ABSTRACT

SIMMONS, KARLA PEAVY. Body Shape Analysis Using Three-Dimensional Body Scanning Technology. (Under the direction of Dr. Cynthia L. Istook and Dr. Trevor Little, co-chairs.)

Clothing fit is a major cause of frustration for consumers today. The current sizing systems for women in the US are based on a study that is over 6 decades old. The greater influence of ethnic diversity along with changes in lifestyles since the 1940s is making our bodies look differently. New technology is allowing the rapid and accurate ability to determine the true shape of human bodies through 3D body scanning. No attempts have been made to study body shapes and sizes using the 3D body scanner until this pilot study.

A computer program was developed to derive a numerical difference in body measurements between those of the subjects and those defined by all current and past sizing standards demonstrating that the current sizing system is insufficient. Three methods were developed in the <u>Best Fit</u> software to ascertain the sufficiency of the standards: percentage difference, tolerance difference, and weighted tolerance difference. Even though the CS215-58 was the most chosen standard for the best fit in the percentage difference, 30% of the measures in that standard deviated more than 5% from the subject's measurements. For the tolerance difference, the ASTM5586-95 was the most chosen standard and had an average of 14 measurements (out of 23) that were out-of-tolerance as compared to the subject's measurements. For the weighted tolerance difference, the ASTM 5586-95 (women over 55) database was the most chosen. If each of

the 23 measurements for a subject were out-of-tolerance to the most severe amount, then the subject would get a score of 69. This study had an average score of 20 for weighted tolerance.

A new shape identification software was developed through the computer program of Visual Basic Pro called FFIT (Female Figure Identification Technique) for Apparel. Nine shape categories were identified: “hourglass”, “oval”, “triangle”, “inverted triangle”, “rectangle”, “spoon”, “diamond”, ”bottom hourglass”, and “top hourglass”. The bust, waist, hip, stomach, and abdomen circumferences were used in combination to describe each shape. The Bottom Hourglass was the shape identified most frequently (40%), followed by the Hourglass (21.6%), Spoon (17%), Rectangle (15.8%), Oval (3.6%), and Triangle (1.8%).

BODY SHAPE ANALYSIS USING

THREE-DIMENSIONAL

BODY SCANNING TECHNOLOGY

By

KARLA KRISTIN PEAVY SIMMONS

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APPROVED BY:

Dr. Nancy Cassill	Dr. Thomas Johnson
Dr. Cynthia L. Istook Co-Chair of Advisory Committee	Dr. Trevor Little Co-Chair of Advisory Committee

DEDICATION

To my loving parents,

***John Lester and Patricia Vail Peavy**:*

through your sacrifices, support,

encouragement and prayers, I

am living my dreams.

BIOGRAPHY

Karla Kristin Peavy Simmons, daughter of John Lester and Patricia (Vail) Peavy, was born July 17, 1970, at Nellis Air Force Base in Las Vegas, Nevada. She graduated from J. U. Blacksher High School in Uriah, Alabama in 1988. She then attended Auburn University and graduated with a Bachelor of Science degree in Textile Management and Technology with a minor in Apparel Production Management in 1992. After working as a quality control supervisor and a cutting department shift supervisor for Oneita Industries, she returned to Auburn University for a master's degree in Apparel Production Management and graduated in December 1996. Karla was a Textile and Apparel Technology Instructor for Central Alabama Community College in Alexander City, Alabama, until she started her doctoral degree in Textile Technology and Management at North Carolina State University in Raleigh, North Carolina. Before graduation, she began teaching at the University of Missouri-Columbia in the College of Human Environmental Sciences, Department of Textile and Apparel Management. She is the head of the Apparel Manufacturing Management area. Karla has been married to Cronor Gilliam (Gill) Simmons of Raleigh, North Carolina, since August 1, 1998.

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CHAPTER 1: INTRODUCTION

> "It is evidently absurd to attempt to cover correctly a simple form, as a cube, without knowledge of it; and how much more absurd to attempt to dress or drape the human form correctly and tastefully without such knowledge." Dr. Henry Wampen (1864), p. 1.

One of the most important goals of a garment manufacturer is to provide the desired fit of their products for their specific consumers. While fit is often a subjective process, it is always based on an identified set of measures. Currently, clothing sizes are based on a biased study that is over 6 decades old. The data, obtained from a volunteer sample which primarily included white women, aged 18-30, from only 8 states, has been "massaged" over time to attempt to "fit" the current population. This method of sizing does not conform to the diversity of human shapes that currently exist in the United States.

Attempts to classify body shapes into analogous types, in order to establish size standards, have resulted in the formation of several size groupings. However, the industry as a whole has not adopted a single system of clothing sizing. We know that manufacturers and retailers use their own sizing systems as a marketing tool, convinced that this is a differential advantage of their product for their market. However, most manufacturers would admit to their frustrations at not being entirely successful in this endeavor.

Regardless of the sizing systems used, almost all are based on the myth that humans have mathematically proportional bodies and that they grow in proportional ways. There are times in most persons' lives that this is relatively true. From birth to the age of about 15, the American population as a whole tends to grow taller as it grows bigger around. Actually less than 2% of the population truly fits the mold described by the mean of the entire population! Additionally, the shapes and proportions of today's American population differ greatly from the shapes of the generations before.

These fit issues continue to be a growing concern. Consumers are not happy with clothing that does not provide good and desirable fit. Regardless of how one defines fit exactly, it must always start from basic human proportional truths. We are currently ill equipped to do this successfully with many products. This is a significant problem for retailers and manufacturers, alike.

New and improved technologies are now available that allow realistic images of human bodies to be classified into categories that will better reflect the differential proportions of the true American population. Mega-computing power, three-dimensional body scanning, dimensional design programs, and computer-aided-design software are allowing advances in the product development process that will lead to a seamless technology of customized clothing and ready-to-wear garments that can provide fit, as they have been designed to do.

Some attempts have been made to chart the body in two-dimensions but they do not yield a satisfactory illustration of true body shape. There is currently no means of viewing, categorizing, and/or comparing the body three dimensionally. No attempts have been made to study body shapes and sizes using the 3D body scanner.

Research Objectives

The objective of this research was to develop a methodology for characterization of body types/forms that would more appropriately replicate the diverse shapes of the American population. A computer model was developed to compare data from three-dimensional (3D) body scans in order to categorize individuals by those differences in body stance, proportions, and body angles that are significant factors in the fabrication of apparel shapes, that fit the body well.

Specific objectives included:

1. To develop a database of 3D body scan data, from a variety of consumer markets, that includes both measurement data and 3D point cloud data.
2. To demonstrate that the current sizing system is insufficient and to determine where significant deficiencies exist.
3. To utilize software that can take 3D data and "sort" it into congruous and related shape categories (body or shape sort) based on measurements, proportion, and shape.
4. To develop preliminary subgroups for the female population that will aid in the better fit of clothing.

Study Limitations

This study was limited by the following factors:

1. The data was obtained from a convenience sample from the Triangle Area (Raleigh, Cary, Durham) of North Carolina. No attempt was made to randomize the selection of the sample. The only criterion was that the subject be female and over the age of 18.
2. The data was obtained using the technology of 3D body scanning developed at $[TC]^2$ as the method of shape and measurement extraction.

Assumptions

This study was conducted on these basic assumptions:

1. The $(TC)^2$ 3D body scanner, with its measurement extraction software, is accurate in obtaining body measurements plus or minus 1/8".
2. Body scanning in 3D is more accurate than physical measuring methods. It is also more private and more expedient. Therefore, most people would choose to be scanned, in complete privacy, instead of having someone take anthropometric measurements with a tape measure, requiring seeing and touching the human body landmarks.

Definitions of Terms

Three-Dimensional (3D) Body Scanning: The use of a light source (laser, white light or other type) to capture the image of the body in the three dimensions of *x, y*, and *z* (width, height, and depth) ([TC]^2 , 2000).

3D Point Cloud: The raw, individual *x, y*, and *z* coordinates without any smoothing or other post-processing (David Bruner, head of R&D at [TC]^2, personal communication, 1999).

Phase Measurement Profilometry (PMP): A 3D scanning method which employs white light to impel a two-dimensional patterned grating on the surface of the body. The grating is shifted preset distances in the direction of the varying phases and images are captured in each position (for each of the four sensors) ([TC]^2 , 2000).

Measurement Extraction Profile (MEP): The file that designates how each measurement is taken on the body (David Bruner, head of R&D at [TC]^2, personal communication, 1999).

Reduced Body Data (RBD): Data that has been filtered of any stray points, smoothed to remove low level noise in the scan data, closed of any small gaps in the scan data and compressed, on the order of 100:1, to achieve a very "light", yet fully defining data set. In the [TC]^2 system, RBD data includes information about the trunk and limbs of the body, differentiating each by color (David Bruner, head of R&D at [TC]^2, personal communication, 1999).

Extracted Measurement Data: Measurement data that has been derived from the segmented body and limbs (arms, legs, torso) (David Bruner, head of R&D at $[TC]^2$, personal communication, 1999).

American Society of Testing and Materials (ASTM): Now formally known as ASTM International, this not-for-profit organization provides a global forum for the development and publication of voluntary consensus standards for materials, products, systems, and services (ASTM, 2002).

CHAPTER 2: LITERATURE REVIEW

Literature was reviewed in the areas of fit and sizing issues, the history of measurement studies, the history of figure typing and somatotyping, three-dimensional body scanning, software for evaluation of the human body, and information concerning knowledge management and its role in decision making.

Fit and Sizing Issues

The purpose of a sizing system for apparel should be to make available clothing in a range of sizes that fits as many people as possible (Ashdown, 1998; LaBat, 1987). Apparel design and production experts believe that the fit of a garment is one of the most important factors in producing garments that flatter the individual (Minott, 1978). Fit has been defined as:

- ..”A correspondence in three-dimensional form and in placement of detail between the figure and its covering to suit the purpose of the garment, to provide for activity, and to fulfill the intended style” (Berry, 1963, p.314).
- ..”Simply a matter of length and width in each part of the pattern being correct for your figure” (Minott, 1978, p.43).

A significant amount of research has been conducted on the topic of fit of apparel for the general population (AAMA, 1975; Croney, 1977b; Green, 1981; O’Brien and Shelton, 1941; Salusso, Delong, and Martin, 1979). In general, consumers have been dissatisfied with fit for some time. In a 1983 study, consumers did not buy an item because of incorrect fit or a too high cost 80% of the time (Wright & Francis, 1987). Wright and Francis also reported that career women were willing to trade styling options, time, and money for sizing and fit options in their career apparel (1987). In 1996, a Kurt Salmon Associates study for the Textile/Clothing Technology Corporation (TC)^2 revealed that over half of all American consumers were unable to find ready-to-wear garments that fit them properly. DesMarteau (2000) reported that this study found 50% of women and 62% of men cannot find a good fit in apparel.

Some of this dissatisfaction could be associated with the fact that the current sizing system for the manufacturing of garments is based on body measurements that are more than 60 years old (Salusso-Deonier, 1982). Dissatisfaction with fit can also be attributed to several factors that have changed the average body types: diets (Meek, 1994; Tamburrino, 1992a, 1992b), physical exercise and activities (LaBat, 1987; Tambarrino, 1992a, 1992b), increased immigration (Meek, 1994; Tamburrino, 1992a, 1992b), disproportionate growth rates in minority groups (Meek, 1994), sedentary lifestyles (CNN, 2001; LaBat, 1987), and changes in ideals of masculinity and femininity (Meek, 1994).

The United States has been called the “fattest country in the world” (Time, 1999) with 54% of the population overweight. Forty million adult Americans weigh more than 20% above their desirable weight (Blumenkrantz, 2001). Obesity has increased 60% in the last 10 years (CNN, 2001). Yet, in a 1992 study, a reported 65 million people in the United States, about 25% of the population, were dieting at any one time (Evans, 2000). The diet industry, including products and programs, is worth over $40 billion (“The Diet Industry

Takes Hit", 2000; Evans, 2000; Pace Group Exercise, 2000; Time, 1999). An estimated 60% of the domestic population has expressed interest in losing weight and/or keeping it off (Kroll, 1997).

Dieting, whether on a consistent or inconsistent basis, can lead to bad dieting habits. The Healthy Eating Index showed that 88% of Americans have diets that are poor or need improvement (President Clinton, 2000). With over half of the country's population overweight and dieting, figure shapes are constantly changing. Extra body weight and constant fluctuation in body shape because of dieting have made the figure types of the current standard, a variation of a 1941 study, not applicable to the figure types of today.

Physical fitness is another area that is changing the current figure types. The fitness industry, including health clubs, exercise videos, and clothing, is worth about $43 billion (Evans, 2000). But, there seems to be a definite divide on this issue. Even though the fitness industry seems to be booming, the predominance of a sedentary lifestyle is also rising. More than 60% of adults do not engage in the recommended amount of physical activity (President Clinton, 2000) and about 25% of all adults, along with 14% of today's youth, get no physical activity at all (Johnson, 2001; President Clinton, 2000).

The United States population distribution has gone through dramatic physiological and demographic transformations since the 1940s when the O'Brien and Sheldon study (which our current sizing system is based on) was undertaken. During this century, the human population has swelled in sheer magnitude that is unmatched to any previous period in human history. During the 1998-2025 time period, it is predicted that the world's elderly population (over 65 years) will more than double while the world's youth (under age 15) will grow by 6% (McDevitt, 1999).

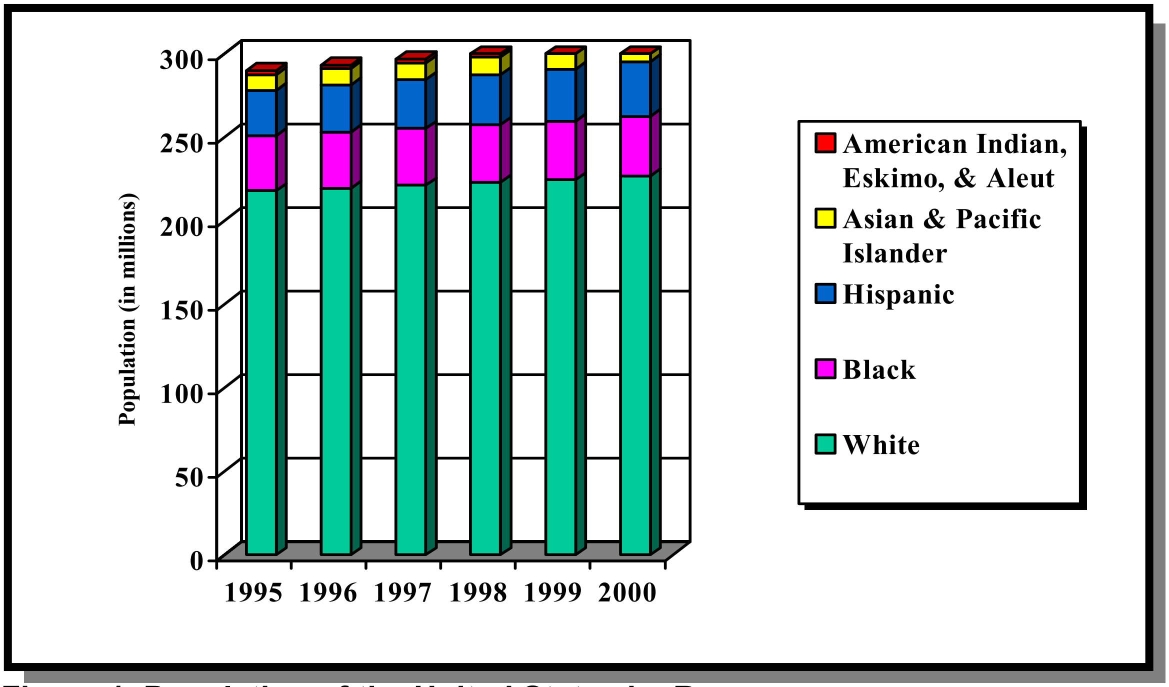
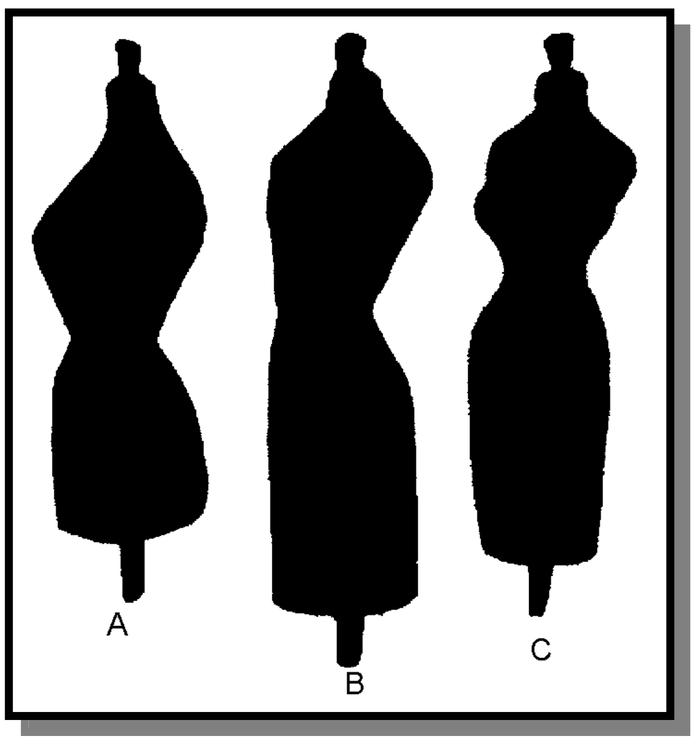


Figure 1. Population of the United States by Race. **(U.S. Census Bureau, 2001).**

For many years, the United States population has been a mixture of ethnic origins, as seen in Figure 1. But over time, the configuration of this mixture has changed. Minority groups have become larger and new groups of immigrants have been added to the mixture (LePechoux, 1998). With consumer trends and products becoming universal, free trade is opening an increasing number of foreign markets to U.S. commerce. Worldwide interaction and travel are heading toward increased interracial mixes. These progressions have had direct impact on body measurements of the international consumer. Many studies have researched the idea that body proportions differ according to their racial origin (Abesekera & Shahnavaz, 1989; Al-Haboubi, 1992; Hertzberg, 1972; Hutchingson, 1981; Miller, 1993; NASA, 1978). The racial mixture in the United States is also different from that in the 1940s, which is the time frame that our current body measurement standard is based on. An illustration of how basic body shapes have changed can be seen in Figure 2. Dress form A is one at the turn of the century. Form B is one that was used in the 1920s flapper period. Dress form C denotes a shape change with the 1950s Dior "new look" (Palmer & Alto, 1998).



<u>Figure 2</u>. Dress forms illustrating changes in body shape from 1900 to 1950s. **(Palmer & Alto, 1998, pg. 17).**

Fit of apparel is a significant problem for retailers, manufacturers, and consumers. The ability to fill the needs of niche markets with high quality, well fitting apparel is the key to the survival of the apparel industry within its current competitive tone. In a 1925 article on the standards in clothing manufacturing, size standardization was being reasoned for the outcome of "better-looking, neater-fitting clothes and elimination of alterations" (Saum, 1925, p.59). This was 15 years before the O'Brien and Shelton study from which clothing sizing standards have been issued. These topics are some of the very complaints that are being heard today.

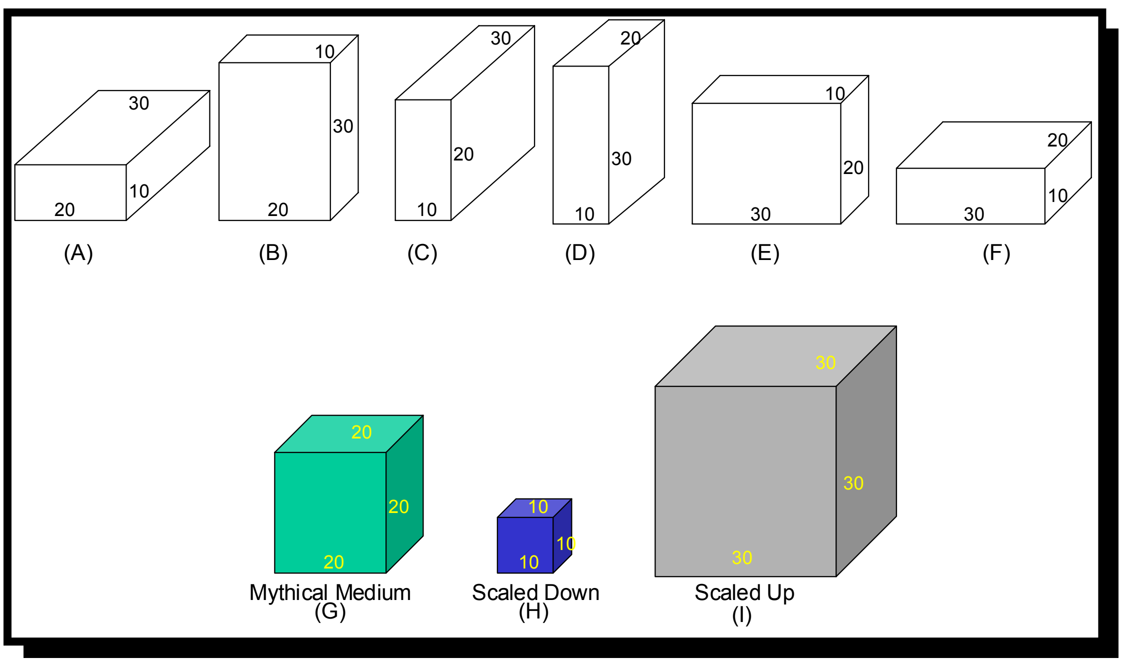
There is a growing need for an updated anthropometric sizing system for women (Delk & Cassill, 1989; LaBat, 1987). It has been recommended that body measurement charts be revised at least every 10 years (Brunn, 1983). Chun-Yoon and Jasper (1995) recommended an anthropometric size description system as a solution to the problems of high return rates caused by consumers purchasing the incorrect size and damaged goods caused by frequent trying-on of garments. Cyclic changes in diet, activity, lifestyle, and immigration influence the size and shape of American consumers of clothing which makes updating sizing systems essential.

The ideal figure of the 1940s was the hourglass shape and, therefore, all women's size specifications were developed to fit that hourglass shape. In a recent study by Gray (1998), the shape of women has changed from hourglass to pear. So our sizing standards must reflect that change.

Yet another issue about fit is the concept of vanity sizing. In a recent study, Workman (2000) pointed out that manufacturers have redefined their fit models. The standards measurements for a size 10 fit model in 1986 are now the standards for a size 8 fit model. The shape is, however, still the hourglass shape. Each manufacturer defines fit for their own specific target market and all manufacturers differ. Fellingham (1991) described that a size 8 fit model weighing 115 pounds and being 5'8" tall has the body measurements of 36-24-34 (bust circumference, waist circumference, hip circumference respectively). The fit model tried on six different size 8 sheath dresses with a remarkable difference in fit among them all, showing that there is a lack of consistency in defining even one size of clothing. Most clothing manufacturers are reluctant to conform to a unified standard set of body measurements (Belkin, 1986). Having a sizing system that is a little different than others is thought to be a competitive advantage. All in all, research clearly indicates that a problem with standardization of sizes exists.

Manufacturers have created their sizing systems around a size Medium, the "perfect size 8", or a specified size model. All of these terms represent an average value for a set of dimensions relevant to a specific garment. The size Medium is then scaled up or down to create a whole range of sizes. But, the shapes of people usually do not calculate to be scale models of each other.

Daniels (1952) graphically illustrated that no one is average in all body dimensions with the use of three- dimensional blocks. But, remember that these blocks have only three variables to its dimensionality, height, length, and width. Human bodies have many curves and are much more complicated. These blocks are not based on true three-dimensional shape. Figure 3 represents a three-size system where a size Medium is based on average values. Block G is the Medium, Block H is scaled down to a Small, and Block I is scaled up to a Large. Blocks A through F represent the different shapes of people. A cover made for Block G would not be large enough in one dimension to fit any of Blocks A through F. In scaled up Block I (Large), a cover would fit Blocks A through F but would be too large in 2 of the 3 dimensions.



<u>Figure 3</u>. Representation of a Sizing System Based on Average Values. **(Daniels, 1952).**

Figure 4 represents a size Medium being based on the dimensions of a selected person that typifies some predetermined criteria for a manufacturer. In this size model method of sizing, Block G (Medium) would only fit a block like Block G. Block H (scaled down Small) would not fit any of the Blocks A through F. The scaled up Large (Block I) will fit Blocks B, D, E, and F but with a 30 unit gap in one place or another.

