while taking measurements on your order form. You may need to repeat self-measurement procedures several times to get accurate measurements. Once you get the same measurement twice, you should use that value in ordering.

Shrinkage

100% cotton twill shorts are garment washed before shipment. They will arrive pre-shrunk to your size. Each garment is designed to fit you the first time you try it on. However, you may experience minor shrinkage with continued laundering. Please DO NOT increase your reported measurements or fit preferences to reflect additional shrinkage concerns. If your RED BIRD clothing does not fit you to your complete satisfaction after laundering, you can still return it for alterations or replacement. We want you to be completely satisfied with the fit of your customized clothing.

SIZING

CUSTOMIZED GOLF APPAREL

RED BIRD

RED BIRD Girth Measurement

Girth

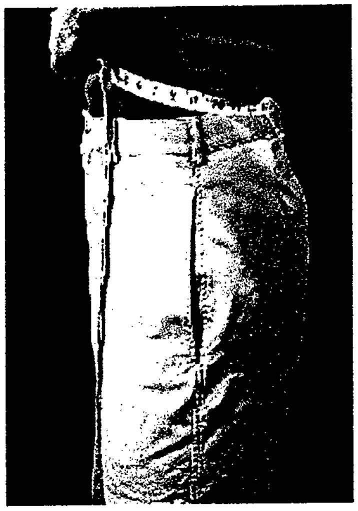
Your girth measurement is the circumference around your mid-section at your belly button. It is a good idea wear a pair of shorts or pants and keep the measuring device parallel with the top of your waistband.

1. **Wrap the measuring tape completely around your body.**
2. **Keep the tape measure an equal distance from the top edge of your waistband all the way around.**
3. **Make sure the tape is snug, but not too tight or too loose.**
4. **Read and record your measurement. You will need to repeat this procedure several times until you get the same measurement twice.**

Common Measuring Errors

Error #1

Don't pull the measuring tape too tight! Not only is it uncomfortable but it results in inaccurate measurements.



Error #2

Make sure your tape is straight! Use a mirror to make sure or ask someone to help you.

To Navigate Our Sizing Section

Test participants click the "NEXT" banner to continue. You may also use the buttons at the top of the page to move through the Sizing Section. You can return to the main website using the "HOME" button. You must complete each page of the Sizing Section.

SIZING
CUSTOMIZED GOLF APPAREL

RED BIRD

RED BIRD Waist Measurement

Waist

Your preferred waist measurement is taken along your natural waistline or the position where you want the waistband of your shorts. For most people, the preferred waistline is "about" an inch below the belly button. However, some people don't mind having their waistband above or further below this position. Determine the location that is most comfortable for you. It is a good idea to put on your favorite pair of shorts or pants and measure over them. Or if you like the placement of the waistband on whatever garment you are wearing you can use it as a guide as well.

1. **Thread the measuring tape through the beltloops of the garment you are wearing. If you don't have beltloops, measure along the bottom edge of your waistband.**
2. **Once the measuring tape is completely around your body, align the bottom edge of your tape measure with the bottom edge of your waistband and read the measurement. Make sure the tape is snug, but not too tight or too loose.**
3. **You will need to take this measurement several times until you get the same measurement twice.**

To Navigate Our Sizing Section

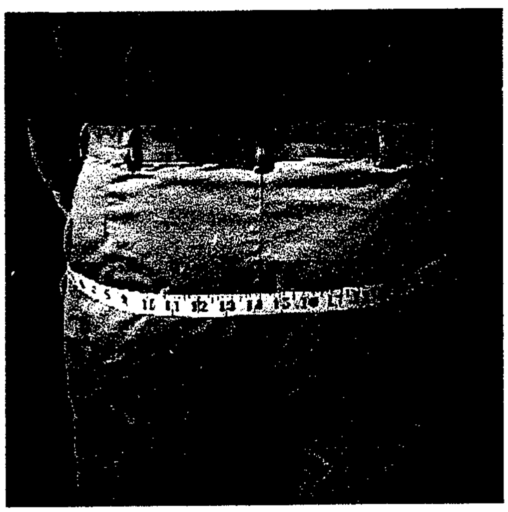
Test participants click the "NEXT" banner to continue. You may also use the buttons at the top of the page to move through the Sizing Section. You can return to the main website using the "HOME" button. You must complete each page of the Sizing Section.

RED BIRD Seat Measurement

Seat

Your seat measurement is taken around the area of your buttocks that has the greatest circumference. For men this is usually along the center on their buttocks.

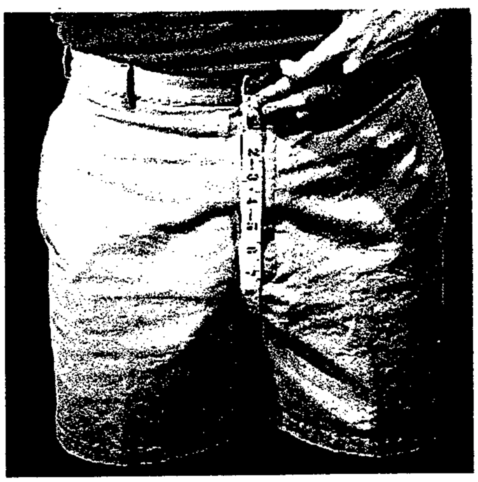
1. **Determine where your widest point is by sliding the measuring tape or string up and down until you find the largest circumference.**
2. **Measure around your body keeping the measuring tape or string parallel to the floor. You don't want the measuring tape or string to be higher in the front or back. It must be level all the way around.**
3. **You will need to take this measurement several times until you get the same measurement twice.**



To Navigate Our Sizing Section

Test participants click the "NEXT" banner to continue. You may also use the buttons at the top of the page to move through the Sizing Section. You can return to the main website using the "HOME" button. You must complete each page of the Sizing Section.