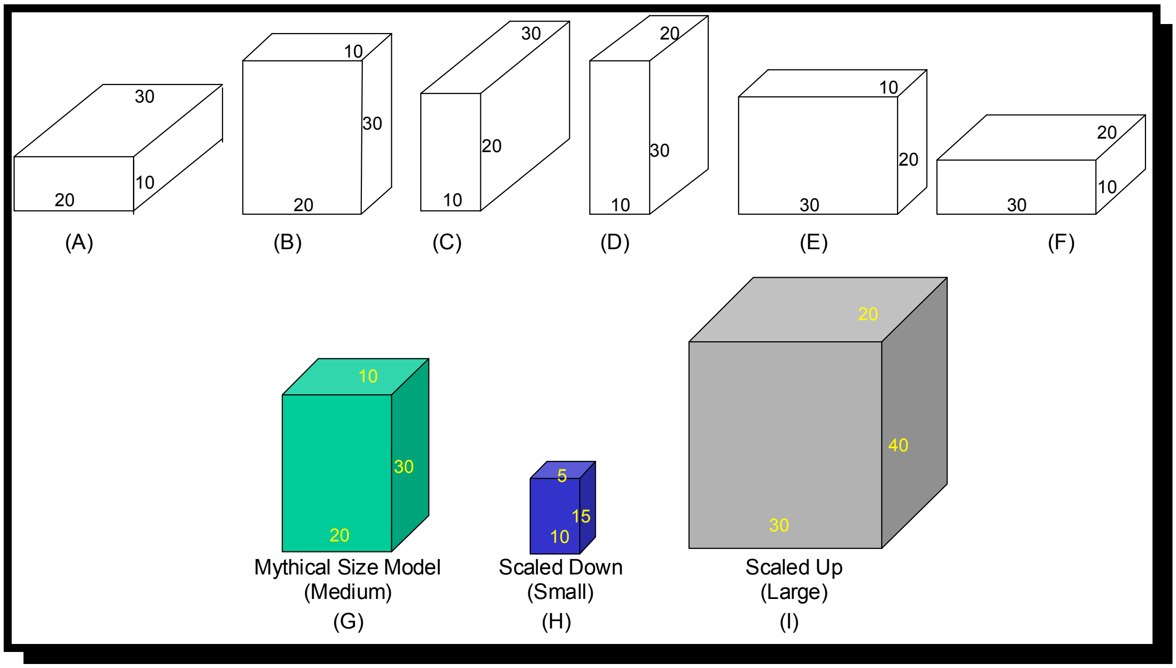
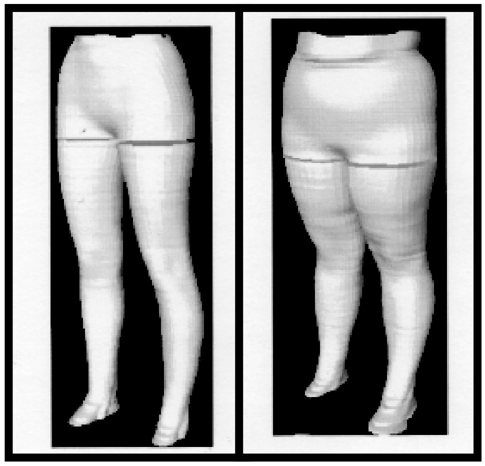


Figure 4. Representation of a Sizing System Based on "Developed" or Proportionate Measures.(Daniels, 1952).

Another illustration of fit is within the pantyhose industry. The National Association of Hosiery Manufacturers (NAHM) published a set of recommended sizing standards in the 1960s which are still being used today (NAHM, 1991). Pantyhose size is determined on a height/weight based grid. Height is charted in increments of 1 inch and weight in increments of 5 pounds. The number and ranges of sizes are decided by the manufacturers using judgement based on their own experience (NAHM, 1970). The NAHM developed regression equations which are functions of height and weight values from which other dimensions can be estimated. Their recommendations include deriving the dimensions that pantyhose are required to fit from this set of regression equations. The surface areas for each height and weight combination have been calculated and used to identify size groupings on a chart.

There are limitations to this sizing system. First, the sizing standards are based on outdated body measurements of women. Second, the regression equations are univariate. Regression equations for height are only related to stature while those for girths are only related to weight. Third, one single set of regression equations many not work for all sizes An example is leg surface areas. These regions which are calculated according to these regression equations do not reflect the within size variations of dimensions and proportions (LePechoux, 1998). Figure 5 shows how two women with very different shapes now fit into the same pantyhose size. Woman A, on the left, is 5'6" and weighs 128 pounds. Woman B, on the right, is 5'2" and weighs 170 pounds.



A B

<u>Figure 5.</u> Two Women of Different Shapes Wearing the Same Size Pantyhose.(Early, 1998).

History of Measurement Studies in United States

Early sizing systems for women were developed in the late nineteenth century by professional dressmakers, tailors, and draftsmen (Ashdown, 2000; Kidwell, 1979; Labat, 1987). They had very individualized techniques of measuring and fitting their clients.

Limited styles and sizes of ready-to-wear were prevalent in the early 1900s. The loose fitting styles of the 1920s generated elevated consumer demand for the mass production of ready-to-wear (Salusso-Deonier, 1982). This, in turn, spawned a need for standard sizes among different manufacturers (Nystrom, 1928). Nystrom (1928) found that a blouse size 36 had a large amount of variation of measurements among different brands. He also recognized that consumers were dissatisfied with ill-fitting garments and retailers were dissatisfied with the expense involved in the alteration department and with garment return. However, the fashion of the 1930s brought about tighter-fitting clothing that augmented confusion of sizing systems and labeling practices. This caused an enormous amount of variation between the individual manufacturers. At the time, mail-order houses were very popular and were becoming very aware of this problem. They were having a large number of returns because of ill-fit (O'Brien & Shelton, 1941).

The U.S. Department of Agriculture Study by O'Brien and Shelton

Prompted by numerous product returns, the Mail Order Association of America (MOAA) furnished the impetus for a sizing survey which was viewed as providing a solution to inconsistent sizing. The U.S. Department of Agriculture sponsored an anthropometric survey that was to become the basis for the development of several sizing systems for women's apparel. Designed and implemented by Bureau of Home economics specialists O'Brien and Shelton, the survey was conducted by the collaboration of Federal and state work project administrators and various educational institutions. No scientific study of the measurements of the human body used to construct women's clothing had ever been reported (O'Brien, 1930). The 1939-40 survey consisted of 59 measurements taken on 10,042 women. Although the sample was large, it was biased by being unrepresentative of the female population. The women were all white, between the ages of 18 and 30, from only 8 states, and all volunteers (O'Brien & Shelton, 1941). As White (1978) suggested, women who were not happy with their body shape were unlikely to volunteer for a process that required being undressed and seen by others for measurement.

The study's primary objective was to provide data from which the garment and pattern industry could develop a sizing system acceptable to consumers (O'Brien & Shelton, 1941). Several sizing systems were suggested that were all based on the proportionate sizing theory. Proportionate sizing assumes that human body forms develop in accordance with common proportional rules. One control dimension is therefore believed to be adequate to project all body dimensions needed in sizing apparel. An example of a control dimension would be the height or weight of an individual. The entire size range was created from the extension of one size by incrementing control dimensions and projecting proportionate increments for the other dimensions.

O'Brien and Shelton found in their study that the best foundation for classifying women's body types for the organization of a standard system of garment and pattern sizes was a stature-weight combination (1941). However, the study also pointed out that if a girth or weight measurement were used as a control, virtually no variation in heights would be allowed. The short women and the tall women would have inadequate fit for their garments (O'Brien & Shelton, 1941).

Alternative systems where weight could not be used as a control measurement were also suggested: 1) Stature and Bust Girth, 2) Stature and Waist Girth, 3) Stature and Abdominal Extension Girth, and 4) Stature and Hip Girth. A disadvantage warned by the researchers of these alternate systems was a lack of balance. Of the four girth measurements, the measurement used as a foundation for the sizing increases too rapidly in relation to the increases in other measurements. O'Brien and Shelton (1941) suggested that if one of the girth measurements must be used, then a third dimension should be added to the sizing system. This could be accomplished by the addition of the "Stouts" and "Slims" categories to the other length categories of "Regulars", "Longs", and "Shorts".

Results of the data collection were to operate as the basic background for inventing a sizing standard. It was published by the U.S. Department of Agriculture as a miscellaneous publication entitled Women's Measurements for Garment and Pattern Construction (O'Brien & Shelton, 1941).

The Organization of CS215-58

It wasn't until the 1950s, after further analysis of the 1939-40 data and another request from the MOAA for a sizing standard, that a standard was proposed. A public review in the fall 1954 mail order catalogs lead to industry and consumer endorsement in 1958. This voluntary standard was published by the National Bureau of Standards (NBS) as CS215-58 titled Body Measurements for the Sizing of Women's Patterns and Apparel (U.S. Department of Commerce, 1958). As a voluntary product standard, the CS215-58 could be acknowledged, discarded, or revised in part or in total by each individual apparel manufacturer.

The CS215-58 identified four classifications of women and covered nine different body types. The four classifications of women included "Misses'", "Women's", Half-Sizes", and "Juniors'". Three height groups were recognized as

“Tall”, “Regular”, and “Short”. Three hip types were recognized as “Slender, “Average”, and “Full”. The bust was the same for all of the groups. This yielded a three-way system of the size number (based on the bust measurement), the height group, and the body type (based on the bust-hip relationship) (US Department of Commerce, 1958). An example of the system would be 14S+. This designation would mean a size 14 bust, short in height, and a full hip type. A complete listing of the size ranges for each of the four classifications is covered in Table 1. The revision of CS215-58 was published in 1970 as PS42-70, Body Measurements for the Sizing of Women’s Patterns and Apparel (U.S. Department of Commerce, 1970).

Problems did exist with the CS215-58 standard that were credited to the 25 year old data which represented obsolete and outdated body proportions (Salusso-Deonier, 1982). At the persistence of the MOAA, the NSB brought about procedures for revising CS215-58.

<u>**The Organization of PS42-70**</u>

The only available data at the time were health surveys made in 1960-62 by the United States Public Health Service (Stout, Damon, McFarland, & Roberts, 1965). The studies followed a census plan and were thus representative of the population. Measurement included height, weight, several girths and diameters that were satisfactory to suggest general size but not to the shape differences (White, 1978; Stout et al, 1965). Because the 1939-40 study was the only resource of all-embracing measurements for the female

Table 1. Size Ranges for the CS215-58 Standard. (US Dept. Commerce, 1958).

Misses Regular Height (R)		Misses Tall Height (T)		Misses Short Height (S)	
Hip Type	Sizes	Hip Type	Sizes	Hip Type	Sizes
Average	8 to 22	Average	10 to 20	Average	8 to 18
Slender(-)	10 to 22	Slender (-)	12 to 18	Slender (-)	12 to 18
Full (+)	8 to 16	Full (+)	10 to 14	Full (+)	8 to 12

Women's Regular Height (R)		Women's Tall Height (T)		Half-Sizes Short Height (S)	
Hip Type	Sizes	Hip Type	Sizes	Hip Type	Sizes
Average	30 to 42	Average	32 to 40	Average	10 ½ to 24 ½
Slender (-)	32 to 42	Slender (-)	N/A	Slender (-)	12 ½ to 22 ½
Full (+)	28 to 38	Full (+)	30 to 36	Full (+)	8 ½ to 20 ½

Junior Regular Height (R)		Junior Tall Height (T)		Junior Short Height (S)	
Hip Type	Sizes	Hip Type	Sizes	Hip Type	Sizes
Average	7 to 19	Average	9 to 17	Average	9 to 15

adult population, it was again used as a base for the revision process (Salusso-Deonier, 1982). The revision of CS215-58 was published in 1970 as PS42-70, Body Measurements for the Sizing of Women's Patterns and Apparel (U.S. Department of Commerce, 1970).

The health surveys of 1960-62 determined that adults were somewhat taller and heavier than those of 1940 (Stout et al, 1965). This prompted a change in the size designations for females particularly in the PS42-70. Because the bust girth was a crucial measurement in the old and the new data, the bust girth was increased by one grade interval per size code for all figure types. The Misses and Junior figure types were also changed so that the hip girth was a constant 2" interval where the old hip girth of the CS215-58 was increased proportionately to bust girth as the size designation increased (Labat, 1987). The "Slim" and "Full" hip options within all figure types were eliminated, as well as the "Tall" option in the Juniors' and Women's figure types. Size ranges for each of the classifications also changed. See Table 2 for a complete listing of size ranges.

Table 2. Size Ranges in PS42-70. (U.S. Dept. of Commerce, 1970).

Juniors'	Juniors' Petite	
Sizes: 3 to 17	Sizes: 3P to 15P	
Misses'	**Misses' Petite**	**Misses' Tall**
Sizes: 6 to 22	Sizes 8P to 18P	Sizes: 10T to 22T
Women's	**Half-Sizes**	
Sizes: 34 to 52	Sizes: 12 ½ to 26 ½	

Within the CS215-58 standard, the Juniors' proportions were smaller than Misses' by ½ inch at the Bust, 1 inch at the Waist and Hip Girths, and 1/8 inch in the Back Length. Within the PS42-70 standard, for the same Bust size code, the Misses' and Juniors' categories continue alike except Juniors' were assigned an even shorter Back Length. Sizes incorporated would span a bust range of 31½ to 44 inches. Changes in the dimensions of Women's sizing from the CS215-58 to the PS42-70 were restricted to increasing Bust, Waist, and Hip Girths by 1 inch and Back Length by 1/8 inch. Half-size girths were changed as in Women's but Back Length remained the same (Salusso-Deonier, 1982).

Current Standards for Female Clothing

Junior Category

For the Junior size category, there is no current standard. The most recent body measurement tables are found in the PS42-70.

Misses' Category

Since 1970, no new research has been completed for the Misses' size category that would update this body measurement information. The current standard in the United States which lists body measurements of the adult female figure type, sizes 2 through 20, is the American Society of Testing and Materials (ASTM) standard # D5585-95. The Standard Table of Body Measurements for Adult Female Misses Figure Type, Sizes 2-20 (1995a) publication was derived originally from the PS42-70 database which was developed from the anthropometric research conducted in 1941 by O'Brien and Shelton.

Women's Category

Current research was conducted at the University of Arizona in 1993 by Reich and Goldsberry that represented body measurements of adult women ages 55 and older. The ASTM publication # D5586-95 is entitled Standard Tables of Body Measurements for Women Aged 55 and Older (All Figure Types) (1995b). This research resulted from the inappropriate representation of the fit concerns for women over 55.

Morris and Bader (1983) documented that aging was accompanied by physical changes that took place gradually, at differing times and in varying degrees. These physical changes included a decrease in stature due to changes in the spine (Croney, 1977; Curtain, 1972; Kohn, 1978; Mezey, Rauchhorst, & Stokes, 1980; Woodson & Horridge, 1990), thinning of weight bearing cartilage (Woodson & Horridge, 1990), careless posture habits (Woodson & Horridge, 1990), increased in waistline and hips (Croney, 1977; Curtain, 1972; Kohn, 1978; Mezey et al., 1980; Woodson & Horridge, 1990), and increases in weight (Croney, 1977; Curtain, 1972; Kohn, 1978; Mezey et al., 1980; Woodson & Horridge, 1990).

Norwood (1944) was the first to study the clothing problems that were characteristic to elderly women. Only a few studies have been conducted that concern the fit problems for these women (Brunn, 1983; Patterson & Warden, 1984; Woodson & Horridge, 1990). The most often reported problem of older women was the unacceptable fit of garments (Bader, 1960; Bartley & Warden, 1962; Ebeling, 1960; Hargeth, 1963).

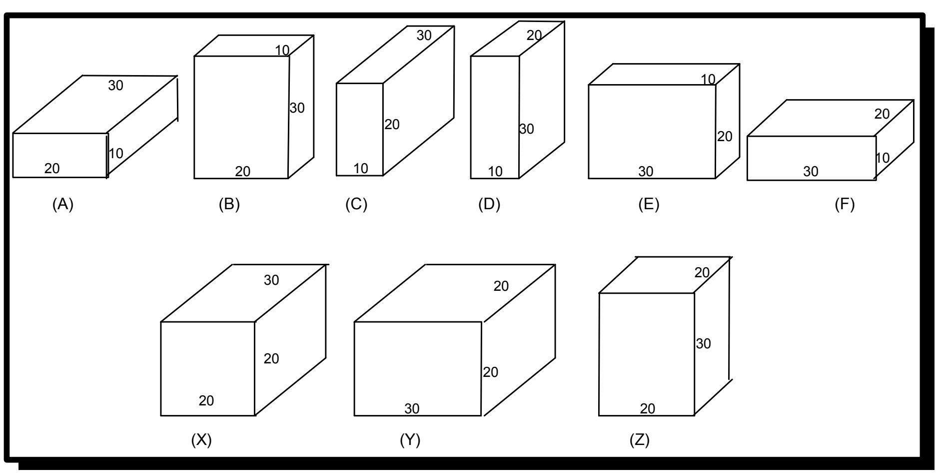
Suggested New Sizing Systems

Several studies have attempted to create new sizing systems or to suggest improvements to the current system but none have yet to be adopted by the United States government as a standard. Gazzuolo (1985) developed a theoretical framework for describing body form variation which could be useful in creating a sizing system. Her research determined that a system based on averages was inadequate. She proposed to limit the variance by sorting the sample by special user groups or by sorting the sample by a major pattern-shape variable. Visual analysis would be a crucial element in developing a standard along with dimensional data.

Salusso-Deonier (1982) proposed a "Principal Component Sizing System" (PCSS) with principal components of laterality and linearity. From an analysis of body measurements of 1330 women, she concluded that a majority of the sample could not achieve appropriate fit with the PS42-70 standard. She found that her PCSS provided "good fit" for 90% of each sub-sample tested.

McCulloch, Ashdown and Paal (1998) proposed an optimization approach to apparel sizing. Efficient sizing systems were defined based on a mathematical model of garment fit. Nonlinear optimization techniques were then used to derive a set of possible sizing systems using multidimensional information from anthropometric data. The proposed methodology enabled the development of sizing systems that could either increase accommodation of the population, reduce the number of sizes in the system, or improve the overall fit in accommodated individuals.

Robinette (1986) derived an anthropometric sizing system that was based on regression estimates from the largest stature and weight values of a sample. The values selected for a given size represented only the people in that size category and were not scaled up or down from other sizes. The key dimension (height and weight) values were the largest for each category. The value of the third dimension was the top of the range. To illustrate this system, the three-dimension block example, mentioned previously, was used as in Figure 6. Size X would fit Block A and Block C, Size Y would Fit Block E and Block F, and Size Z would fit Block B and Block D. There would be a 10 unit gap occurring in some blocks. This system would have the same number of sizes, all of the blocks would be covered, and would be covered with less error than the scaled Medium or the scaled size models.



<u>Figure 6.</u> Illustration of Robinette's anthropometric sizing system. (**Robinette, 1986**).

History of Figure Typing/Somatotyping

<u>Early Physique Classifications</u>

In the pre-Christian era, the Greeks dominated the scientific and philosophical studies of the time. As early as 400 BC, the founder of modern medicine, Hippocrates, had proposed that certain physical types were susceptible to certain diseases (Wells, 1983). He described people with long, thin bodies as *habitus phthisicus* and noticed that they were susceptible to tuberculosis. Individuals with short, thick bodies were called *habitus apoplecticus* (Hippocrates,1886) . These people were said to be susceptible to vascular disease and apoplexy (Carter & Heath, 1990). In the fourth century BC, Aristotle attempted to additionally elaborate and develop Hippocrates' ideas (Tsang, Chan, & Taylor, 2000). However, there would be many more years until further studies were conducted on the differing types of human body forms.

Around the 17th century, anthropometry started to be used in combination with morphology. At the University of Padua, Elsholtz documented a method for taking body measurements. It would be two hundred years later before Quetlet would be a pioneer in studying the measurements of man statistically (Carter & Heath, 1990).

The physicians of the late 18th and early 19th centuries continued to produce physique classifications following the blueprint of Hippocrates. Halle in 1797, with Rostan following in 1828, portrayed three types of physical structures as *type digestif, type musculaire*, and *type cerebrale* (Carter & Heath, 1990;

Sheldon, Stevens, & Tucker, 1940). In about 1880, another important contribution to the study of human body classification was by Huter. He divided people into three types: *cerebral* (prevailing with ectodermic[1] composition), *musculen* (prevailing with mesodermic[2] composition), and digestive (prevailing with endodermic[3] composition). At the end of the 19th century, di Giovanni conducted an extensive series of anthropometric studies at the University of Padua. One of his students, Viola, distinguished three physical types. Large, heavy bodies with short limbs were named *macroplanchnic* while those with small trunks and long limbs were named *microsplanchnic*. An intermediate typology was named *normosplanchnic*. As Viola himself points out, this *microsplanchnic* is the old *phthisic habitus*, the *macrosplanchnic* is the *apoplectic*, and the *normosplanchnic* is merely an intermediate variation (Viola, 1909). These findings corresponded closely with those of Hippocrates (Carter & Heath, 1990).

The 20th century had the most significant contributions of any time period before that concerning the figure typing and classifications of the human body. A German psychiatrist, Ernst Kretschmer (1926), began important scientific studies

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[1] Ectodermic means the outermost of the three primary germ layers of an embryo (Webster's, 1987).
[2] Mesodermic means the middle of the three primary germ layers of an embryo that is the source of bone, muscle, connective tissue, inner layer of the skin, and other adult structures (Webster's, 1987).
[3] Endodermic means the innermost of the germ layers of an embryo that is the source of the epithelium of the digestive tract and its derivatives (Webster's, 1987).

in the early 1920s. His findings grouped the human body-build in four categories very similar to those of di Giovanni: *pyknic* (extreme instinctive development and extra fat), *asthenic* (thin, narrow, and light skeletal construction), *athletic*[4], and *dysplastic* (a mixture of types). His bodily characteristics were, like those of most early physicians, associated with particular disease susceptibilities. The *pyknic* body type was linked with manic-depressives and the *asthenic* body type was linked with schizophrenics.

Although Kretschmer was an experienced researcher, weaknesses were evident in this methodology. His body type categories were somewhat extreme which could only be appropriate for a minority of individuals. Also, aging was a contributing factor to the slenderness or stoutness associated with his body types that was overlooked. Schizophrenia occurred mostly in young people that tend to be slender. Manic-depressives usually start their symptoms in the middle ages when the metabolism in the body slows and fat deposits form (Wells, 1983).

Twentieth Century Contributions to Figure Typing

William Sheldon

The most significant contribution to the existence of body type classifications began in the 1930s by American psychologist William Sheldon. He was a university professor and focused his research on the variety of human

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[4] In the later book editions, Kretschmer discarded the athletic type and relied upon a dicotomy of two types: pyknic and leptosomic (Sheldon, Stevens, & Tucker, 1970).

bodies and temperaments. In 1940, Sheldon, with Stevens and Tucker, introduced the concept of "somatotype" in their book The Varieties of Human Physique. "The patterning of the morphological components as expressed by three numerals is called the somatotype" of the individual (Sheldon, Stevens, & Tucker, 1940, p. 7). Sheldon remarked that the purpose was "to provide a three-dimensional system for description of human physique" (Sheldon & Stevens, 1942, p.11). Table 3 lists the various classifications of body types by the many sources mentioned in this study.

Table 3. Classifications of Body Types

Source	Large frame & fat	Athletic	Mixture of athletic and small frame	Small frame & thin
Hippocrates	Habitus apoplecticus			Habitus phthisicus
Halle	Abdominal	Muscular	Thoracic	Nervous, cephalic
Rostan	Digestive	Muscular	Respiratory	Cerebral
Di Giovanni	Third combination	Second combination (Plethoric)		First combination (Phthisic)
Huter	Digestive	Musculen		Cerebral
Viola	Macro-splanchnic	Normo-splanchnic		Micro-splanchnic
Kretschmer	Pyknic	Athletic		Leptosomic
Sheldon	Endomorph	Mesomorph		Ectomorph

The original Sheldon study consisted of a sample of 4,000 undergraduate male students aged 16-20. Equipment included a 35mm camera, controlled lighting, a pedestal, and a grided screen. Three photographic poses of the frontal, dorsal, and profile views were taken of each nude subject posed in a standard manner. Even though photographs were taken, negatives measuring 5”x7” were used for determining the measurements of the subjects’ bodies. The researchers concluded that there were three primary components which when combined together, make up all physiques or somatotypes. The categories of body types were very similar to those of Kretschmer. However, Sheldon believed that there were not just three clear-cut body types but mixtures of each of those. He remarked that “Kretschmer’s attempt to handle human morphology with three types is comparable to trying to build a language with three adjectives” (Sheldon et al, 1940, p. 25).

Sheldon and his colleagues had worked out a system to measure these components and express them numerically (“Inner Explorations”, 1999). These components were called endomorphy, mesomorphy, and ectomorphy. A thorough listing of characteristics of each component can be found in Table 4. Briefly, the descriptions of each component are:

- Endomorph – characterized by being round and usually soft, having somewhat little muscular development, and a light skeletal frame.
- Mesomorph – characterized by massive skeletal development, heavy bones, broad chest, and resilient muscles.
- Ectomorph – characterized by frail skeletal frame, lightly boned, delicately muscled, and with a narrow chest (Wells, 1983).

Table 4. A Listing of Component Characteristics

	Endomorph	Mesomorph	Ectomorph
Body	**Round & soft. Mass concentrated in abdominal area. Smooth contours without projecting bones. High waist.**	**Square & hard. Chest area dominates over abdominal area. Narrow & low waist.**	**Ribs are prominent. Shoulders droop.**
Arms & Legs	**Short & tapering.**	**Well-developed.**	**Long & weak.**
Hands & Feet	**Comparatively small.**	**Heavy & massive.**	**Small & nonprominent joints.**
Skin	**Soft & smooth.**	**Thick & coarse.**	**Dry & thin.**
Head	**Large in size. Tendency for premature balding. Spherical in shape.**	**Prominent bones & muscles. Cubical in shape.**	**Long & slender neck. Small in size. Small features.**
Face	**Broad. Features of roundness.**	**Square & heavy jaw. Clearly defined cheek bones. Long & broad in shape.**	**Sharp & fragile features. Triangular in shape. Receeding jawline.**
Skeletal Frame	**Light.**	**Massive.**	**Frail.**
Muscular Development	**Relatively little.**	**Well-defined.**	**Slight.**

Each component was rated on a scale of 1-7 where 1 referred to the minimum and 7 referred to a maximum. Components are always listed in the sequence of endomorph, mesomorph, and ectomorph. An example would be a 1-4-7 individual who has almost no endomorphic development, an average degree of mesomorphy, and an extreme amount of ectomorphic maturity. These somatotypical ratings were then charted on a two-dimensional diagram to graphical represent the rating. An example is shown in Figure 7. Figure 8, Figure 9, and Figure 10 how a graphical depiction of a true ectomorph with a 1-1-7 somatotype, a true mesomorph with a 4-4-4 somatotype, and a true endomorph with a 7-1-1 somatotype, respectively.

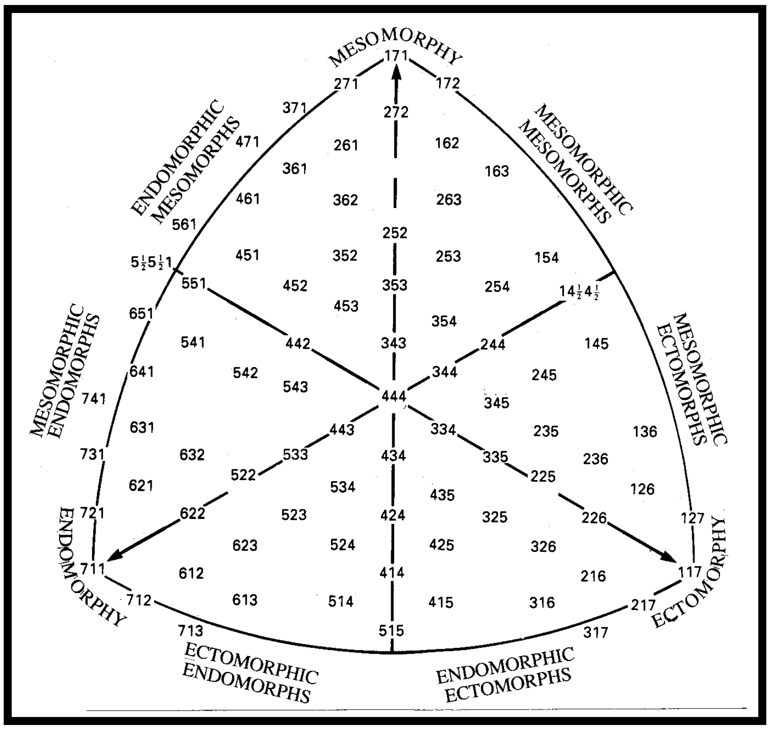


Figure 7. Graphical representation of a somatochart. **(Sheldon, W.H. 1949, p.16)**

The study began by dividing the body into five regions: (1)head, face, and neck, (2) chest area, (3) arms, shoulders, and hands, (4) abdominal trunk, and (5) legs and feet. A framework was established for the scaling of the three components. Fifteen values of ascending series would be made with the value of one component in one body region. The value of the component (endomorphy, mesomorphy, and ectomorphy) was based simply on picture-to-picture comparison in evaluation of the component checklist of characteristics (Sheldon et al, 1940). No anthropometric or other measuring devices were used to determine the value of these components.

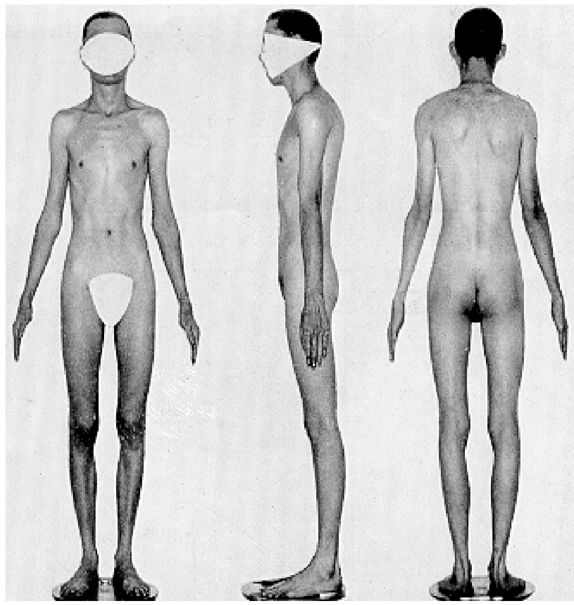


Figure 8. Photograph of a subject with a 1-1-7 somatotype.(Sheldon, 1954, pg. 39)

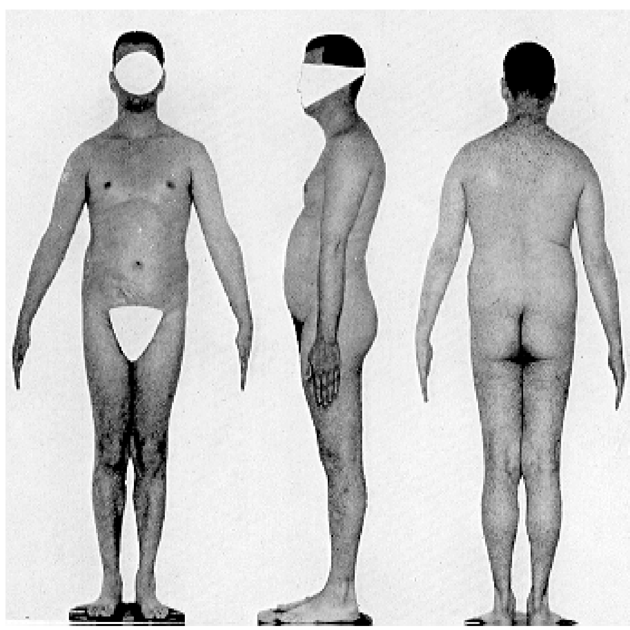


Figure 9. Photograph of a subject with a 4-4-4 somatotype.(Sheldon, 1954, pg. 223)

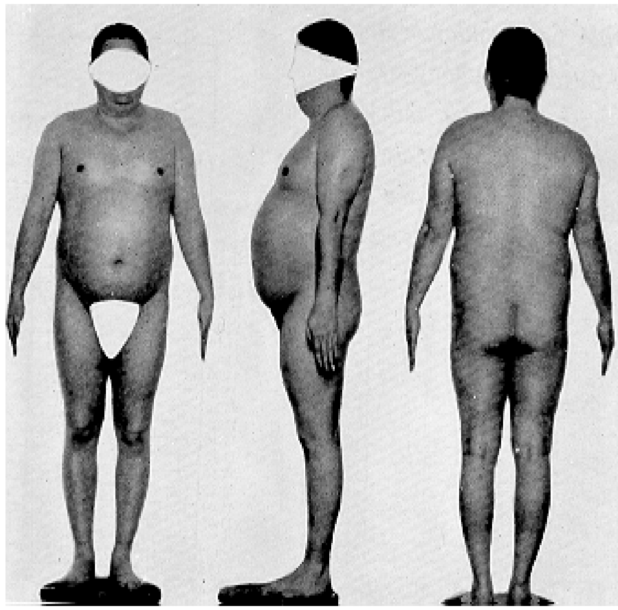


Figure 10. Photograph of a subject with a 7-1-1 somatotype.(Sheldon, 1954, pg. 325)

Weight and height were taken on all of the subjects whose photograph was taken. In determining a technique for accurately measuring these subjects from photographs, Sheldon described the method as:

> In 1926, we had found that by carefully standardizing a photographic technique it is possible to take anthropometric measurements of diameters which agree not only with the same measurements taken on the living, but also with one another when successive photographs are taken of the same series of subjects. In the experimental phases of the standardization of the photographic method, it was found that diameter measurements of the head, trunk, arms, and legs taken with needle-point dividers from sharp negatives are more reliable than are similar measurements taken on the living. Indeed, it appears that there is no precisely accurate anthropometric technique for measuring soft parts of the body, except a photographic one. We found that by using an ordinary light box, with a ground-glass window against which to place the negative, together with a device for holding the negative in position, it was possible to measure diameters with adequate precision. The measurements can be read off directly under a magnifying glass against a special steel rule graduated to tenths of a millimeter (Sheldon et al, 1940, p.50, 51).

The researchers could read 120 measurements per hour with less than 1 percent disagreement of the measurements. Sheldon remarked this was only true in diameters of specific and clearly noticeable landmarks. He also claimed that this accuracy could be achieved "after a few hours of practice" (1940, p. 51). Yet, in another instance, Sheldon claimed that the accuracy "depended on the training and experience of the investigator which had a minimum requirement of a medical course in anatomy and years of training in physical anthropometry" (1940, p.100).

All of the measurements were expressed as simple ratios to stature. The seventeen measures used are listed in Table 5 and can be seen in Figure 11. These measurements were selected by trial and error. They were originally included in the study because of their photographic availability and reliability. They were kept in the study because they produced fairly sharp and constant differentiation among the physiques (Sheldon et al, 1940).

Sheldon summarized his photoscopic somatotype method as follows:

1. Calculation of height/$\sqrt{}^{3}$weight ratio (HWR).
2. Calculation of ratios of 17 traverse measurements (taken from photographic negatives) to stature.
3. Inspection of the somatotype photograph, referring to a table of known somatotypes distributed against the criterion of HWR, comparing the photograph with a file of correctly somatotyped photographs, and recording the estimated somatotype.

4. Comparison of the 17 traverse measurement ratios with a range of scores for each ratio, to give a final score (Carter & Heath, 1990, pg. 32).

Table 5. 17 Measurements Used in Sheldon's Study. **(Sheldon et al,1940, p. 54-57).**

Region 1	Region 2	Region 3	Region 4	Region 5
FB_1 Facial-Breadth-One	TB_1 Trunk-Breadth-One	ATU Arm-Thickness-Upper	TT_2 Trunk-Thickness-Two	LTU_1 Leg-Thickness-Upper-One
FB_2 Facial-Breadth-Two	TT_1 Trunk-Thickness-One	ATL_1 Arm-Thickness-Lower-One	TB_3 Trunk-Breadth-Three	LTU_2 Leg-Thickness-Upper-Two
Ntap Neck-Thickness-Anteroposterior	TB_2 Trunk-Breadth-Two	ATL_2 Arm-Thickness-Lower-Two	TT_3 Trunk-Thickness-Three	LTL_1 Leg-Thickness-Lower-One
NTt Neck-Thickness-Transverse				LTL_2 Leg-Thickness-Lower-Two

Sheldon believed that a person's somatotype never changed as they grew older. They would only vary in relative thinness or fatness around the same somatotypical rating (Sheldon et al, 1940). He was also very confident of the reliability of his inspectional judgement in the somatotyping of the photographs. These ideas brought about criticism toward Sheldon. Carter and Heath (1990) maintained that "the procedure (of somatotyping) was laborious and obviously not feasible for general use" (p. 31). Tanner (1964) said "this system does not work, and has never, in fact, been used" (p. 37).

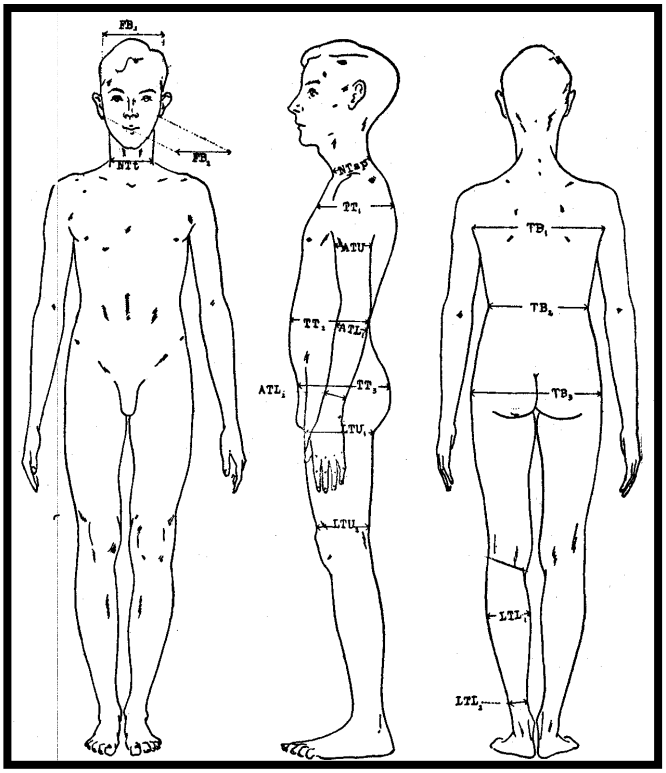


Figure 11. Locations of the 17 measurements in Sheldon's study. **(Sheldon et al, 1940, p. 55).**

Carter and Heath (1990) distinguish four persistent criticisms about Sheldon's method of somatotyping: (1) the somatotype changes, (2) somatotyping is not objective, (3) there are two, not three, primary components, for endomorphy and ectomorphy are essentially the inverse of each other, and (4) somatotyping omits the factor of size. "It appears that Sheldon responded to continued criticism of this method with a quantum leap from an original, albeit moderately subjective system of somatotyping to a method that he said was objectively determined but has little or no apparent relationship to his previous method" (Carter & Heath, 1990, p. 34). Sheldon met this criticism with the development of the Trunk Index method. "In the Trunk Index, the TT (thoracic trunk) is the numerator and the AT (abdominal trunk) is the denominator" (Sheldon, 1965, p. 8). This new method was very different from his previous system. Sheldon emphasized that his new system provided a measure of massiveness (the height-to-weight ratio), a separator for the kinds of mass into endomorphy and mesomorphy (the Trunk Index), and a measure of height (Carter & Heath, 1990).

Almost all of Sheldon's research was conducted on the male population. Little was published on the somatotypes of women. In The Varieties of the Human Physique, Sheldon (1940) shows the prevalence of somatotype components for 2500 women that were rated by photoscopy only. There were also nine "highly misleading" drawings of allegedly prototypical female somatotypes in the Appendex (Carter & Heath, 1990).

In Atlas of Men (1954), Sheldon remarked that the Atlas of Women would be published in a few years and discussed briefly the rating scales and height-weight criteria for males and females. He and his colleagues had decided on a single somatotyping system for males and females and "to let the female somtotypes fall where they would" (Sheldon, 1954, p. 13). He included a somatochart that represented a female population of 4000. Heath recalls that by 1954 when the Atlas of Men was published, she had taken part in photographing 3000 college females and 3000 women in hospital and clinical situations which was an adequate sample for the construction of the Atlas of Women, but was never published (Carter & Heath, 1990).

Carter and Heath

In the 1960s, the research team of Lindsay Carter and Barbara Heath collaborated on continuing the modification of Sheldon's somatype methodology suggested by Heath in 1963. Heath's (1963) suggested modifications included: (1) redistribution of somatotype ratings for a linear relationship between somatotype and the height-weight ratio, (2) elimination of the distribution tables that extrapolated height-weight ratios according to age, (3) adoption of the modified table for both sexes at all ages, and (4) adoption of an open-ended rating scale. The validation of the modifications (Heath & Carter, 1966) and the presentation of the Heath-Carter modified somatotype method (Heath & Carter, 1967) were products of this joint effort.

The Heath-Carter somatotype method is a modification of the work of Sheldon and his colleagues. The modifications include: (1) the somatotype rating is a phenotypic rating which allows for change over time, (2) the rating scales for the three components are open and have been redefined so as to apply to the physiques of both sexes at all ages, and (3) selected anthropometric dimensions help to objectify somatotype ratings (Carter & Heath, 1990). The three components for a somatotype rating are the same as in Sheldon's research: endomorphy, mesomorphy, and ectomorphy. The somatotype is expressed as three numbers, each representing the amount of the components, endomorphy, mesomorphy, and ectomorphy, always in that order. Ratings of each component begin at one-half and have no upper end points. Reliable ratings can be made to the nearest one-half unit.

There are three methods for obtaining a Heath-Carter somatotype (Carter & Heath, 1990):

- *The photoscopic somatotype*. This method requires a photograph to be taken consistent with standard instructions for visual inspection by an experienced somatotyper, measurements of height and weight of the subjects, and a table of somatotypes according to the ratios of height divided by the cube root of weight.
- *The anthropometric somatotype.* This type of somatotype can be calculated from 10 anthropometric dimensions [height, weight, 4 skinfolds (triceps, subscapular, supraspinale, medial calf), 2 girths (flexed upper arm, and calf), and 2 breadths (biepicondylar humerus and femur)].
- *The anthropometric plus photoscopic somatotype.* As the method of choice, it is based upon reference to a average somatotype photograph and rating criteria, to the anthropometric somatotype, and to the table of distribution of somatotypes according to height-to-weight ratio (Carter & Heath, 1990).

In the last six decades, the somatotype studies have continued to grow in number, particularly those using the Heath-Carter method. This method was used in 28% of all studies in the 1960s, 70% in the 1970s, and is still being utilized today.

<u>Douty</u>

Influenced by Sheldon, another researcher became interested in somatometry with respects to the clothing industry. Dr. Helen Douty, a clothing specialist in the School of Home Economics at Auburn University, wanted to help her students become more realistic in their self-assessment of traits for the application of aesthetic principles of clothing (Douty, 1968b). She believed a greater understanding of the body and of the principles of aesthetics could allow students to become more successful at solving problems and creating illusions in relation to the fit of clothing. Dr. Douty stated that ..

> "..to speak meaningfully of relative body characteristics there must be information on norms and variations with valid conceptions of size and contour of normal bodies. Detailed measurements of body units can provide for observation of these specific details and for statistical treatment of data but they provide little information on the nature and location of unit masses in relation to each other and to the whole" (Douty, 1968b, p. 65).

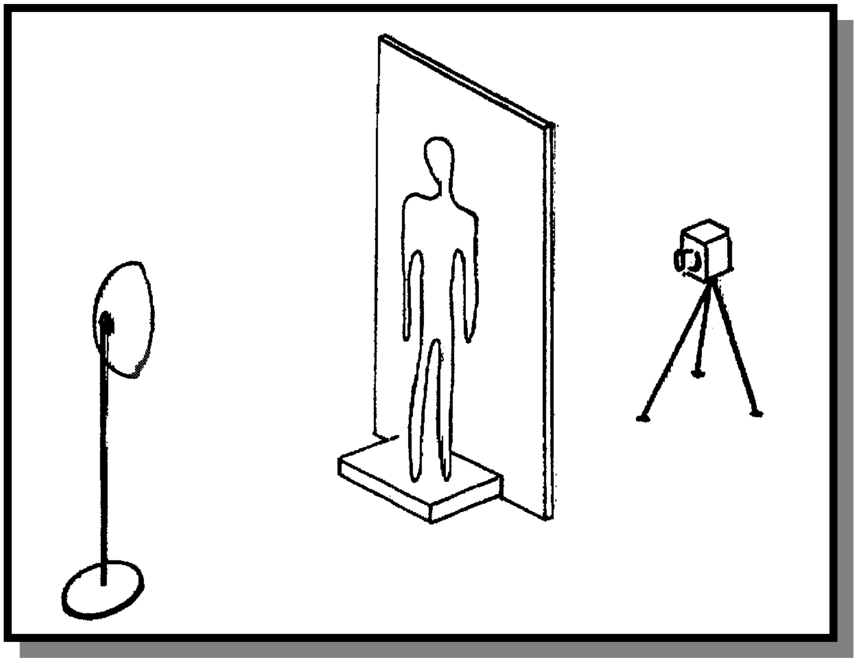
The research of Dr. Douty resulted from a need of: (1) more precise understanding of the nature of the configuration of the body as an object in space, (2) method of recording and comparing data on characteristics, and (3) precise ways of communicating about them. In order to test the accuracy of a subject's perception of their body, a simple method for identifying body characteristics and types was created. The method is known as "graphic somatometry", *soma* meaning body and *metry* meaning measurements. Consequently, it means to measure the human body visually with a graph.

Realizing the difficulty of measuring the body visually in three dimensions, Dr. Douty believed that a silhouette projected onto a graph simplified the entire process. "The multiple stimuli and responses triggered by the actual complex body are reduced to a few and it is possible to concentrate on the fundamental issues of size and shape" (Douty, 1968b, p. 66). The equipment for the method included a light source, a translucent grided screen, a camera, and, of course, a subject. The resulting photograph was called a "somato-graph". It showed the body mass and shape in graph form, where the characteristics were clearly visible and could be analyzed objectively and classified into figure types.

The photographic setup.

Figure 12 represents the configuration used by Dr. Douty to take the shadow-based photographs. A light source, a simple bulb with a reflector or overhead projector placed 13-15 feet from screen, was on the left. A translucent screen was in the center with the subject facing the light and their back towards the screen, as close as possible. The subject was situated in their natural standing position with their thumbs resting on the thighs as to keep the arm and hand silhouette separate from the body.

The camera was placed on the side of the screen opposite the light and subject. A 35 mm camera was used. Subjects were photographed in minimum



<u>Figure 12</u>. Photographic setup for Douty "graphic somatometry" method.
(Douty, 1968a).

clothing, usually their own undergarments (Douty, 1968c). The graph screen was portable and used 1-inch units with 3- and 6-inch lines defined by markings of precut plastic tape. A balance line was clearly defined. A total space of 30-35 feet in length was minimum for this photographic setup.

Two photographs were taken of the subject, a back and side view. Dr. Douty thought that back and front views varied little in their contour with the back view being easier to position the subject and more comfortable for him/her. From the back view, the mass and shape, size and contour, alignment, and proportional relationships of the body units could be observed. The side, or profile view, generated what was called a "posture-graph" because it clearly

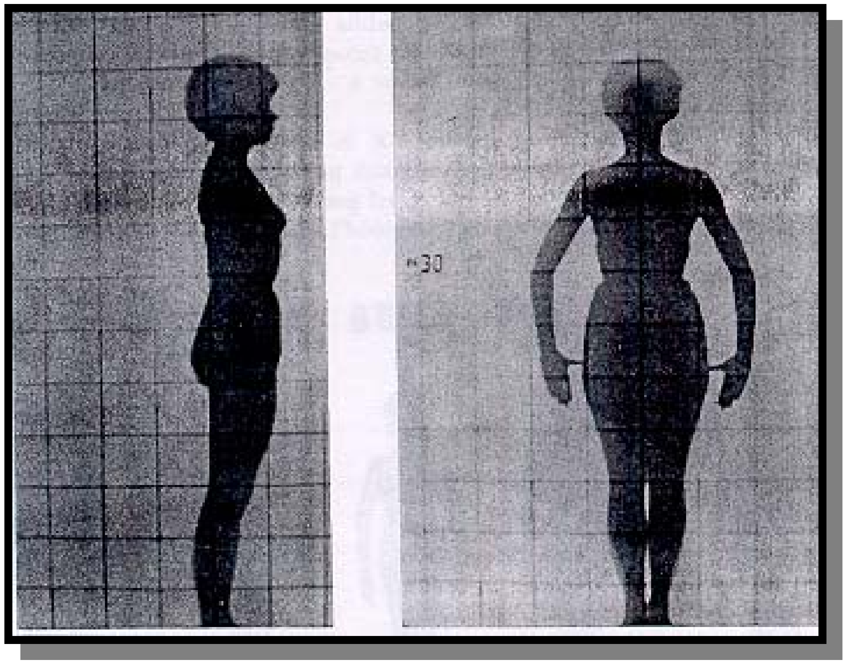


Figure 13. "Posture-graph" and "Somato-graph" of a subject. (Douty, 1968a, p. 26).

defined the alignment or disposition of body segments (Douty, 1968a). Figure 13 exhibits a "posture-graph" and "somato-graph" of a subject.

Douty body build scale.

Dr. Douty saw a need for a way to classify and quantify information about her subjects. A standard for reference and comparison was badly needed because no adequate standard was obtainable. From 1963-1965, silhouette photographs of 300 women students at Auburn University were taken to develop a body build scale. See Figure 14 for an illustration of Douty's Body Build Scale.