RED BIRD Crotch Measurement



Crotch

Do not pull too tight or loose on this measurment. Keep comfort in mind and make sure you measure your crotch length accurately.

1. **Measure from the bottom of your waistband in the front, passing the measuring tape through your legs, to the bottom of your waistband in the back.**
2. **It is important to stand straight and not lean your upper body in any direction.**
3. **You will need to take this measurement several times until you get the same measurement twice.**

Common Measuring Error

Too Tight!

Don't pull the measuring tape too tight! Not only is it uncomfortable but it results in inaccurate measurements.

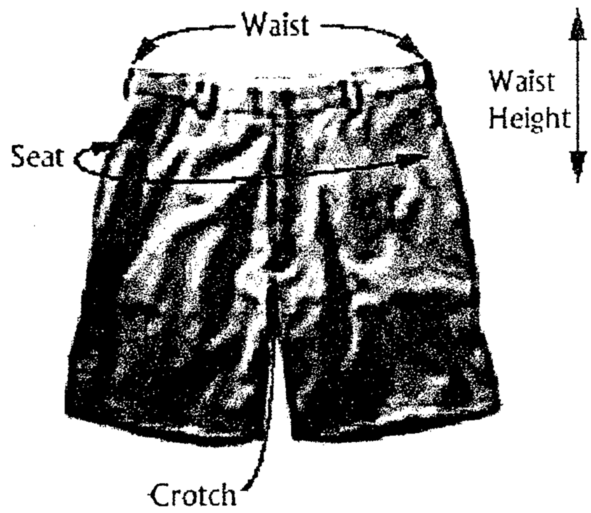
RED BIRD Fit Preference

Fit preference questions are easy to answer. Areas of the lower body that impact satisfaction of fit have been isolated. Remember that good fit involves the highest level of comfort and best appearance for your golf shorts.

Do not attempt to use fit preferences to change the styling features of your shorts. If you'd like a different style, simply order one and use your fit preferences to optimize the fit of that garment.

Fit Preference

Individualized fit preference is the key to your satisfaction with your new RED BIRD golf shorts. By answering the following four questions, we guarantee your satisfaction of fit. All questions are rated on a scale from 1 to 5. Please list your responses on the order form. If you are unsure of your preference for a specific area, answer in general how you would like your shorts to fit. For example, if you like baggy shorts but are unsure about the crotch length, answer with "4" Loose or "5" Very Loose for the question on crotch length. If you have any questions with these fit preference questions, please e-mail them to us using the link at the bottom of the page.



1. Waist - how snug or loose do you like the waist of your shorts?

   (Very snug) 1 .... 2 .... 3 .... 4 .... 5 **(Very loose)**

2. Seat - how snug or loose do you like the seat of your shorts?

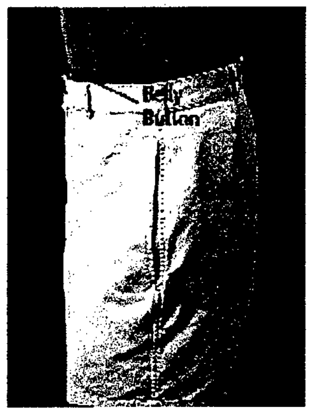
   (Very snug) 1 .... 2 .... 3 .... 4 .... 5 **(Very loose)**

3. Crotch - how snug or loose do you like the crotch of your shorts?

   (Very snug) 1 .... 2 .... 3 .... 4 .... 5 **(Very loose)**

4. Waist Height - how high or low do you like the waistband of your shorts?

   (Very high) 1 .... 2 .... 3 .... 4 .... 5 **(Very low)**



High Waist

Mid Waist

Low Waist

To Navigate Our Sizing Section

Test participants click the "NEXT" banner to continue. You may also use the buttons at the top of the page to move through the Sizing Section. You can return to the main website using the "HOME" button. You must complete each page of the Sizing Section.

ORDER FORM

CUSTOMIZED GOLF APPAREL

RED BIRD

RED BIRD Ordering

Please fill in your personal information, measurements, and fit preference responses. Remember to request a date and time for your fit session. You will receive an e-mail confirmation of your fit session time within 24 hours. Thank you for your participation in this portion of the research project.

RED BIRD Order Form

Name (Last, First MI)	
Short Style	Augusta
Short Color	Parchment
Short Length	Medium 7-inch
Girth Measurement	
Waist Measurement	
Seat Measurement	
Crotch Measurement	
Type Clothing Worn	Casual Shorts
Waist Preference	Very Snug (1)
Seat preference	Very Snug (1)
Crotch Preference	Very Snug (1)
Waist Height Preference	Very High (1)
Fit Session Date	11 October
Fit Session Time	8:00 am

Send other information as attachments via E-mail to sfa3@cornell.edu

Send Order Form | Clear Order

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