Three trained judges, using the mode of distribution of the 300 subjects as the central point, classified the subjects into five categories of body types. These figures were based on height-weight relationships even though Douty asserted the figures were independent of height because a body of any height could be placed in any one of the categories. The subject needed a majority of the attributes of that category, but not all, to fit into it. The ratings were on a 5-point scale but decisions could be made to the one-quarter scale point, or 0.25, for experienced judges.

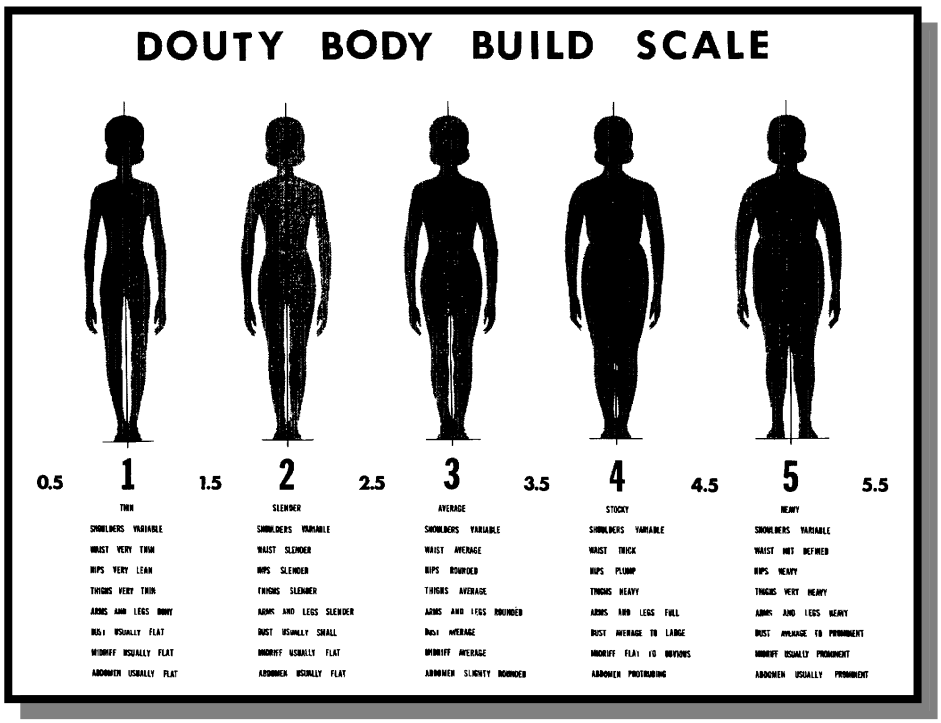
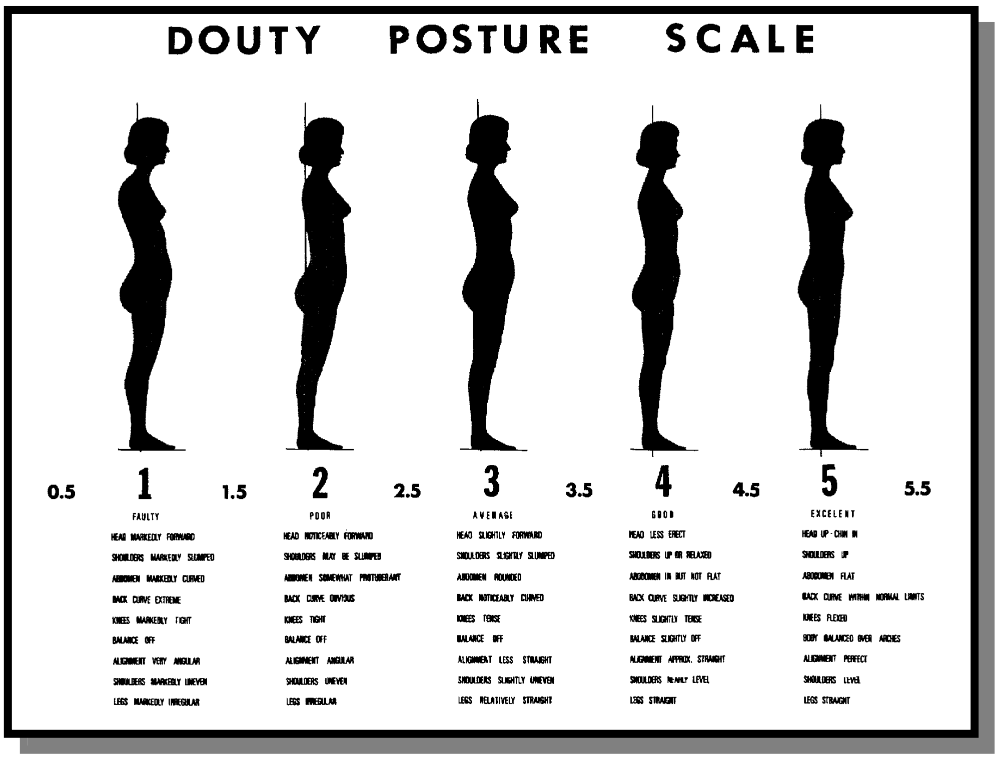


Figure 14. Douty scale of body build types. **(Douty, 1968a, p. 28).**

Douty posture scale.

Dr. Douty's Posture Scale was developed using the same approach as the Body Build Scale (see Figure 15). Other postural studies, as well as posture specialists, were consulted for the development of this scale. The side view of the somato-graph yielded the “posture-graph”. The subject was positioned with the front edge of the outer ankle bone on the balance line. This balance line could then be used as a reference for comparison with the axes of segmental body units and alignment of key gravity points (Douty, 1968c).



<u>Figure 15</u>. Douty’s posture scale. **(Douty, 1968a, p. 29.)**

This scale was on a five-point directional continuum. It was “based on the theory of recommended alignment of segmental body units relative to the force of gravity as it affects muscle stress, or the amount of effort required to maintain a static body in an upright position” (Douty, 1968c, p. 9). The alignment of the body segments was compared with the balance line and any misalignment of any unit could be identified.

Dr. Douty's research was carried out on a limited basis at Auburn because of lack of funding. Studies were conducted but with limited samples. Dr. Douty had always hoped that Alabama would become a leader in this new version of somatology. Even though she never was able to carry out a large study where these scales could be used, other researchers have used her methodology as a foundation and as a jumping-off point for their research.

In a 1997 study, Lakner, Paff, and Din performed a citation analysis on the first issue to the December 1993 issue of the Clothing and Textiles Research Journal (CTRJ) and the Home Economics Research Journal (HERJ). Of the 456 total qualifying articles and 16,104 citations, Dr. Douty was cited 38 times. She was ranked number 21 out of the top 52 most cited authors in CTRJ and HERJ. The authors of the study concluded that the 52 most cited authors produced scholarship that was among the highest in quality in the field. Other research concluded that those who were cited most often are considered to be those who have contributed most to the development of the field (Medoff & Skov, 1990). So, the frequency, with which the authors were cited by the scientific community, was an indication of the quality of their scholarship (Garfield, 1978; Volker & Deacon, 1982).

Research using Douty's scales.

Over the years, many researchers have used Douty's method of "graphic somatometry" in their studies of clothing. In 1977, Brinson used the graphic somatometry method to evaluate the body characteristics of posture, general mass, proportion, contour, and balance and symmetry of alike body parts. She was successful in the satisfactory fit of her subjects by using body angle measurements to alter basic bodices and skirts.

Pouliot (1980) developed a methodology for altering pants using the "graphic somatometry" method in combination with computerized procedures by using angle measurements obtained from computer plots. Pouliot evaluated the body mathematically and developed a computer program that would plot the body curves using data points from the somatograph.

Farrell-Beck and Pouliot (1983) used Douty's "graphic somatometry" method for measurements of body length and circumference and added body angles and body proportions mathematically as a basis for developing seamlines and waist darts for pant patterns. They found that the graphic silhouettes produced front waist placement, front waist dart size, back crotch curve and horizontal grain better than the traditional method of alteration.

Heisey, Brown and Johnson (1986) presented a mathematical framework for analysis of the graphic somatometry method of alteration developed by Brinson (1977), based on the work by Douty (1968a, b, c) on analyzing the body form. Their work supported the idea that the three-dimensional form of sections of numerous garments could be modeled as a truncated cone or part of several cones. This research found a relationship between the conical model and the flat pattern to be the implied geometrical foundation for the "graphic somatometry" method of alteration. Their conical method seemed to be valid for the lower half of the bodice and the darted areas of the skirt and pant but not for areas which curve in more than one direction.

All of this research conducted by Douty and those who have used her methods were all dealing with body types, body shapes, and pattern development as it relates in two-dimensions. The body is a three-dimensional object that must be evaluated in such a dimension. To this point, no research has been found that would achieve such an evaluation. With the technologies available today, evaluation of the human body in three-dimensions is possible.

CAD Modelling

An Italian company called CAD Modelling believes that body scanning technology is very useful in its output of data but all data should be relative to the mathematical model of the volume of the naked body, the 3D volume. They also think that within a population, only a few consumers have a body type which exactly fits the standard forms. CAD Modelling has proposed the idea that it is possible to individualize all possible human physical structures with a few parameters that correspond to the most important and irregular body features with respect to clothing needs (Quattrocolo & Holzer, 1992). Those parameters include the physical base, height, and size.

They have developed a complete anthropometric identification system with their own body scanner, ScanFit®, and a set of anthropometric dummies, Formax®. Formax® mannequins were developed as their physical bases. These are identifiers of the shapes of individuals. They include slim (physical base 10), harmonious (physical base 8), regular (physical base 6), robust (physical base 4), corpulent (physical base 2), and extra corpulent (physical base 0).

Figure Type Classifications by Pattern Industry

When descriptions of different body or figure types are being discussed, the terms “endomorph, mesomorph, and ectomorph” are not usually the most common. Most often, terms are divided into two separate groups of “apple, pear, triangle, oval” or “Missy, Junior, Women’s, Half-Size”. All of these terms can be very confusing. Some appear misleading because they seem to indicate the age of the person. Others just seem to be saying the same thing (isn’t the shape of a pear the same as a triangle, being proportionately larger on the bottom than the top?).

All of these terms are associated with the pattern industry. Unlike ready-to-wear apparel manufacturers, American pattern companies agreed on the body measurements that were used for each size, even though, they changed the standard measurements four times before 1972 (Palmer & Alto, 1998). In 1967, the pattern companies used the measurements from the O’Brien & Shelton (1941) study to be more inline with the ready-to-wear industry.

The pattern industry then devised its own standard set of figure types and sizes. Figure 16 is a composite of the pattern industry figure types. Many pattern making and sewing books (Joseph-Armstrong, 2000; Leichty, Pattberg, & Rasband, 1992; Reader's Digest, 1976; Sara, 1986) reference these figure types as having differences in height and contour according to its designation. Table 6 describes each of the figure types. These figure types are in alignment with the groupings of the current ASTM classifications.

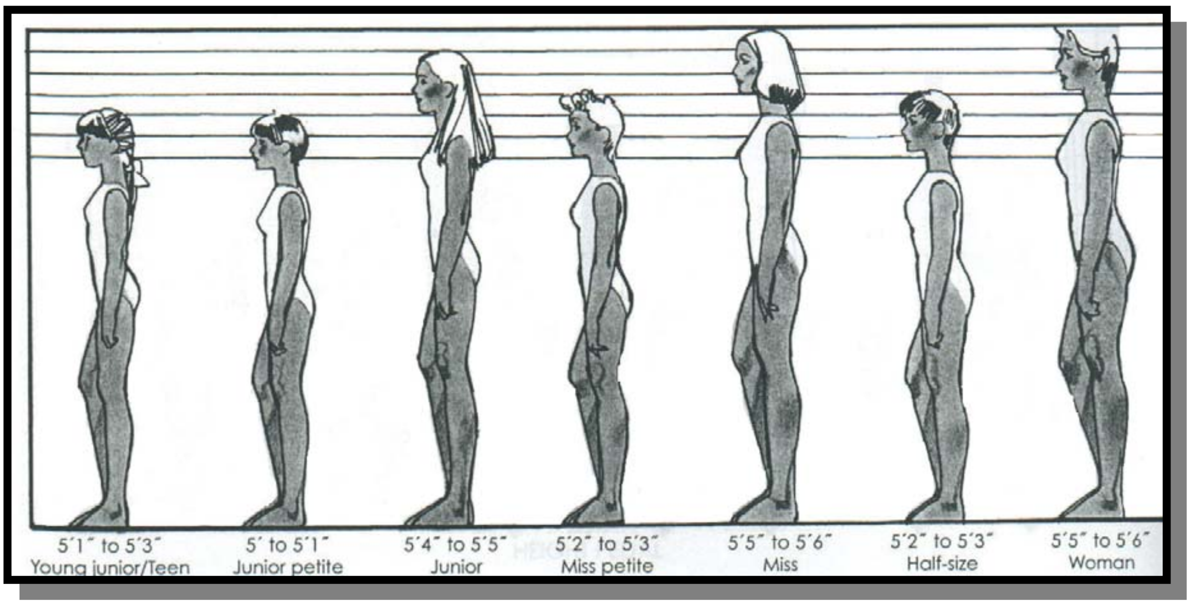


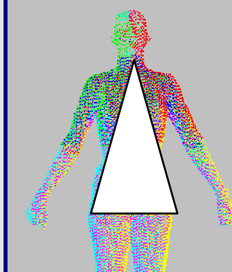
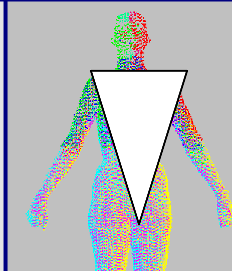
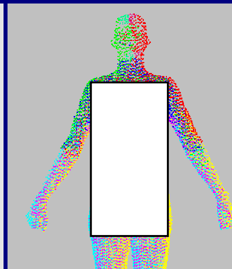
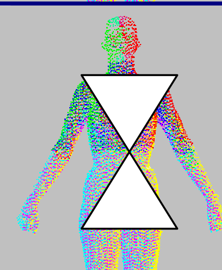
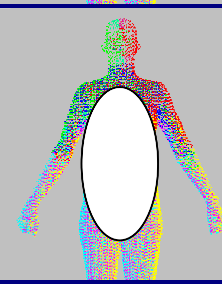
Figure 16. Compostion of pattern industry figure types. **(Joseph-Armstrong, 2000, pg. 25).**

The other grouping of terminology for figure types is categorized by names of shapes, letters/numbers, and fruits/vegetables. Apple and pear are identifiers in the fruits/vegetables category. Oval, circle, round, hourglass, diamond, rectangle, straight, ruler, triangle, inverted triangle, spoon, Christmas tree, and cone belong to the shapes category. In the letters/numbers category, "O", "X", "H", "A", and Figure 8 are included. These lists are not exhaustive as other terms may apply. Table 7 characterizes these figure types.

Table 6. Pattern Industry Figure Type Characteristics (Joseph-Armstrong, 2000, pg. 25; Reader's Digest, 1976, pg. 46-47).

Figure Type	Height	Body Characteristics	Hip Measure Placement	Size Range
Young Junior /Teen	5'1" to 5'3"	Developing figure. Small, high bust. Waist larger in proportion to bust.	7" below waist	5/6 to 15/16
Junior	5'4" to 5'5"	Well developed. Shorter back waist length than Misses'. Higher bustline than Misses'.	9" below waist	5 to 15
Junior Petite	5' to 5'1"	Fully developed figure. Shorter than Junior. Similar proportions to Junior.	7" below waist	3jp to 13jp
Misses'	5'5" to 5'6"	Well developed and proportioned. Taller than all figure types except Women's. Longer back waist length than all figure types except Women's.	9" below waist	6 to 20
Miss Petite	5'2" to 5'4"	Similar proportions to Misses'. Shorter overall than Misses'. Narrower shoulders than Misses'.	7" below waist	6mp to 16mp
Women	5'5" to 5'6"	Similar in height and proportions to Misses but larger figure overall.	9" below waist	38-50
Half-Size	5'2" to 5'3"	Larger waist than Misses'. Shorter back waist length than Misses'. Narrower shoulders than Misses'.	7" below waist	10 ½ to 24 ½

Table 7. Characteristics of Different Figure Type Terminology .

Figure Type	Traits	Illustration
Triangle[c, h, l, j, n, o, p] "A" Frame[l, m,] Pear[a, b, d, e] Spoon[g, k] Christmas Tree[f]	Shoulders narrower than hip. Bottom heavy with weight mainly in buttocks, low hips and thighs. Bust is small to medium. Upper body smaller than lower body.	
Inverted Triangle[c, p, h, l, j, o, n] Cone[g, k] "V" Frame[d, m]	Heaviest part of body is on top. Shoulders wider than hips. Weigh gain in upper body and stomach. Usually large chest. Very narrow hips.	
Rectangle[c, p, h, l, j, o, n] Ruler[g, k] "H" Frame[m, l]	No definition at the waistline. Shoulders and hip about the same width. Equal body proportions.	
Hourglass[c, g, h, l, j, k, n, o, p] Figure 8[m] "X" Frame[l]	Equally broad on top and hips. Thin at the waist, usually 10 or more inches smaller than chest and hips.	
Oval[c, h, l, j] Circle/Rounded[o] Apple[a, e] Diamond[p, o] "O" Frame[l]	Top and bottom are narrow. Chest and belly are where weight is found. Skinny legs.	

Note: (a) Self, 2000 (b) iVillage.com, 2001(c) la.assortment.com, 2001(d) teraformahealth.com, 2001(e) tinajuanfitness.com, 1999 (f) Farro, 1996 (g) Jackowski, 1995 (h)betterhalf.com, 2001 (i) carlamathis.com, 2001 (j) Beauty Is, 2001 (k) exude.com, 2001 (l) Duffy, 1987 (m) Your Total Image, 2001 (n) Palmer & Alto, 1998 (o) Rasband, 1994 (p) eswimmers.com, 2001.

Figure types are said to be used as a guideline for easier clothing selection. However, not all bodies conform exactly to one particular figure type. Women with the same figure type are most flattered with the same set of clothing styles in spite of height and size. Clothing has most generally been used to camouflage figure imperfections and highlight key features. While this sounds like a great idea, many consumers are still very dissatisfied with the clothing they are purchasing.

Three-Dimensional Body Scanning

During the 1960s, research began on technology that would revolutionize the study of human measurement. But it wasn't until the early 1990s that three-dimensional (3D) body scanning technology would make significant contributions to the apparel industry.

As the currently most advanced user of this technology, the apparel industry has noteworthy potential for its use while the concept is still in its early stages of development. There are some retailers and manufacturers who have adopted 3D body scanning with open arms. Levi Strauss premiered body scanning in their San Francisco, California store, providing customers the opportunity to be scanned and have a pair of custom jeans made. This 5 year old program, called Levi's Original Spin, has made others retailers stand up and take notice (Lajoie, 1999).

From October through December of 2000, Lands' End sponsored the "My Virtual Model Tour 2000" as the world's first body scanning truck. Individuals were scanned with a $(TC)^2$ scanner and experienced the Lands' End "My Virtual Model". This realistic, size accurate virtual model was created with the scan measurements and could be used to try on clothes, create outfits, and determine what size to buy through the Lands' End catalog and website. Lands' End called it "the future of fitting rooms today!" (Lands' End, 2001).

Large, well-organized groups are using 3D body scanning technology to gather anthropometric data. One project is the Civilian American and European Anthropometry Resource (CEASAR) project. This effort has attempted to gather the most recent and complete set of data relating to the various shapes and sizes of the Westerns world's 18- to 65-year-old population. The U.S. Air Force at Wright-Patterson Air Force Base provided a team to conduct on-site measurements using a Cyberware WB-4 whole body scanner. Companies wishing to participate in the project paid a $40,000 fee and, in return, received raw body measurement data as well as demographic information. Nonparticipating companies paid as much as $250,000 for the data (Ponticel, 1999).

In the Fall of 2001, *Size UK*, a comprehensive national sizing survey of the United Kingdom (UK) of 10,000 men and women, began. Utilizing 3D body scanning technology, this is the first national men's sizing study, the first research of women's sizes in over 50 years, and the first time that shape data will be collected. The 3D body scanner that was chosen following a worldwide comprehensive search was the Body Measurement System whole body scanner by (TC)^2. Their scanner was chosen for its accuracy of data and its ability to extract the measurements required for the study ((TC)^2, 2001).

Several studies have been completed concerning 3D body scanning. A 2000 study by McKinnon investigated the effect of respiration and foot stance in a whole body scanner on critical measurements of the body. An analysis of differing types of scanners and scanner manufacturers was revealed in a study by Simmons and Istook (2001). A comparative analysis of the Textile/Clothing Technology Corporation (TC)^2 scanner models 2T4 and 3T6 was also conducted (McKinnon & Istook, 2001).

Currently, there are four general types of body scanning technologies including laser, infrared, structured white light, and photogrammetry. They range in level of sophistication, cost, measurement extraction ability, and floor space needed. With respects to the consumer, people are very interested and intrigued by new technology but at the same time concerned about their safety, privacy, cost, and convenience.

Three-dimensional body scanners have several identifying positive features. First, 3D body scanners generate an unlimited number of linear and nonlinear measurements of the human body in just a few seconds. Second, these measurements are more precise than traditional physical measurements and are reproducible. Third, 3D body scanners can generate outcomes in a digital format that could integrate automatically into apparel CAD systems and be used for size and shape analysis.

There are also limitations to this new technology. Poor quality data in the form of the point cloud information, is a significant issue with some scanners. Some regions of the body may be missing information on the scan, depending on the type of scanner used. There is inconsistency in the output among the different scanner manufacturers. Some systems do not have their own software for automatic extraction of measurements. A few systems have very limited measurements that can be extracted. The inability to get a stature measurement because of the shadowing effect of human hair is also an issue for some scanners. And, finally, some scanners do require that physical landmarks be placed on the body for scanning purposes.

Full body scanning has the potential to provide the data needed to identify and characterize the segments of the population not being served well with current sizing systems. Development of models that use three-dimensional body scan data to identify different body types can provide the industry with tools to identify and design for these market segments that are not being provided with well-fitting clothing.

From a 2001 study comparing the body measurement techniques of three different scanners, it was found that the $(TC)^2$ scanner was the most appropriate for the use of measurement extraction in the manufacturing of clothing (Simmons). From eight scanner manufacturers worldwide, the $(TC)^2$ scanner was chosen for the national sizing survey in the United Kingdom, *Size UK*. These findings coupled with the existence of a scanner of this nature at this facility, the $(TC)^2$ was chosen as the scanner for this study.

Textile/Clothing Technology Corporation $(TC)^2$ Body Measurement System

History

In 1981, a concept generated from the National Science Foundation was formed into Tailored Clothing Technology Corporation. Their mission was to conduct Research and Development activities, demonstrate technology and provide education programs for the apparel industry. In 1985, they became Textile/Clothing Technology Corporation [$(TC)^2$]. $(TC)^2$ is located in Cary, North Carolina where their teaching factory is visited by thousands of industry representatives each year ($(TC)^2$, 2000).

One of the research and development products invented by $(TC)^2$ has been a 3-Dimensional whole body scanner and body measurement system (BMS). Work on the system began back in 1991. In 1998, the first 3D scanner model, the 3T6, was made available to the public. The first four systems to be delivered were to Levi Strauss & Company, San Francisco, the U.S. Navy, North Carolina State University College of Textiles, and Clarity Fit Technology of Minneapolis ($(TC)^2$, 2000).

The $(TC)^2$ scanner was the first scanner to be developed with the initial focus for the clothing industry. In order for the American apparel industry to be more competitive, $(TC)^2$ saw the need for the drive toward mass customization. A move toward made-to-measure clothing necessitated fundamental technology that would make the acquisition of essential body measurements quick, private, and accurate for the customer ($(TC)^2$, 2000).

Body Measurement Systems (BMS)

The first scanner model 3T6 was named by the number of towers (3) and the number of sensors (6) that were used for the scanning process. New models have been designed that have the same basic function but a smaller footprint: the 2T4 and 2T4s. The 2T4 and 2T4s have 2 towers with 4 sensors. The "s" in 2T4s stands for short which denotes a smaller layout than the 2T4 (David Bruner, personal communication, 2000). A comparison of the 2T4 and 2T4s scanner models is shown in Table 8. The layout of the 2T4s scanner can be seen in Figure 17.

Table 8. Comparison of $(TC)^2$ Scanner Models, 2T4 and 2T4s.

Hardware	2T4	2T4s
System Dimensions		
Height	**7.9 ft.**	**7.9 ft.**
Width	**5 ft.**	**5 ft.**
Length	**20.5 ft.**	**13.5 ft.**
Weight	**600 lbs.**	**600 lbs.**
Field of view		
Height	**7.2 ft.**	**7.2 ft.**
Width	**3.9 ft.**	**3.9 ft.**
Depth	**2.6 ft.**	**3.6 ft.**
Setup time	**4 hrs.**	**4 hrs.**
Calibration time	**15 mins.**	**15 mins.**
Portability	**Yes**	**Yes**
Cost	**$65,000**	**$65,000**

<u>Figure 17</u>. Booth layout of the (TC)^2 scanner ((TC)^2, 1999).

<u>System Design</u>

The BMS utilizes phase measurement profilometry (PMP) where structured white light is employed. The concept was first introduced by M. Halioua in 1986 (Halioua & Hsin-Chu, 1989). The PMP method employs white light to impel a curved, 2-dimenional patterned grating on the surface of the body. An example of this grating can be found in Figure 18. The pattern that is projected is captured by an area array charge-coupled device (CCD) camera. Each system utilizes four stationary surface sensors. A single sensor captures an area segment of the surface. When all sensors are combined, an incorporated surface with critical area coverage of the body is formed for the use in the production of apparel. Four images per sensor per grating are attained. This information is used to calculate the 3D data points. The transitional yield of the PMP method is a data cloud for all four views ((TC)^2, 2000).

Figure 18. Patterned grating in the $(TC)^2$ scanner.

Once the image is obtained, over 400,000 processed data points are determined (Figure 19). Then segmentation of the body occurs and the measurement extraction transpires (Figure 20). The specific measurement output is predetermined by the user. A printout is available with a body image and the measurements (Figure 21) ($(TC)^2$, 2000).

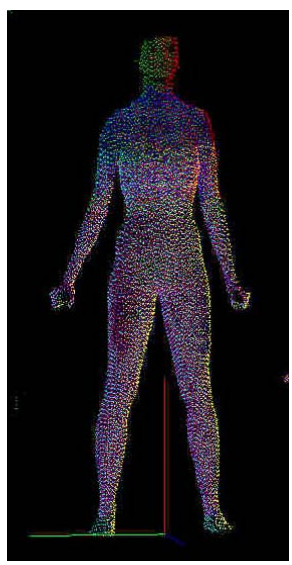
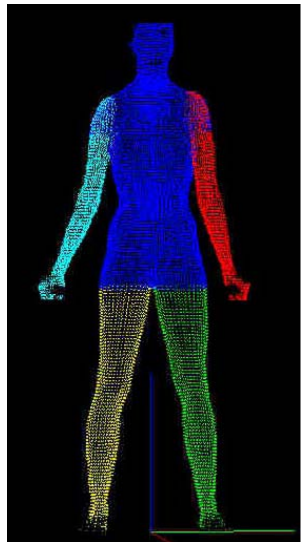
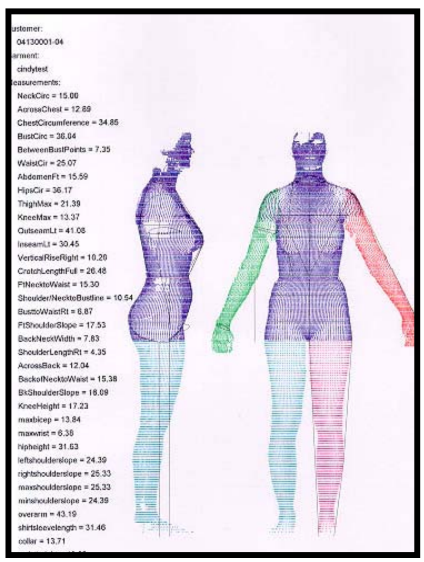


Figure 19. 3D point cloud data.



<u>Figure 20.</u> Segmentation of the body.



<u>Figure 21.</u> Printout available to subject.

Software for Body Evaluation

Several software packages have been developed that calculate somatotype variables and sample statistics for data of individuals and small groups. However, all of them view the body 2-dimensionally (2D). The software takes the 3D image and reduces it down to 2D. Somatotypers do not currently use 3D for visually rating somatotype photos (Carter, L., personal communication). Examples of the different kinds of software follow.

PROSOMAN is a program written by S.P. Aubry and Carter that consists of programs for calculating somatotypes, descriptive and comparative statistics, and plotting somatocharts. An earlier version of this package was named SOMATOGRAPH. This program was written in the Fortran 77 computer language for the use on large mainframe computers such as CYBER, IBM, and VAX (Carter & Heath, 1990). The program was used for two decades but, since mainframes are rarely still in use, can seldom be found in practice (Aubry, S., personal communication). Table 9 lists the capabilities of the PROSOMAN program.

SOMATYPE is a basic program executable on a personal computer (PC). The program carries out somatotype calculations interactively using anthropometric data (Carter, L., personal communication). A program using SAS/GRAPH, a component of a large suite of software collectively known as SAS (SAS User's Guide, 1988, 1990), was used to draw somatocharts and plot somatotype data. SOMATMAN SAS was written on an IBM mainframe but could be altered to run the PC version of SAS. IT consisted of three parts. The first part placed the data into SAS and prepared the data for plotting. The second part set up the plot grid and created the data set. The third part plotted the somatotype data (Satake, Morris, Hopfe, & Malina, 1993).

Table 9. PROSOMAN Computer Program Description. (Carter & Heath, 1990, p. 419)

PROSOMAN Program	Description
STYPE	Calculates anthropometric Heath-Carter somatotype. Provides descriptive statistics for all derived variables.
CATE	Calculates frequencies in a histogram and a table. Lists subjects by category.
SPLOT	Draws a bi-dimensional somatochart. Plots the frequencies of the somatoplots. Provides descriptive statistics for somatotype and somatoplot.
SANOV	Calculates one-way ANOVA. Provides descriptive statistics for the somatotype attitudinal distances (SAD) or somatotype dispersion distance (SDD).
TPAIR	Calculates t-ratio for paired somatotypes
MIGDIS	Calculates sum of distances between sequential somatoplots and plots position.
INFREQ	Calculates and lists number of subjects from each somatotype sample which lie outside, inside, or in the intersection of circle.

Knowledge Management

Data lives in our lives and on our desks as isolated elements. Only when we assemble this data into a significant configuration do we have information. When this information is converted into a valid foundation for action, it becomes knowledge. Knowledge is "taken to be an attitude towards a proposition which is true (Dienes & Perner, 1999). Knowledge management is "a strategy that turns an organization's intellectual assets (both recorded information and the talents of its members) into greater productivity, new value, and increased competitiveness (Murray, 2002).

This recorded information, which is obvious knowledge found in manuals, documentation, files, and other accessible sources, is known as explicit knowledge (bestbooks.com, 2002). Explicit knowledge is information and skills that are easily communicated and conveyed to others. It is shared, stored, and distributed (hyltonassociates.com, 2002).

However, the greater level of knowledge in an organization is tacit-unarticulated knowledge (Saint-Onge, 1996) and may be the real key to getting things done (Murray, 2002). The definition of tacit knowledge has been identified in several ways:

- Knowing more than we can tell (Polanyi, 1966).
- Found in the heads of an organization's employees being far more difficult to access and use for obvious reasons (bestbooks.biz, 2002).
- The personal knowledge in people's heads, that has not been written down or documented. It is largely gained through experience and is influenced by beliefs, perspectives, and values. Tacit knowledge usually requires joint, shared activities in order to transmit it. Personal (tacit) skills such as expertise, gut feel, subjective insights, and intuitions are not easily communicated and documented (hyltonassociates.com, 2002).

- Knowledge that is used as a tool to handle or improve what is in focus (Svelby, 1997).
- An aspect of practically intelligent behavior that is acquired through experience and is unrelated to general cognitive ability (Wagner, 1985).

Tacit knowledge allows a person to engage in an activity and have little or no conscious experience of what it is causing it. Wagner states that it is not simply the amount of experience that matters but also how well one is able to learn from and apply knowledge gained through experience (Wagner, 1985 & 1987).

Many industries have begun to understand and use tacit knowledge to enhance their future performance: law enforcement (Kerr, 1995), social work (Holland, 1985; Imre, 1985), anthropology (Heath, 1984), survey research methods and sampling (Maynard, Houtkoop-Steenstra, Schaeffer, Van Der Zouwen, 2002), systems engineering (Tatalias & Kelly, 2001), gemology (Collins, 2001), laser-building (Collins, 1992), nuclear weapons (MacKenzie & Spinardi, 1995), biology (Jordan & Lynch, 1992), and vetinerinary science (Pinch, Collins, & Carbone, 1996).

METHODOLOGY

Body Scanning Database Development

The first objective of this research was to develop a database of three-dimensional body scan data, from a variety of consumer markets, including measurement data, 3D point cloud data, and demographic data. This initial step provided an established catalog of subjects for all research pertaining to 3-dimensional body scanning. Before this research, a comprehensive database for the $[TC]^2$ Body Measurement System 2T4 model scanner that resides at North Carolina State College of Textiles did not exist.

Subject Recruitment and Data Collection

A convenience sample of women was solicited primarily from the Triangle area of North Carolina (Raleigh, Durham, Cary) through several avenues. First, students from North Carolina State University, College of Textiles, were recruited through participation in apparel related classes as part of their coursework. Posters with research information were placed in College of Textile classrooms and common areas. Emails were also sent to College of Textile students and employees requesting participation in this study. No incentives were provided for subject involvement other than a printout of the subject's personal scan and refreshments.

Second, other North Carolina State University students and employees were recruited by placing advertisement posters in 16 WolfLink buses, as well as in over 100 common areas of main campus. Third, a website link to Body Scan Central (www.bodyscancentral.com), maintained by North Carolina State University College of Textiles and created through funds from the National Textile Center, was created that allowed an Internet sign-up for a body scanning appointment. All information posters referred to the website. Fourth, any visitor to the College of Textiles wishing to experience body scanning was invited to participate.

Scanning Protocol

Each subject read a sheet describing the study which included the scanning procedure, possible risks, confidentiality, and contact names and phone numbers in accordance with the rules of the Human Subjects Review Board of North Carolina State University. Every subject was given an identification number for confidentiality. Demographic information, such as weight, height (without shoes), age, gender, and ethnicity were taken. In order to comply with the rules of confidentiality, this information was placed in a secure location available only to the researcher. The subject was then given a tour of the body scanner and instructed on the specifics of body scanning procedure.

Each subject was led into a private dressing room, which held multi-sized scanning garments. These garments were unisex athletic shorts and tops that were light gray in color. They were instructed to disrobe to their undergarments, choose a garment set (top and bottom for women) that was not too restricting nor too loose, take off all jewelry and glasses, and to situate their hair so that it was completely off their neck. Hair accessories were provided.

When the subject was clothed in the athletic wear and ready to proceed with the scan, she/he was asked to step into the scanner. The scanner door was closed to protect their privacy. The subjects were instructed to stand upright with normal posture, hold their heads erect, place their feet 12 inches apart (foot placement was pre-marked), and take hold of the handrails allowing their arms to remain near their side, yet far enough away to allow light to flow through. The subject were also informed that they could start the scan at any time with the push of an identified button on their handhold. When the scan was complete, the subjects were asked to wait to make sure the scan was of good quality before changing into their street clothes. If the scan was not first quality or did not give complete information, the process was repeated. The subjects would then change clothes and be given a printout of their body measurements along with a picture of their three-dimensional body image. Extracted measurements, 3D point cloud data, and reduced body data were stored, and maintained entirely by the subject identification number.

Sample Selection

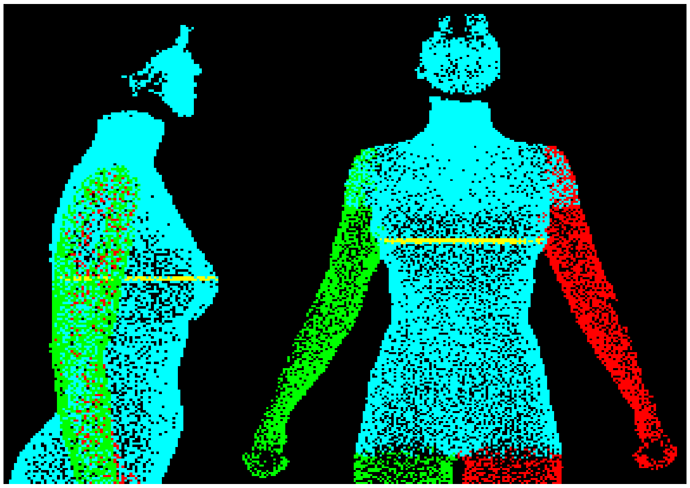
All interested parties were scanned and their data included in the body scan database. No potential subject was excluded on the basis of race, gender, size, or shape. For this specific study, a subset of only females, aged 18 and older, who had complete demographic data, good 3D body scans and complete extracted measurement data were used.

Measurement Procedure

The $(TC)^2$ 3D scanner is a whole body scanner that was developed with the initial focus for the clothing industry. With the specific objective of identifying body part locations and measurements with respect to apparel development, this scanner produces measurements that coincide with the best known practices for apparel pattern development. Several measurements were chosen as critical in the determination of body shape for comparison for this study. The process of how each measurement was determined in the $(TC)^2$ scanner is explained in the following paragraphs.

Bust Circumference

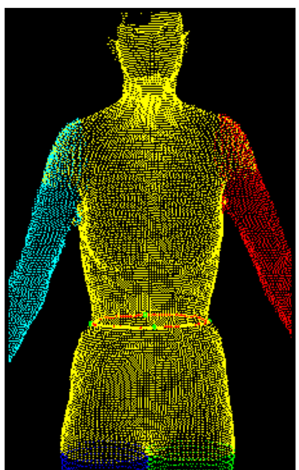
The “Bust” measurement was defined as the horizontal circumference taken across the bust points at the fullest part of the chest ([TC^2], 1999). Even though ASTM defines Bust as being parallel to the floor, the Bust measurement in this study was taken as parallel as possible. In the traditional method of body measurement, the measuring tape is usually not held exactly parallel. So, therefore, this measure attempts to approximate the physical measurement process. See Figure 22.



<u>Figure 22.</u> Bust circumference by the $(TC)^2$ body scanner.

<u>Waist Circumference</u>

The "Waist" was the smallest circumference between the bust and hips determined by locating the small of the back and then allowing the software search for this measure up to 2 ½ inches towards the bust to find the smallest circumference. The system was forced to determine a Waist definition that was parallel to the floor ([TC^2], 1999). See Figure 23. (Note that the measure may not appear parallel to the floor due to the 3D nature of the image.)



<u>Figure 23.</u> Waist circumference by the $(TC)^2$ body scanner.

Hip Circumference

The "Hip" measure was defined as the largest circumference parallel to the floor, located between the waist (as determined previously) and the crotch. Note, however, that this measurement definition differs from the original definition of the Hips being the largest protrusion from the rear ([TC^2], 1999). See Figure 24.

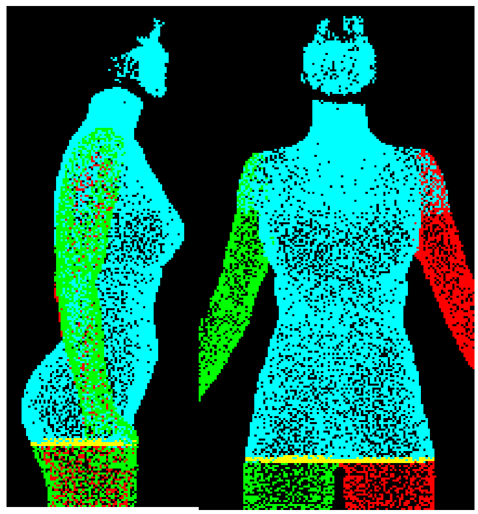
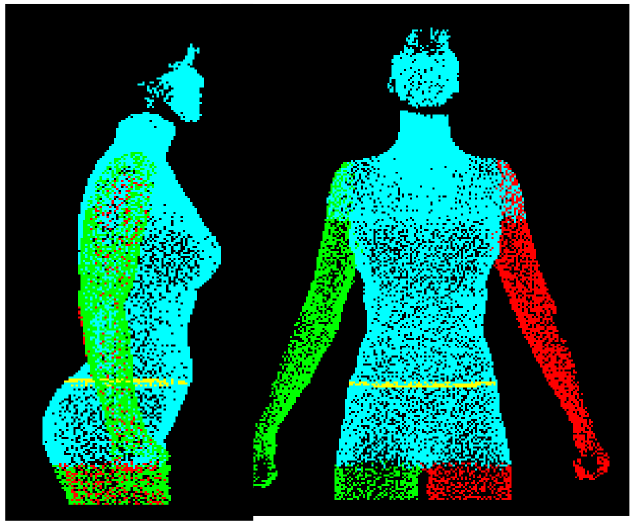


Figure 24. Hip circumference by the (TC)^2 body scanner.

High Hip Circumference

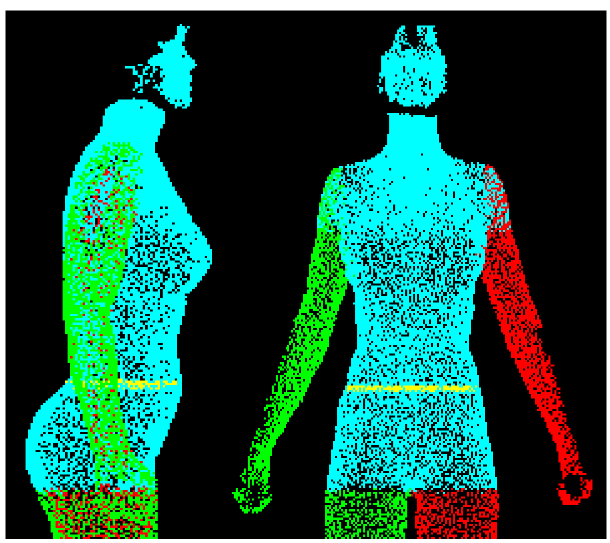
The "High Hip" circumference was defined as the largest circumference, parallel to the floor, located between the crotch and the waist, starting at 75% of the distance above the crotch. ([TC^2], 1999). See Figure 25.



<u>Figure 25.</u> High Hip circumference by the $(TC)^2$ body scanner.

<u>Abdomen Measure</u>

Using the Waist as a reference point, the "Abdomen" measure was defined as the largest circumference, parallel to the floor, between the waist and the hips ([TC^2], 1999). See Figure 26.



<u>Figure 26.</u> Abdomen circumference by the $(TC)^2$ body scanner.

Stomach

Using the Waist as a reference point, the "Stomach" measure was defined as the largest circumference, parallel to the floor, between the bust and the waist ([TC^2], 1999). See Figure 27.

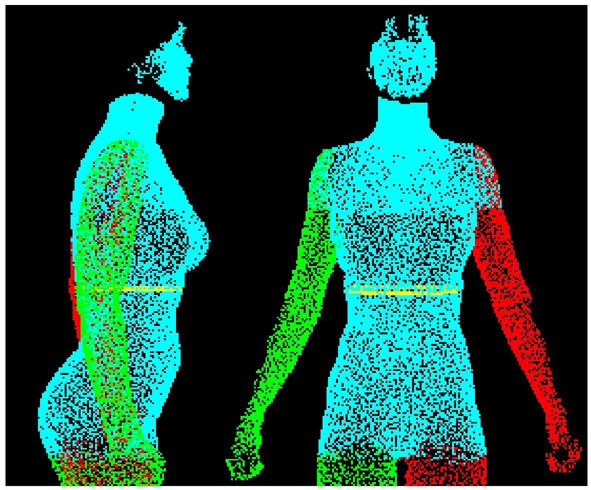
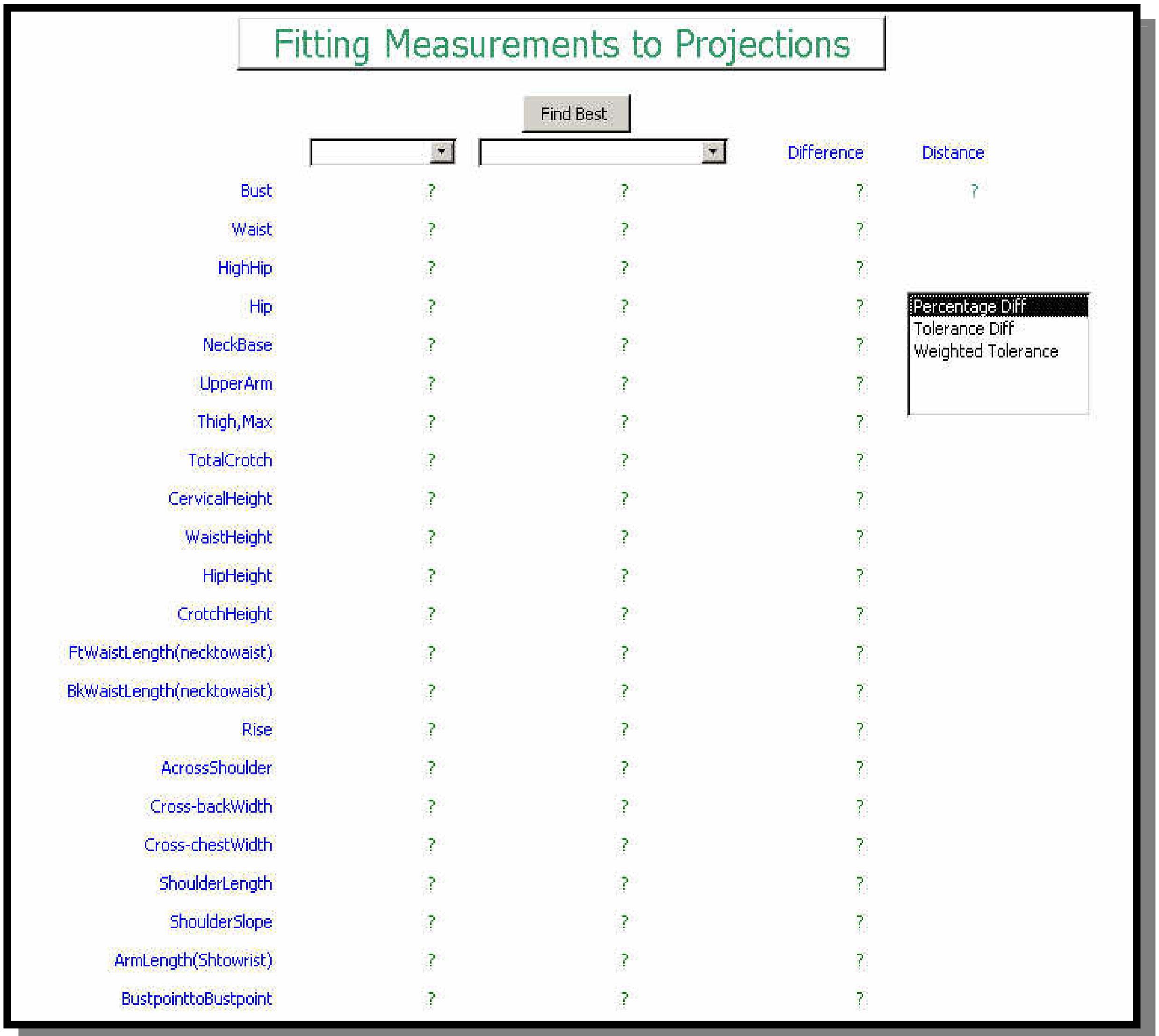


Figure 27. Stomach measure by the $(TC)^2$ body scanner.

Evaluation of Current Sizing Standards

The second objective of this research was to demonstrate that the current standards for body type classification are insufficient to meet the needs of the American people and to determine where significant deficiencies exist. A computer program was developed in Microsoft Access 2000 to derive a numerical difference between those of the subjects and those defined by the current and past standards (see Appendices A-D). The basic format of the program output is shown in Figure 28.



<u>Figure 28</u>. Template for the <u>Best Fit</u> program.

In the program display, there are five columns: (1) the selected measurements for the study that were common among all standards, (2) a pull-down list of the scanned body measurements per selected subject, (3) the sizing standard that best corresponds to the scanned data, (4) the difference between the scanned data and the standard based on the specific mathematical formula selected, and (4) the total number of measurements that were different according to that particular mathematical formula.

The first column represents the measurements common to all current and previous sizing standards. Measurement data from the 3D body scan database is located in the second column. A pull-down menu allows access to a particular subject data set. Measurement data were obtained according the ASTM requirements to insure comparability.

Once a subject data set has been chosen, the “Find Best” hotkey can be depressed to provide the standard and specific size with measures that corresponds most closely with the subject data set. This information is located in the third column. Current ASTM and past sizing standards were chosen for the evaluation because, with each revision of the original PS42-70, groupings of body types were added and/or taken away. See Appendices A-D for a complete listing of all standards used in the study. Having all of the past and current sizing standards in a central database, it is possible to determine which, if any, standard that correctly reflects the true shapes of women. Table 10 exhibits the list of standards that were used for comparison.

Table 10. Standards Included in Best Fit Program.

Standard	Size	Standard	Size
ASTM 5585	2-20	CS215-58 Missy (S,F)	8-12
ASTM 5586 (55+) Junior	3-17	CS215-58 Women's (R,A)	30-42
ASTM 5586 (55+) Junior Petite	3-15	CS215-58 Women's (T,A)	32-40
ASTM 5586 (55+) Misses Petite	8-18	CS215-58 Women's (R,S)	32-42
ASTM 5586 (55+) Missy	6-22	CS215-58 Women's (R,F)	28-38
ASTM 5586 (55+) Misses Tall	10-22	CS215-58 Women's (T,F)	30-36
ASTM 5586 (55+) Half Sizes	12.5-26.5	CS215-58 Half Sizes (S,A)	10.5-24.5
ASTM 5586 (55+) Women's	34-52	CS215-58 Half Sizes (S,S)	12.5-22.5
CS215-58 Missy (R,A)	8-22	CS215-58 Half Sizes (S,F)	8.5-20.5
CS215-58 Missy (T,A)	10-20	PS42-70 Junior	3-17
CS215-58 Missy (S,A)	8-18	PS42-70 Junior Petite	
CS215-58 Missy (R,S)	10-22	PS42-70 Missy Petite	
CS215-58 Missy (T,S)	12-18	PS42-70 Missy Tall	
CS215-58 Missy (S,S)	12-18	PS42-70 Women's	
CS215-58 Missy (R,F)	8-16	PS42-70 Half Sizes	
CS215-58 Missy (R,T)	10-14		

The fourth column shows the numerical differences calculated using a variety of accepted mathematical descriptors of difference including percentage difference, tolerance difference and weighted tolerance difference. Each description of difference can be selected for comparison by choosing it from the box on the right side of the display. These differences were evaluated to determine the best descriptor for apparel sizing purposes and fit. The fifth column represents the amount of difference between the scan data and the standard based on the particular formula.

Determining Percentage Difference

For the percentage difference, the scan data was subtracted from the Best Fit data, and then divided by the Best Fit data. See Figure 29. A positive number indicates that the scan data was larger than the Best Fit standard. A negative number indicates that the Best Fit standard was larger than the scan data.

$$\text{Percentage Difference} = \frac{\text{Scan Data - Best Fit Data}}{\text{Best Fit Data}} \times 100$$

Figure 29. Percentage difference formula.

The last column of distance indicates how many of the measures were 5% or more different from the Best Fit standard. An example of the usage of percentage formula is shown in Figure 30.

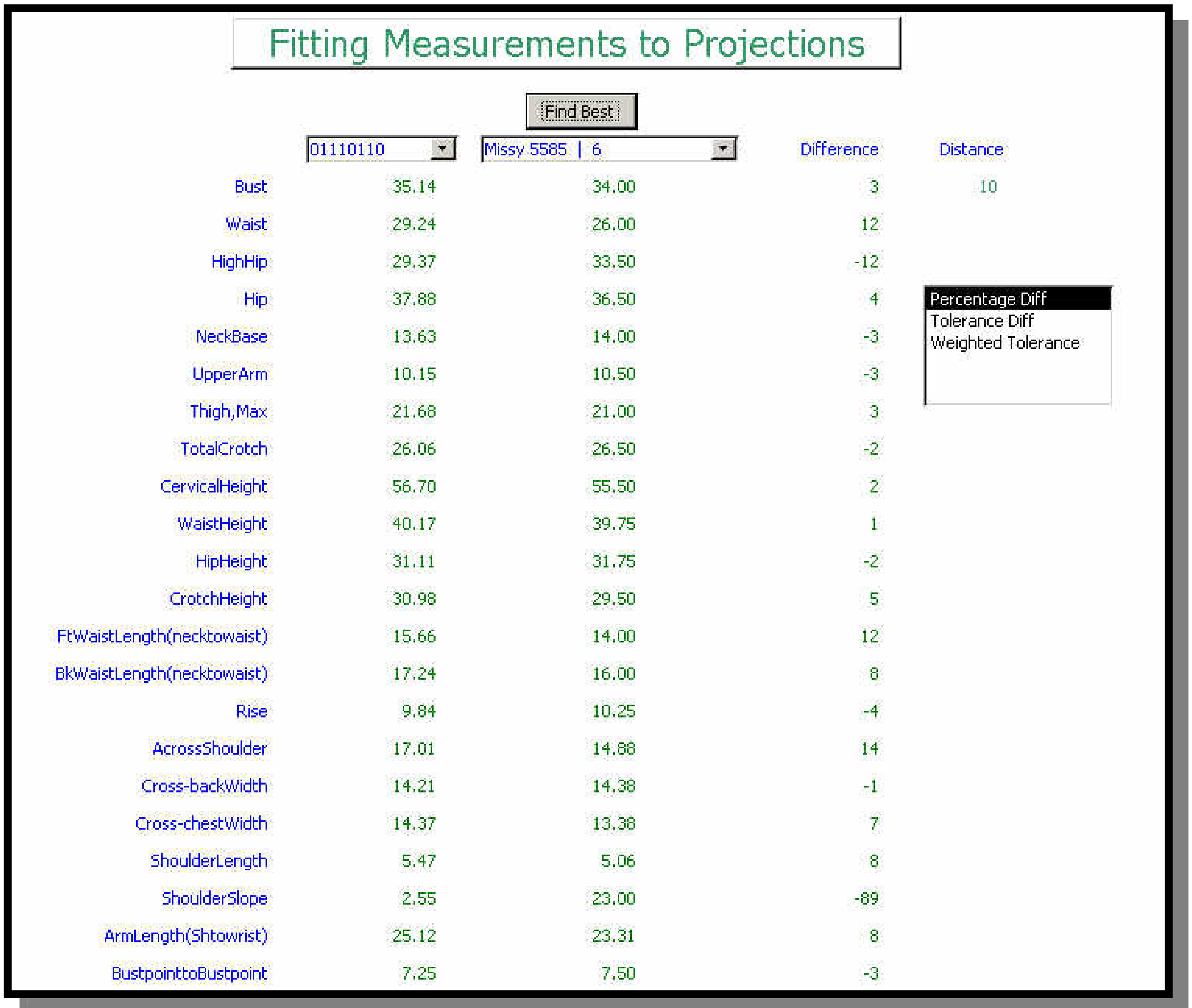


Figure 30. Example of percentage difference.

Determining Tolerance Difference

In calculating the tolerance difference, each measurement was identified with an acceptable tolerance that is most commonly used in the manufacturers of apparel. If the measurement was in-tolerance, the difference was identified as a "0". If the measurement was out-of-tolerance, the difference was calculated as a

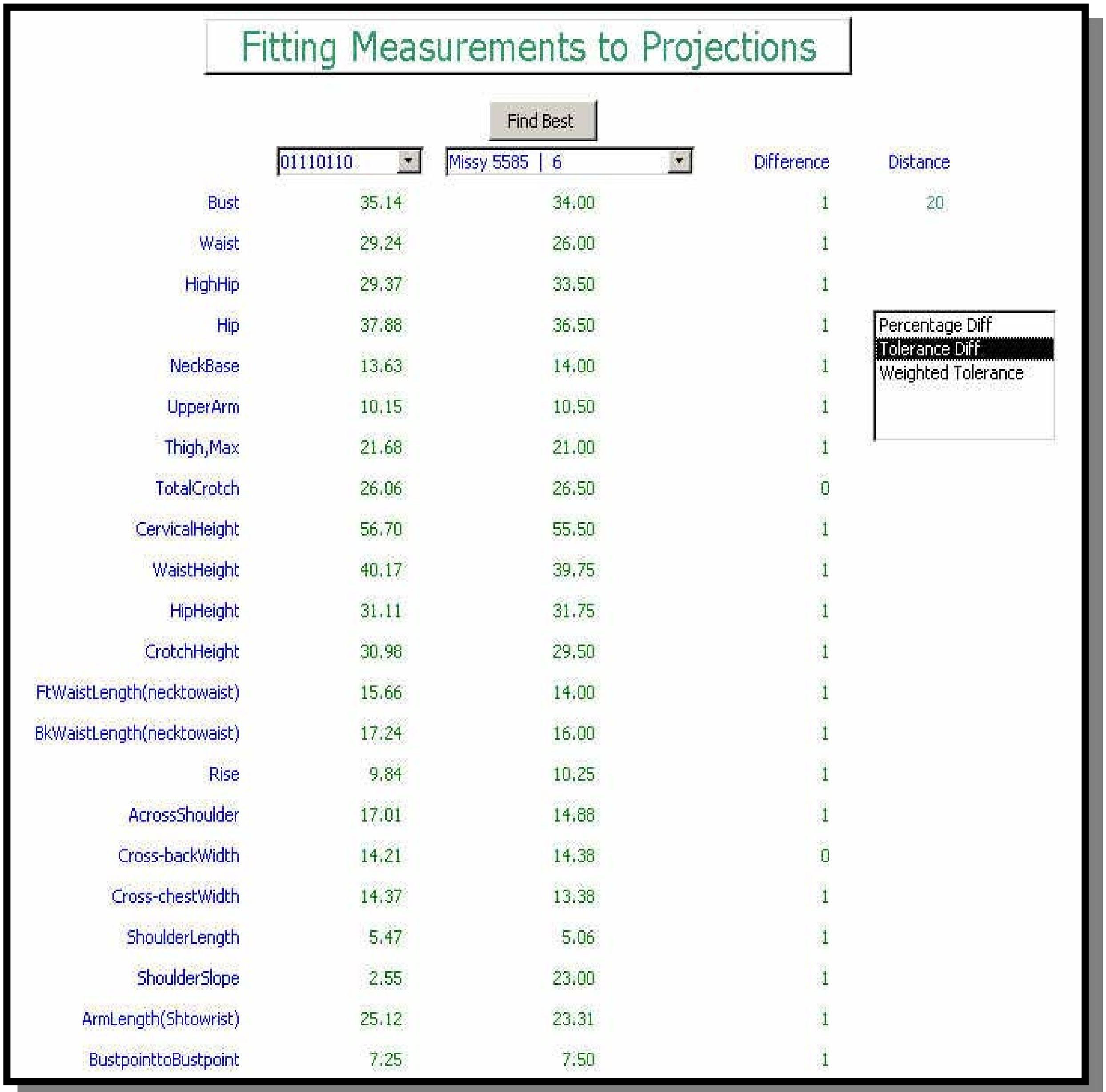
"1. Table 11 details the tolerances for each measurement used. The last column of distance indicates the total amount of measurements that were out-of-tolerance. See Figure 31 for an example of tolerance difference.

Table 11. Tolerances Used in the Best Fit Program.

Measure	Tolerance (inches) +/-	Measure	Tolerance (inches) +/-
Bust	0.5	Hip Height	0.25
Waist	0.5	Front Waist Length	0.375
Hip	0.5	Back Waist Length	0.375
High Hip	0.25	Rise	0.25
Neckbase	0.25	Cross Shoulder	0.375
Upper Arm	0.25	Cross Back Width	0.375
Thigh, Max	0.5	Cross Chest Width	0.375
Total Crotch	0.5	Shoulder Length	0.125
Cervical Height	0.75	Arm Length	0.25
Waist Height	0.375	Bust Point to Bust Point	0.25

Determining Weighted Tolerance Difference

In the production of clothing, some measurements have more importance, or might be weighted more, with respect to the production and fit of clothing. For the weighted tolerance difference, each measurement tolerance was given a weight based on best practices of apparel manufacturing. If the measurement was within tolerance, it was given a "0". If the measurement was out of range less than 2 times the tolerance amount, it was given a "1". If the measurement was out of range more than 2 times and less than 3 times the tolerance amount, it was given a "2". If the measurement was out of range more than 3 times the tolerance amount, it was given a "3". Figure 32 shows an example of the weighted tolerance difference. Table 12 illustrates the weights for the different measurements.



<u>Figure 31</u>. Example of a tolerance difference.

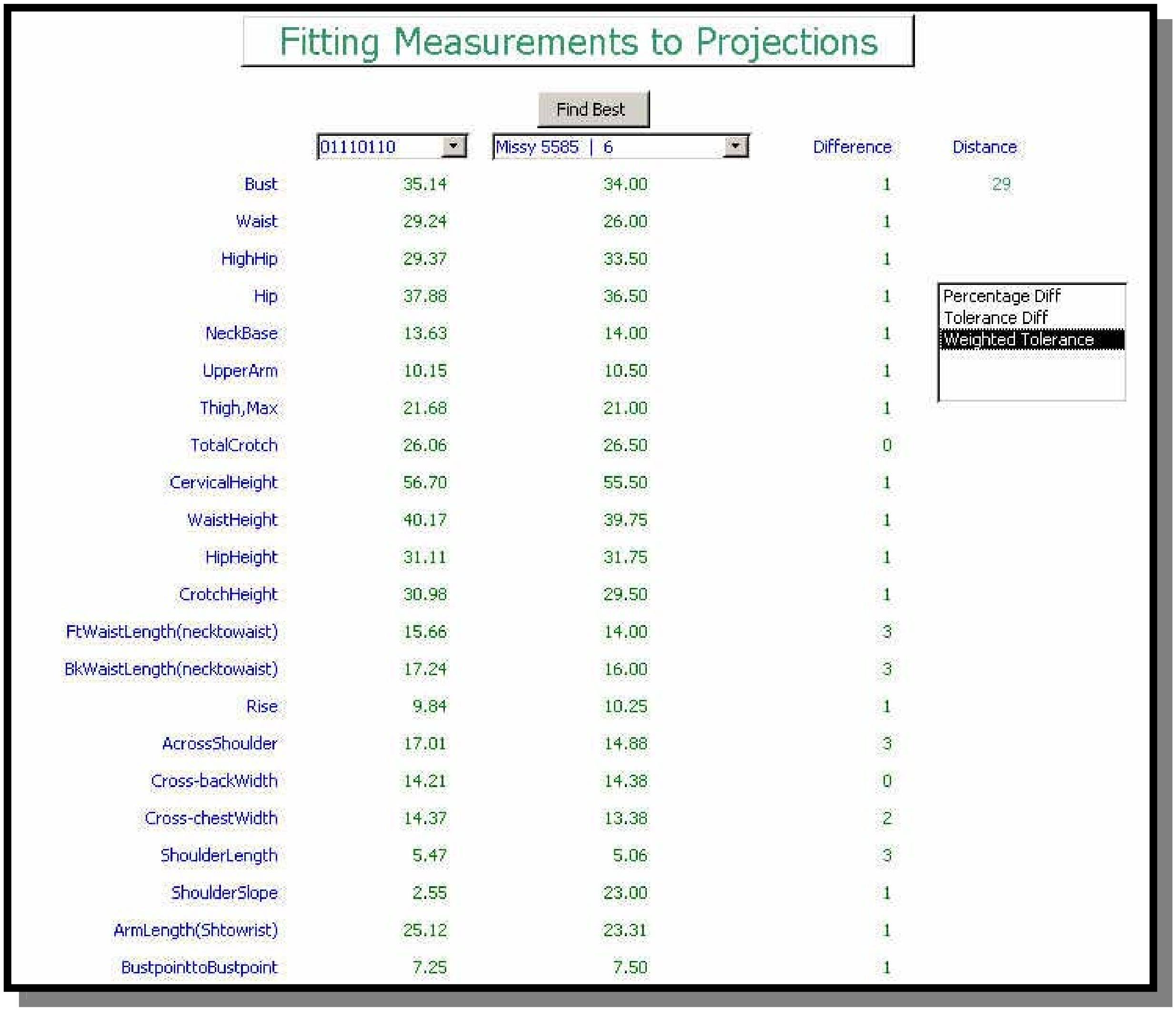


Figure 32. Example of a weighted tolerance difference.

Table 12. Weighted Tolerances for Each Measurement.

Measurement	Weighted Tolerance (inches)
Shoulder Length	0 = ≤ 0.125 1 = > 0.125 & ≤ 0.25 2 = > 0.25 & ≤ 0.375 3 = > 0.375
High Hip Neckbase Upper Arm Hip Height Rise Arm Length Bust Point to Bust Point	0 = ≤ 0.25 1 = >0.25 & ≤ 0.5 2 = > 0.5 & ≤ 0.75 3 = > 0.75
Bust Waist Hip Thigh, Max Total Crotch	0 = ≤ 0.5 1 = >0.5 & ≤ 1.0 2 = > 1.0 & ≤ 1.5 3 = > 1.5
Front Waist Length Back Waist Length Cross Shoulder Cross Back Width Cross Chest Width Waist Height	0 = ≤ 0.375 1 = >0.375 & ≤ 0.75 2 = > 0.75 & ≤ 1.125 3 = > 1.125

Body Shape Identification

The third objective of this research was to utilize software that could take 3D data and "sort" it into congruous and related categories (body or shape sort) based on measurements, proportion, and shape. After an exhaustive search for software that would be able to sort bodies into shape categories, it was determined that no software existed for that purpose. For this pilot study, computer code was written using Visual Basic programming that took extracted measurement data and identified certain body characteristics based on those measurements. Each of the subjects' measurement data was analyzed using this code to determine their shape or body type. The software code has been named, FFIT (Female Figure Identification Technique) for Apparel.

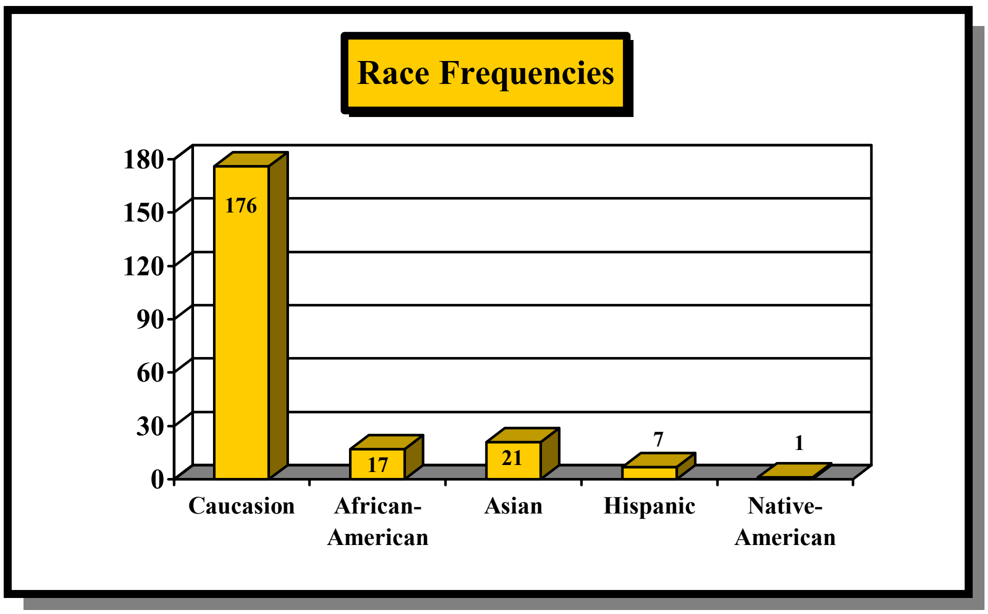
Subgroup Identification

The fourth objective of this research was to develop preliminary subgroups for the female population that would aid in the development of better fitting clothing. After analyzing all of the shapes that were identified by the FFIT for Apparel code, a name was developed that would reflect the characteristics of each shape.

RESULTS

Subject Information

In this study, 222 females 18 years of age and older were scanned as subjects. Almost 80% of the subjects were Caucasian with Asians and African-Americans trailing with 8.6% each. There were also a few Hispanics and a single Native American. See Figure 33.



<u>Figure 33</u>. Race frequencies for the 222 subjects.

The average age of the subjects was 24 with a range of 18 to 66 years of age. The majority of the subjects were less than 30 years old. See Figure 34. The average weight was 137 pounds with a range of 90 to 244 pounds. The majority of the subjects weighed between 100 and 150 pounds. See Figure 35. The average height was 5’5” with a range of 4’6” to 6’1”. The majority of the subjects were between 5’2” and 5’6” tall. See Figure 36.

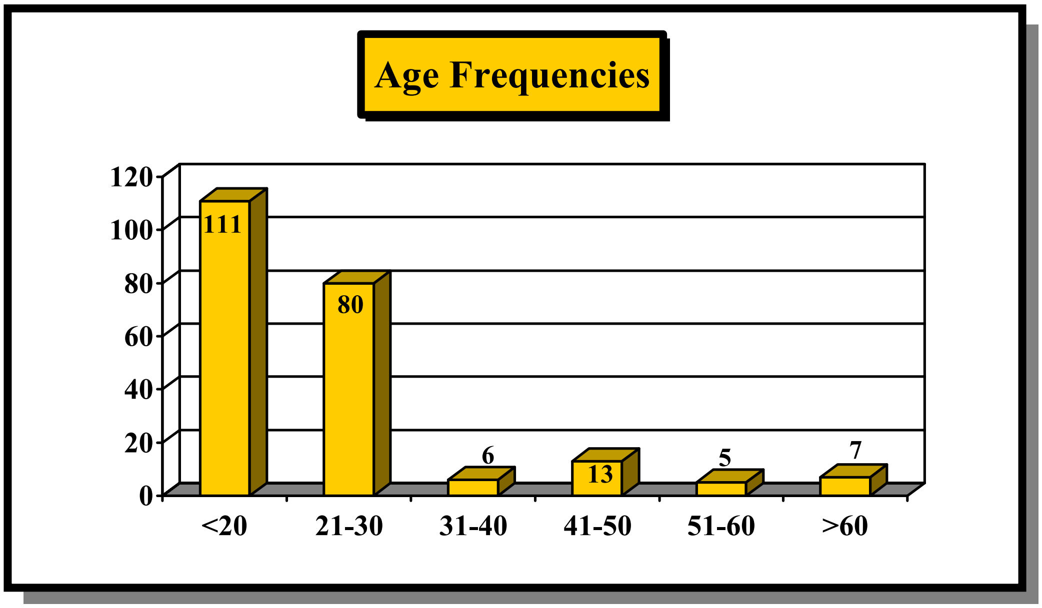


Figure 34. Age frequencies for the 222 subjects.

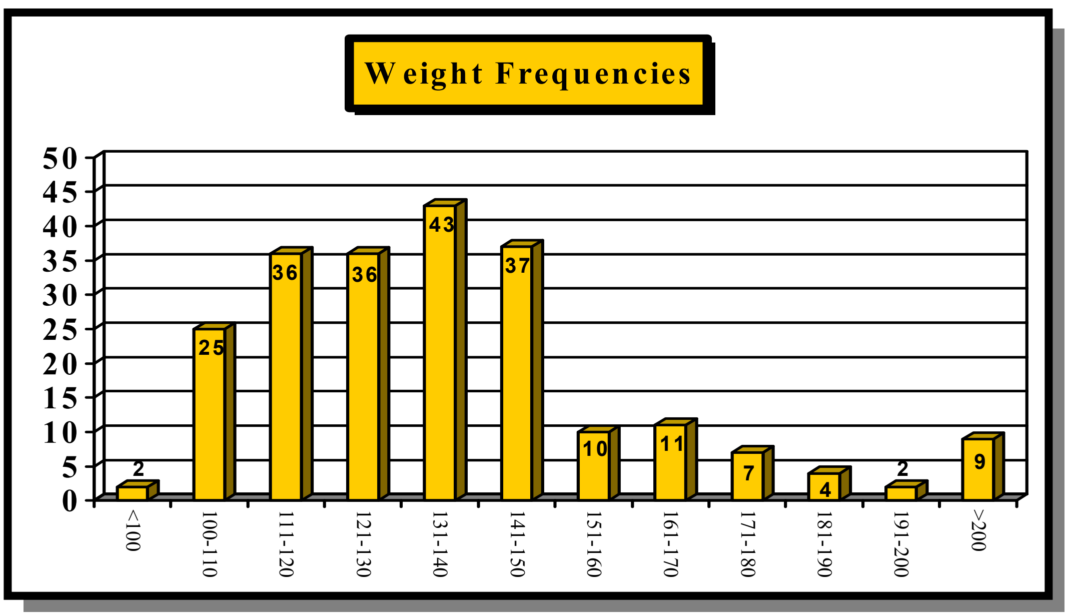


Figure 35. Weight frequencies for the 222 subjects.

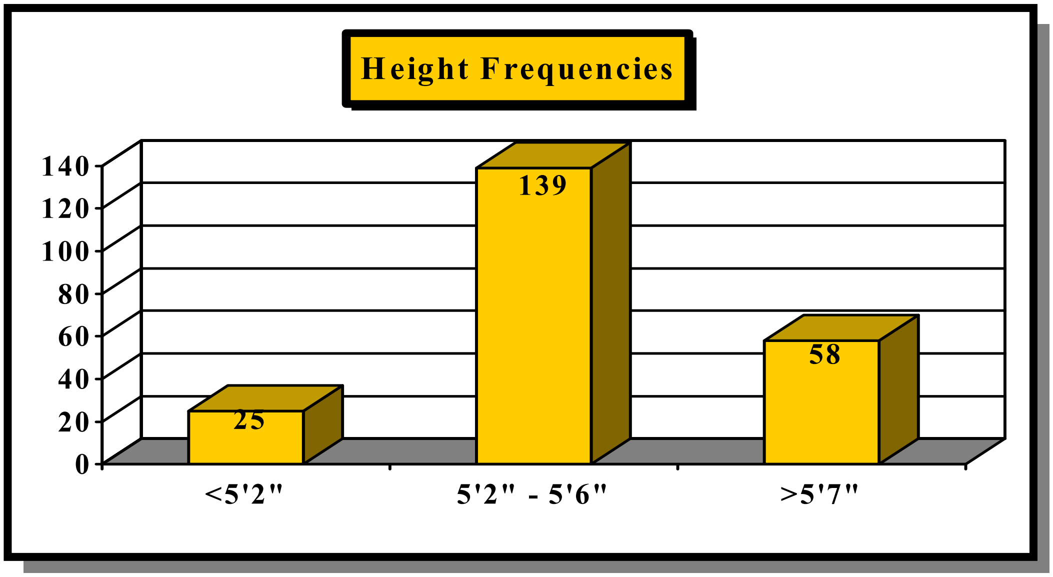


Figure 36. Height frequencies for the 222 subjects.

Database Development

The first objective of this research was to develop a database of 3D body scan data, from a variety of consumer markets, that included both measurement data, 3D point cloud data, and demographic data. A comprehensive database for the [TC]^2 Body Measurement System 2T4 model scanner that resides at North Carolina State College of Textiles was established using Microsoft Access 2000 as a platform. A total of 499 subjects were entered into the database that including demographic information (age, race, sex, height, and weight) on both males and females. The subjects ranged in age from 18 over 90 years. If for some reason a good scan was not acquired, that subject was dropped from the database.

Evaluation of Current Sizing Standards

The second objective of this research was to demonstrate that the current standards for body type classification are insufficient to meet the needs of the American people and to determine where significant deficiencies exist. A program was developed in Microsoft Access 2000 to derive a numerical difference in body measurements of the subjects compared to the current ASTM sizing standards, as well as past sizing standards, and to determine where inconsistencies exist.

Percentage Difference

The frequency of the standards that corresponded most closely with the subject data sets, according to the percent difference, can be found in Figure 37. The standard that was the most compatible with the majority of subjects was the CS215-58 database. A description of the tally for the standards can be found in Table 13.

For the percentage difference, the scan data was subtracted from the Best Fit data which was divided by the Best Fit data then multiplied by 100. A positive number indicated that the scan data was larger than the Best Fit standard. A negative number indicated that the Best Fit standard was larger than the scan data. In this study, all of the "Best Fit" measures that exceeded a 2% difference were smaller than the subjects scanned measures. Over 93% of the subjects measurements that were greater than 5% larger than the standard that gave them the best fit. See Figure 38 .

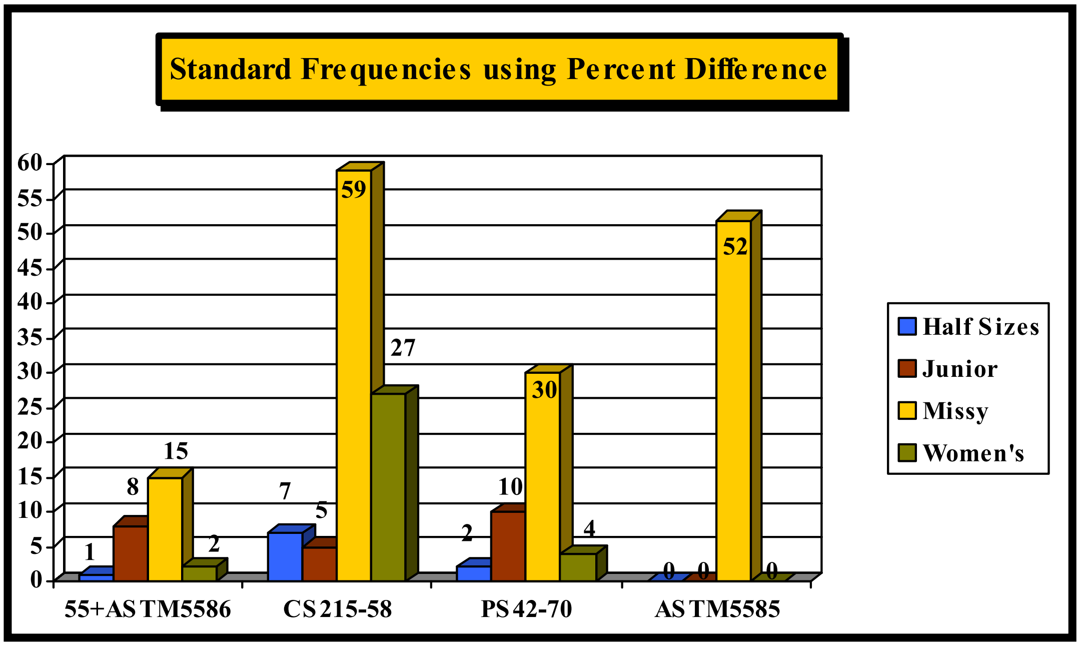
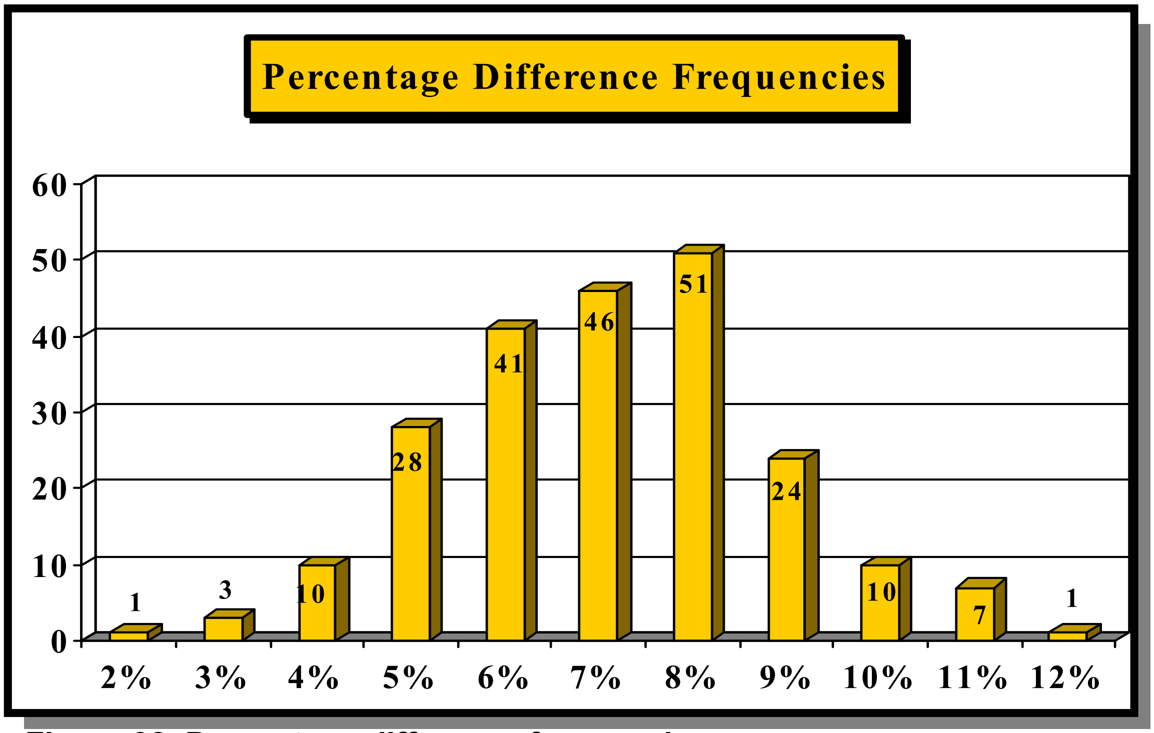


Figure 37. Standard frequencies using percentage differences.

Table 13. Tally of Most Compatible Standards for Percentage Difference.

Standard	Frequency
CS215-58	98
ASTM 5585	52
PS42-70	46
55+ASTM 5586	26



<u>Figure 38</u>. Percentage difference frequencies.

<u>Tolerance Difference</u>

The frequency of the standards that corresponded most closely with the subject data sets, according to the tolerance difference, can be found in

Figure 39. The standard that was the most compatible with the majority of subjects was the 55+ASTM 5586-95 database. A description of the tally for the standards can be found in Table 14.

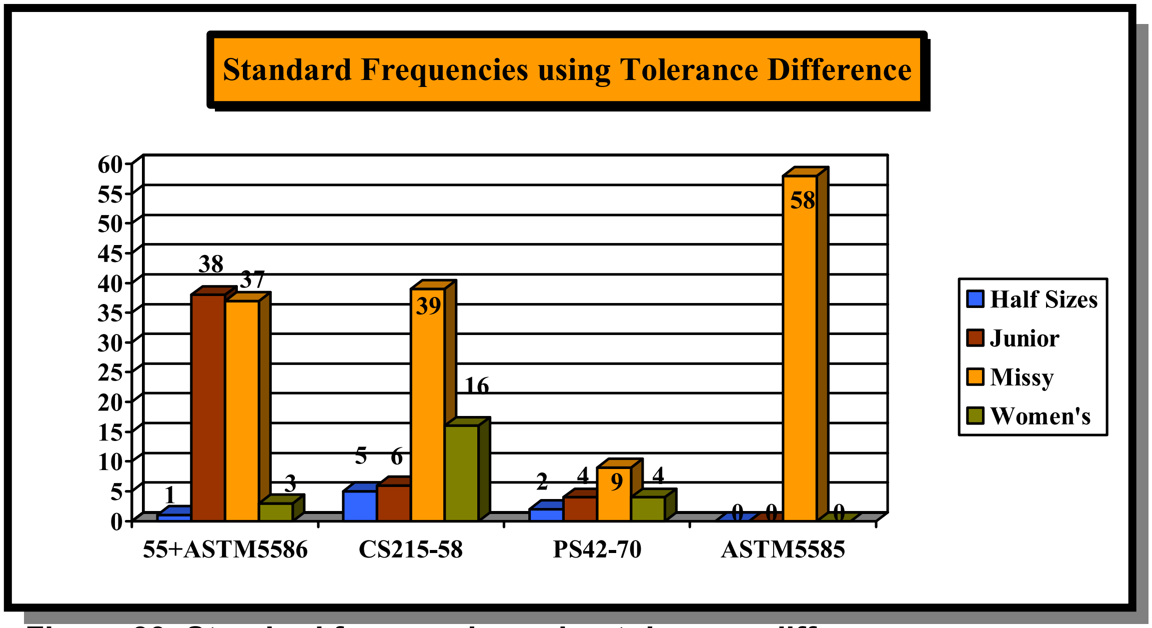
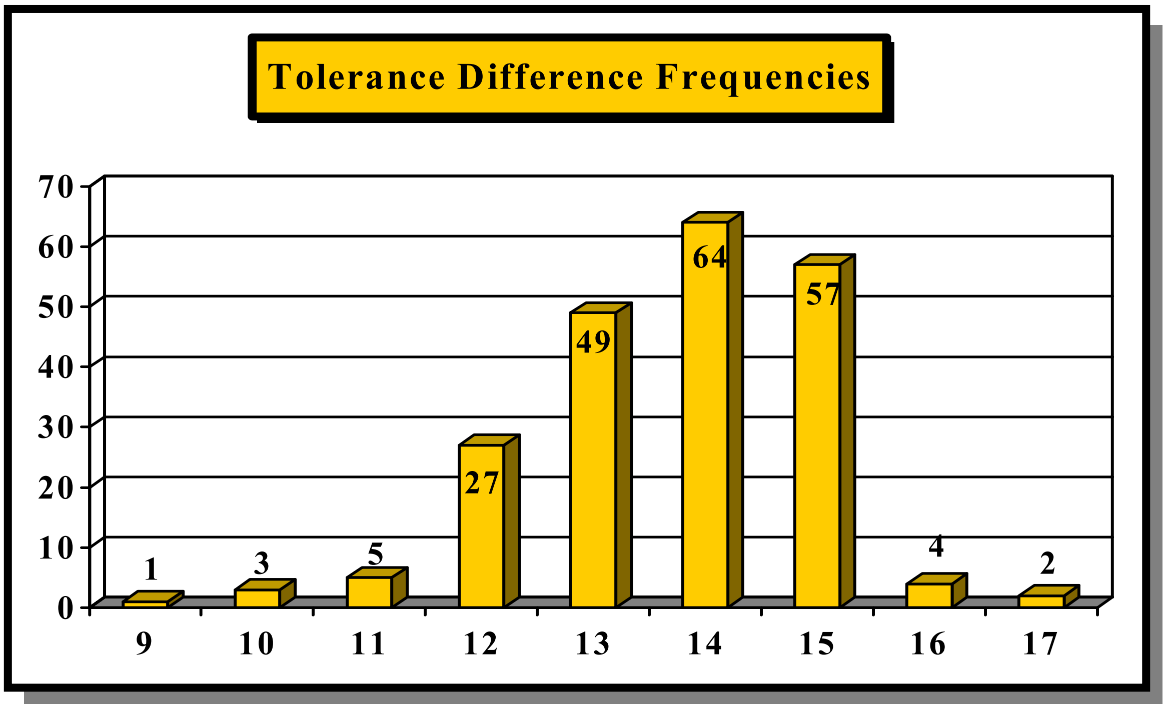


Figure 39. Standard frequencies using tolerance difference.

Table 14. Tally of Most Compatible Standards for Tolerance Difference.

Standard	Frequency
55+ASTM 5586	79
CS215-58	66
ASTM 5585	58
PS42-70	19

In calculating the tolerance difference, each measurement was identified with an acceptable tolerance that is most commonly used in apparel manufacturing. If the measurement was in-tolerance, the difference was identified as a "0". If the measurement was out-of-tolerance, the difference was calculated as a “1. In this study, all of the subject data sets were had at least 9 measurements that were out-of-tolerance with the defined “best fit” standard. Over 96% of the data sets had 12 to 17 measurements that were out-of-tolerance. See Figure 40.



<u>Figure 40</u>. Tolerance difference frequencies.

<u>Weighted Tolerance Difference</u>

The frequency of the standards that corresponded most closely with the subject data sets, according to the weighted tolerance difference, can be found in Figure 41. The standard that was the most compatible with the majority of subjects was the 55+ASTM 5586-95 database. A description of the tally for the standards can be found in Table 15.

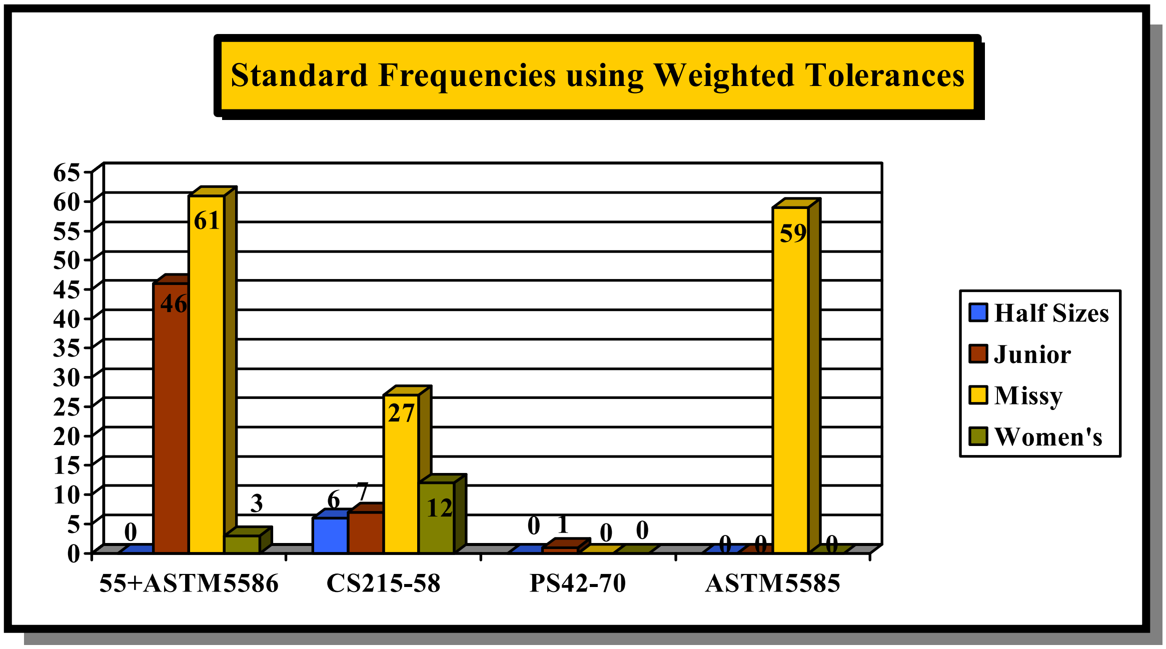


Figure 41. Standard frequencies using weighted tolerance difference.

Table 15. Tally of Most Compatible Standards for Weighted Tolerance Difference.

Standard	Frequency
55+ASTM 5586	110
ASTM 5585	59
CS215-58	52
PS42-70	1

For the weighted tolerance difference, each measurement tolerance was given a weight based on best practices of manufacturers of apparel. If the measurement was within tolerance, it was given a “0”. If the measurement was out of range less than 2 times the tolerance amount, it was given a “1”. If the measurement was out of range more than 2 times and less than 3 times the tolerance amount, it was given a “2”. If the measurement was out of range more than 3 times the tolerance amount, it was given a “3”. In this study, all of the subjects had combined weighted tolerances for all the measurements that were greater than 11. Over 95% of the data sets had combined weighted tolerances of 16 to 28. See Figure 42.

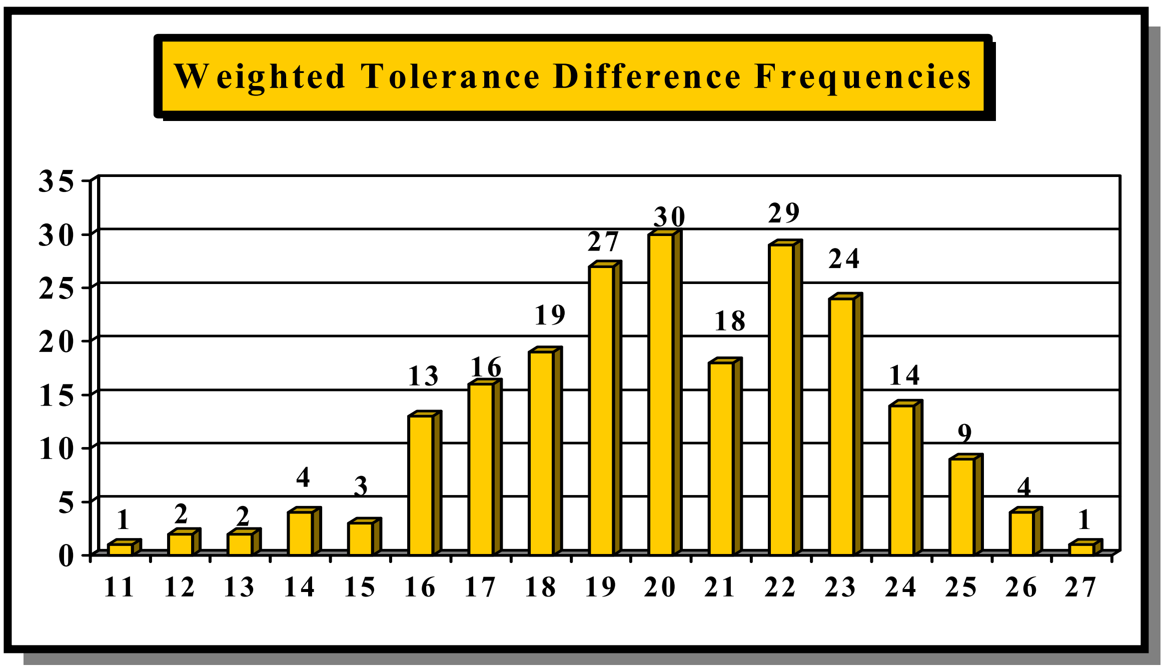


Figure 42. Weighted tolerance difference frequencies.

Best Fit for All Subjects

The objective of the Best Fit software was to demonstrate that the current standards for body type classification are insufficient and to determine where significant deficiencies exist. For all three criteria of the Best Fit software (percentage difference, tolerance difference, and weighted tolerance difference), the standard that most closely matched the subject measurements was the CS215-58 standard. See Table 16.

Table 16. Tally for Standards Used in Best Fit for All Subjects.

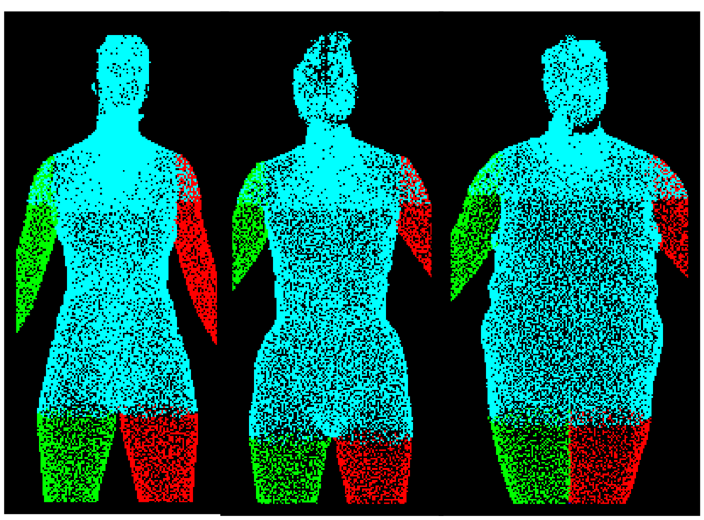
	CS215-58	55+ASTM 5586-95	ASTM 5585-95	PS42-70
Percentage Difference	98	26	52	46
Tolerance Difference	66	79	58	19
Weighted Tolerance Difference	59	110	52	1
Total	**223**	**215**	**162**	**66**

Shape Sorting and Subgroup Identification

The third objective of this research was to utilize software that can take 3D data and "sort" it into congruous and related categories (body or shape sort) based on measurements, proportion, and shape and then to develop preliminary subgroups for the female population that would aid in the development of better fitting clothing (fourth objective). After an exhaustive search for software that would be able to sort bodies into shape categories, it was determined that no software existed for that purpose.

However, a rudimentary software, written with Visual Basic programming, was obtained from [TC^2]. It took extracted measurement data and identified certain body characteristics based on those measurements. These characteristics included prominent/regular/flat seat, long/regular/short-waisted torso, and several other body characteristics. The [TC^2] software did not, however, include anything that placed bodies into shape categories. New code was developed to achieve the shape sorting objective.

To help determine the measurement grouping that would adequately describe figures for these subjects, a statistical examination using variable distribution and cluster analysis was performed on the data. The cluster analysis did not seem to work by evidence of subjects being placed with visually different body shapes in the same category. It was determined after a consultation with a statistician that cluster analysis and any other statistical method were not appropriate in this instance. The experts at SAS Institute, in Cary, North Carolina, are being contacted to help develop a solution for this problem. Examples of the different shapes that were placed together by the cluster analysis can be found in Figure 43.



<u>Figure 43</u>. Cluster analysis of shapes within the same category.

A comprehensive literature search was conducted to examine the elements or qualifiers for all of the pre-existing body shape classifications. The majority of methods used a simple visual process of classification with a vague list of descriptors to define the bodies that fell in each category. None of the methods used mathematical formulas, ratios, or descriptors to aid in the determination of body shapes. Through Visual Basic, a new shape sorting software was created using the [TC^2] software as a structural base. The elements for shape classification determined from the literature search were used as a starting point for the shapes. Once the basic shape categories were identified from literature, the relative visual and descriptive information was evaluated to help determine a mathematical logic that could be of valuable, requisitic information that could successfully identify shapes. Using mathematical criteria, the tacit knowledge of experts in apparel design, development, and fit, code was written for the software.

In the first draft of the software, five shape categories were identified, “hourglass”, “oval”, “triangle”, “inverted triangle”, and “rectangle”. Each shape category was then given ranges of numerical values that corresponded to the body measurements that were significant for that shape. The “bust”, “waist”, “hip”, “stomach”, and “abdomen” circumferences were used in combination to describe each shape. Measurements such as shoulder width, rise, and others were not included because they can more easily adjusted within each shape category. After consideration of all of the available measurements that would describe the body, these basic ratios were essential circumferential measurements that are elemental for shape and for well fitting clothing.

A control data set of 31 females was obtained from [TC]^2 with unknown height, weight, and age information. This data was not part of the subject sample group. The software was initially tested on this group and yielded a subject in every shape group, indicating that the software would work. It was also used as a testing mechanism throughout the iterations of the software.

When the 222 subject measurements were tested using the software for the first time, many subjects did not fall into any category. This indicated that more categories were needed. As a result, four new categories were created that resembled shapes of a “spoon”, “diamond”, ”bottom hourglass”, and “top hourglass”. Numerical values that corresponded to the body measurements that were significant to these new shapes were added into the programming through Visual Basic. With the addition of these four new groups, now a total of nine groups, every subject fell into a shape category. In order to verify that all of the categories were correctly identified and the numerical values associated with each were accurate, the control data set was tested using the software with all shape categories being given an identifying shape. However, when the 222 subjects were run through the software for the second time, all of the subjects were given a shape identifier but all categories were not represented. Also, a visual check was made to each subject shape for verification that the shape labeled by the software was correct.

Individual Shape Category Information

All Categories

For the 222 subjects, over 40% of were designated as belonging to the Bottom Hourglass category followed by Hourglass (21.6%), Spoon (17.1%), Rectangle (15.8%), Oval (3.6%), and Triangle (1.8%). See Figure 44. There were no bodies that reflected the shapes of Inverted Triangle, Diamond, or Top Hourglass. In the control data set, there were representatives of all shape categories except for Triangle and Top Hourglass. Demographic information for each of the shape categories can be found in Figure 45. Each shape category section will cover this information in detail.

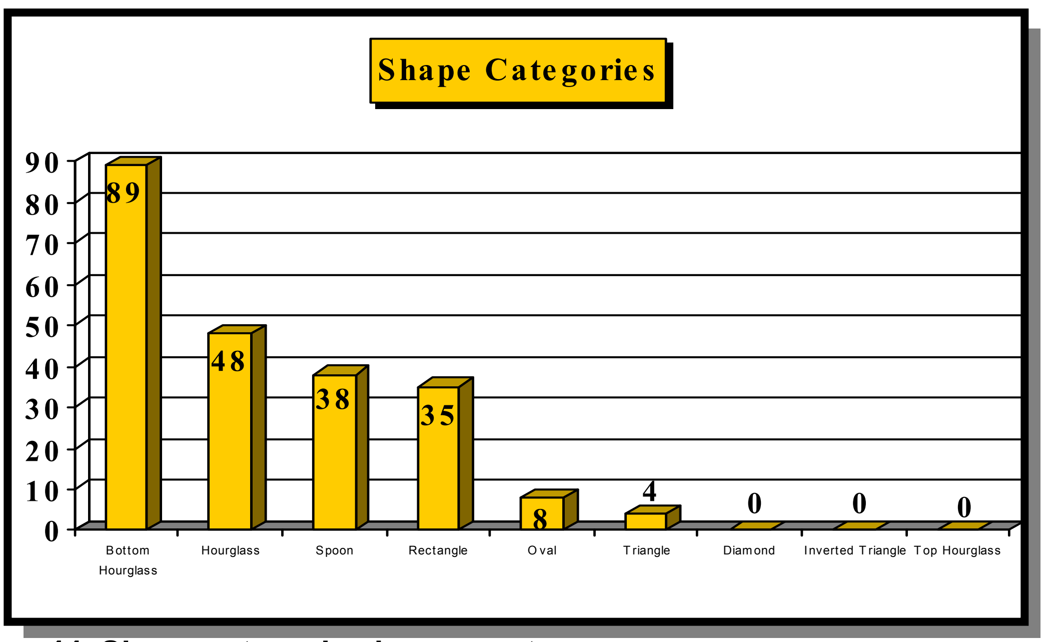


Figure 44. Shape categories by amounts.

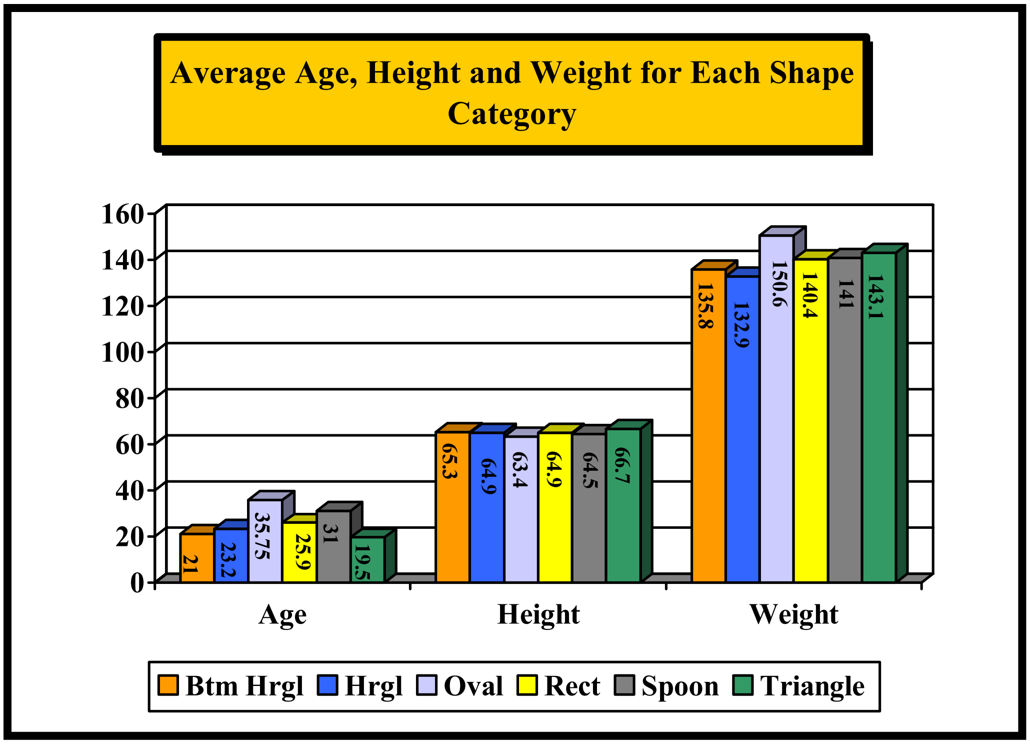


Figure 45. Average age, height, and weight for each shape category.

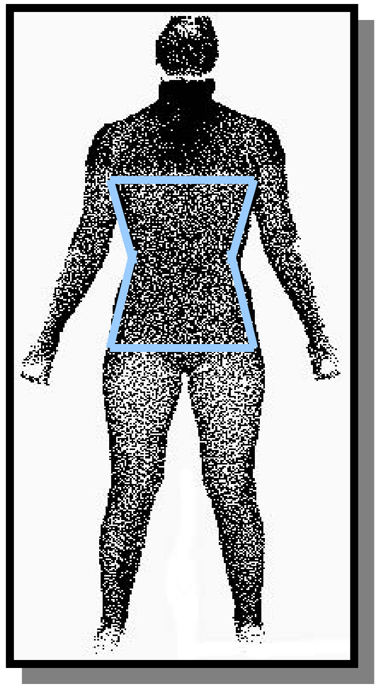
Hourglass Shape

Even though the Bottom Hourglass category was the dominating category for this study, the Hourglass category warrants discussion first because it is the basis from which the Bottom and Top Hourglass categories were created. In the Hourglass category, there were 48 subjects whose body shapes resembled a sand-filled timepiece called an Hourglass. The Hourglass shape category was the second largest category having 21.6% of the total (48/222). The predominate race of the subjects was Caucasian (90%) with a few African-Americans (6.3%) and Hispanics (4.2%). The average age for this category was 23 with a range of 18 to 61 years old. The average height was 65 inches (5'5") with a range of 60 inches (5') to 71 inches (5'11"). The average weight for the Hourglass category was 133 pounds with a range of 103 to 211 pounds.

The body measurements used to define the Hourglass category were the bust, waist, and hips. The underlying criteria of the Hourglass shape says that if a subject has a very small difference in the comparison of the circumferences of their bust and hips AND if the ratios of their bust-to-waist and hips-to-waist are about equal and significant, then it will fall into the shape category of Hourglass. The person with an Hourglass shape has the appearance of being proportional in the bust and hips with a defined waistline.

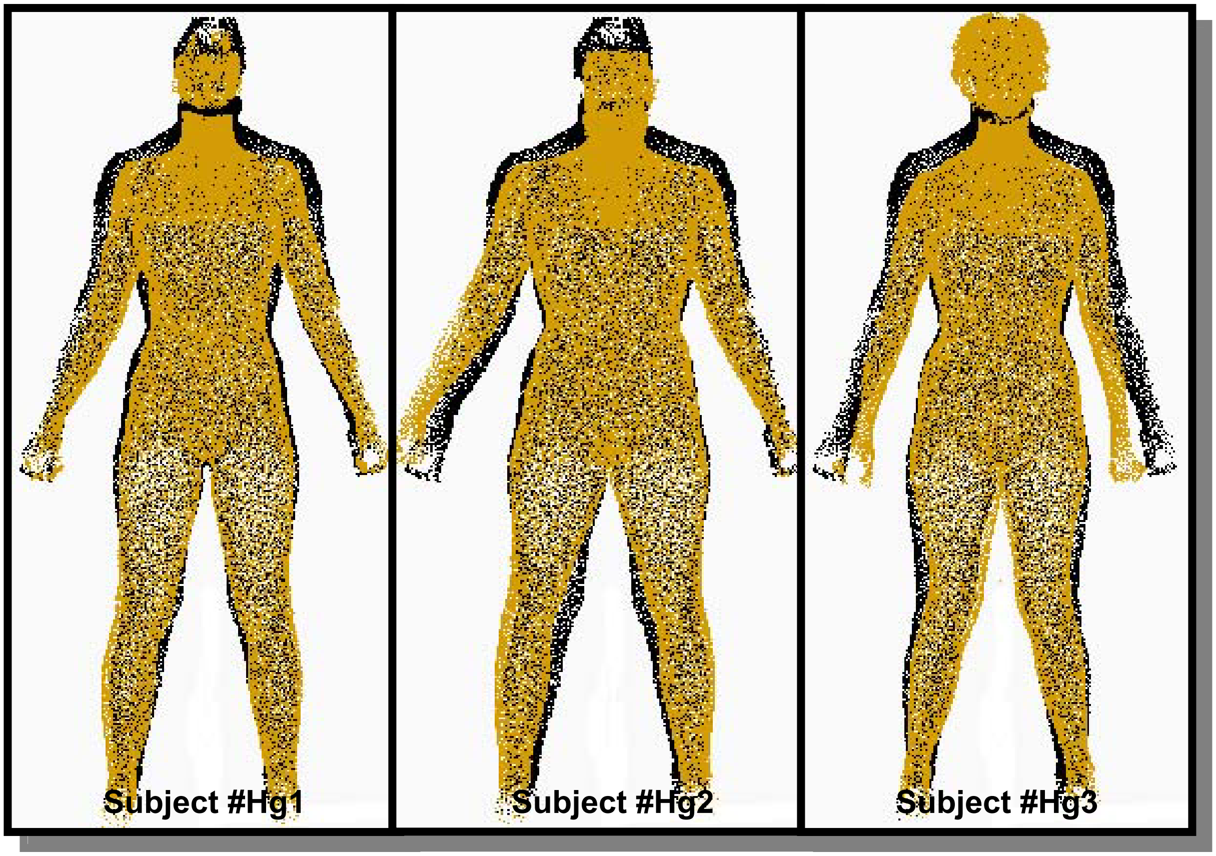
The FFIT for Apparel program searches for the Hourglass shape criteria first. If the subject's measurements fall within the range of values set for each measure of the Hourglass shape, then the program with give the subject a shape designation of Hourglass. If the subject's measurements DO NOT fall within the range of values set for each measure of the Hourglass shape, then the program will continue to search for a qualifying shape.

In Figure 46, Subject #HgTrue has the circumferential measurements that meet the Hourglass shape criteria and is an example of a true Hourglass shape. She is equally proportionate in her bust and hips AND the ratios of her bust-to-waist and hips-to-waist are about equal and create a defined waistline.



<u>Figure 46</u>. Example of a true Hourglass shape, Subject #HgTrue.

All of the 48 subjects with the Hourglass shape were visually verified individually to determine that the shape designation given by <u>FFIT for Apparel</u> was correct. Examples of 3 random Hourglass shaped subjects are found in Figure 47. Each is superimposed over the true Hourglass shape example (Subject #HgTrue) to visually verify the proportionate body shape of the Hourglass figure.



<u>Figure 47</u>. Subjects in the Hourglass shape category superimposed on the example of a true Hourglass shape.

<u>Bottom Hourglass</u>

The Bottom Hourglass was the largest shape category of this study with 40% of the subjects. There were 89 subjects with body shapes which were defined as Bottom Hourglass. The racial breakdown of the subjects was Caucasian (77.5%) with a few African-Americans (10.1%), Asians (9%), Hispanics (2.2%) and a single Native-American (1.1%). The average age for this category was 21 with a range of 18 to 46 years old. The average height of the subjects in this category was 65.5 inches (5'5½") with a range of 61 inches (5'1") to 73 inches (6'1"). The average weight for the subjects in the Bottom Hourglass category was 137 pounds with a range of 101 to 218 pounds.

This shape category is a subset of the Hourglass category. The shape category of Bottom Hourglass was determined by utilizing the same body measurements of the bust, waist, and hips just as in the Hourglass. However, there is a slight difference in the two categories. The Bottom Hourglass shape category utilizes the underlying criteria that if a subject has a larger hip circumference than bust circumference AND if the ratios of their bust-to-waist and hips-to-waist are significant enough to produce a definite waistline, then their body will fall into the shape category of Bottom Hourglass. The person with the Bottom Hourglass shape has the appearance of being larger in the hips but still having a defined waistline.

This shape differs from the Triangle because it has a defined waistline and the Triangle does not. The FFIT for Apparel program searches for the Bottom Hourglass shape criteria before the Triangle. If the subject's measurements fall within the range of values set for each measure of the Bottom Hourglass shape, then the program with give the subject a shape designation of Bottom Hourglass. If the subject's measurements DO NOT fall within the range of values set for each measure of the Bottom Hourglass shape, then the program will continue to search for a qualifying shape. Most subjects whose measurements slightly miss the Bottom Hourglass shape category will usually end up being a Triangle primarily due to the lack of waist definition.

In Figure 48, Subject #BHgTrue has the circumferential measurements that meet the Bottom Hourglass shape criteria and is an example of a true Bottom Hourglass shape. Her bust-to-waist and hips-to-waist ratios are significant with her hips measurement being slightly larger than her bust. She also has a defined waistline. A visual representation of the difference in the Hourglass and Bottom Hourglass shapes (primarily in the hips) can be found in Figure 49.

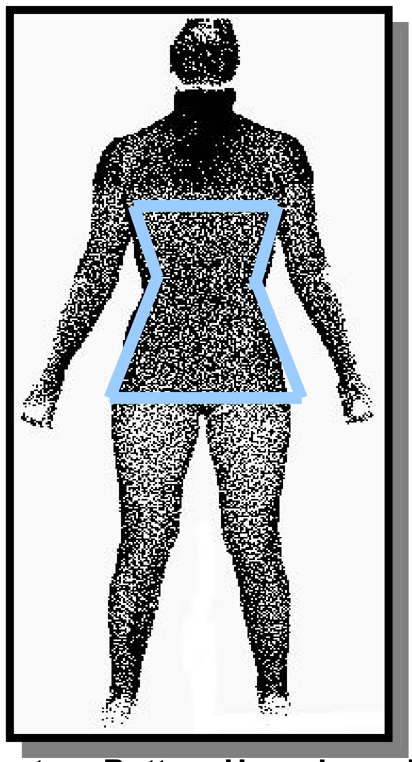
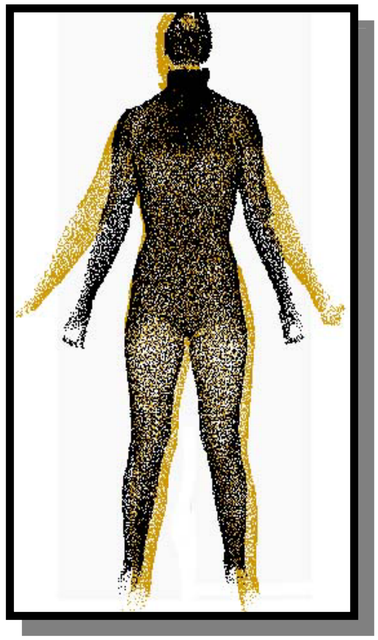
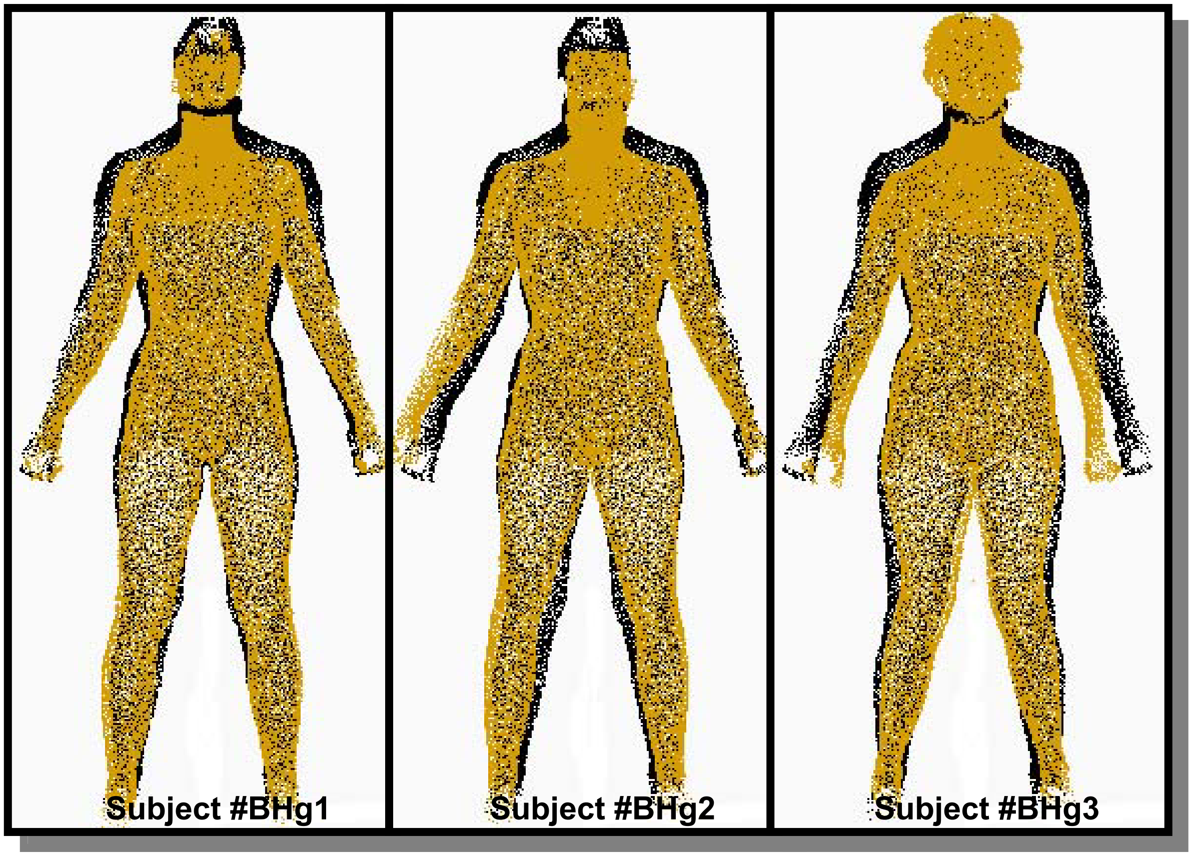


Figure 48. Example of a true Bottom Hourglass shape, Subject #BHgTrue.



<u>Figure 49.</u> An Hourglass body shape (black) superimposed onto a Bottom Hourglass body shape (yellow).

All of the 89 subjects with the Bottom Hourglass shape were visually verified individually that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Bottom Hourglass shaped subjects are found in Figure 50. Each is superimposed over the true Bottom Hourglass shape example (Subject #BHgTrue) to visually verify the proportionate body shape of the Bottom Hourglass figure.



<u>Figure 50.</u> Bottom Hourglass shape comparison.

<u>Top Hourglass</u>

The shape category of Top Hourglass was determined by utilizing the same body measurements of the bust, waist, and hips as in the Hourglass. However, there is a difference in the two categories. The underlying criteria for the Top Hourglass shape category says that if a subject has a larger bust circumference than hips circumference AND if the ratios of their bust-to-waist and hips-to-waist measures are significant enough to produce a definite waistline, then their body will fall into the shape category of Top Hourglass. The person with a Top Hourglass shape has the appearance of being heavy in the bust as compared to the hips but still has a defined waistline.

This shape differs from the Inverted Triangle because it uses the bust-to-waist ratio to identify a defined waist where the Inverted Triangle does not. The FFIT for Apparel program searches for the Top Hourglass shape criteria before the Inverted Triangle. If the subject's measurements fall within the range of values set for each measure of the Top Hourglass shape, then the program with give the subject a shape designation of Top Hourglass. If the subject's measurements DO NOT fall within the range of values set for each criteria of the Top Hourglass shape, then the program will continue to search for a qualifying shape. Most subjects whose measurements slightly miss the Top Hourglass shape category will usually end up being an Inverted Triangle primarily due to the lack of waist definition.

For this study, no subjects fell into the Top Hourglass category, nor for the control data set. A simplistic representation of the shape without contrast of a body form is compared with the Hourglass and Bottom Hourglass shapes in Figure 51.

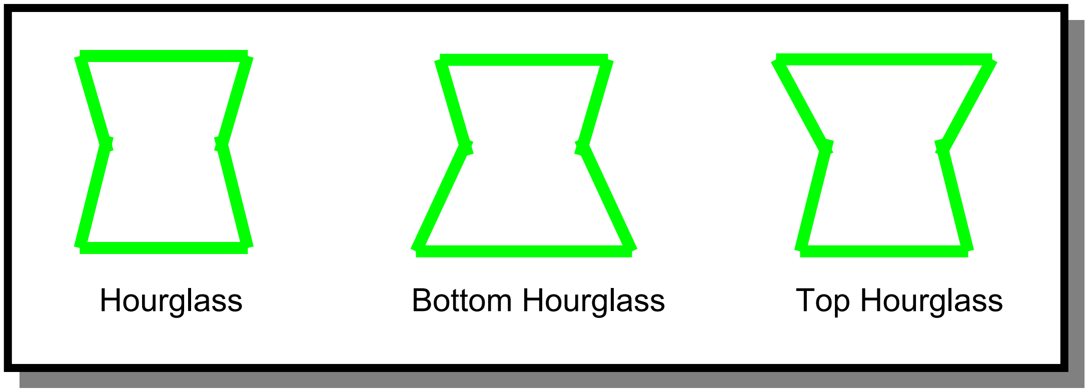


Figure 51. Comparison of the Hourglass, Bottom Hourglass, and Top Hourglass shapes.

Spoon

The Spoon was the third largest shape category of this study with 17% of the subjects or 38 of 222. The racial mix of the subjects was Caucasian (76.3%) with a few African-Americans (10.5%), Asians (10.5%), and a single Hispanic (2.6%). The average age for this category was 30 with a range of 18 to 65 years old. The average height was 64.5 inches (5'4½") with a range of 59 inches (4'11") to 69.5 inches (5'9½"). The average weight for the Spoon category was 141 pounds with a range of 90 to 217 pounds.

The shape category of Spoon was determined by utilizing the body measurements of the bust, waist, hips and high hip. The Spoon shape category utilizes the underlying criteria that if a subject has a larger circumferential difference in their hips and bust AND if their bust-to-waist ratio is lower than the Houglass shape AND high hip-to-waist ratio is high, then it will fall into the shape category of Spoon. The person with a Spoon shape is characterized by having a "shelf" at their hips. The waist tapers from the bust yielding a prominent waistline but, starting at the waist going down, the high hip and hip project straight out to the side unlike other shapes that gradually taper from the waist to the hip area.

The FFIT for Apparel program searches for the Spoon shape criteria immediately following the Hourglass. If the subject's measurements fall within the range of values set for each measure of the Spoon shape, then the program with give the subject a shape designation of Spoon. If the subject's measurements DO NOT fall within the range of values set for each measure of the Spoon shape, then the program will continue to search for a qualifying shape. The critical identifier for this shape is the high hip to waist ratio.

In Figure 52, Subject #SpoonTrue has the circumferential measurements that meet the Spoon shape criteria and is an example of a true Spoon shape. Her waist tapers from her bust with a definite waistline and there is a distinct shelf that protrudes from the hip area. A visual representation of the difference in the Hourglass and Spoon shapes (primarily in the high hip area) can be found in Figure 53.

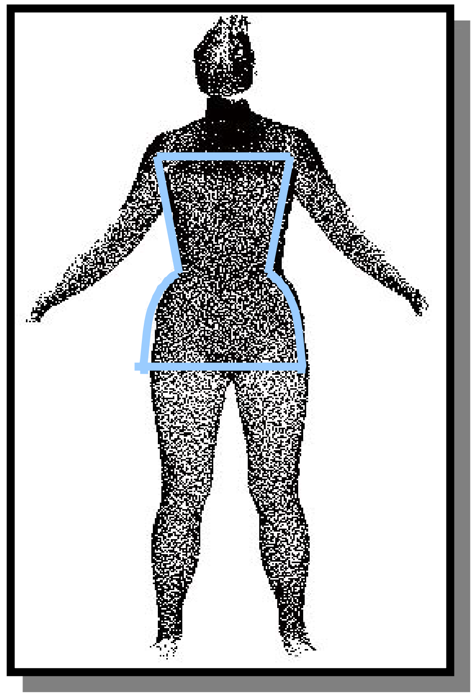


Figure 52. Example of a true Spoon shape, Subject #SpoonTrue.

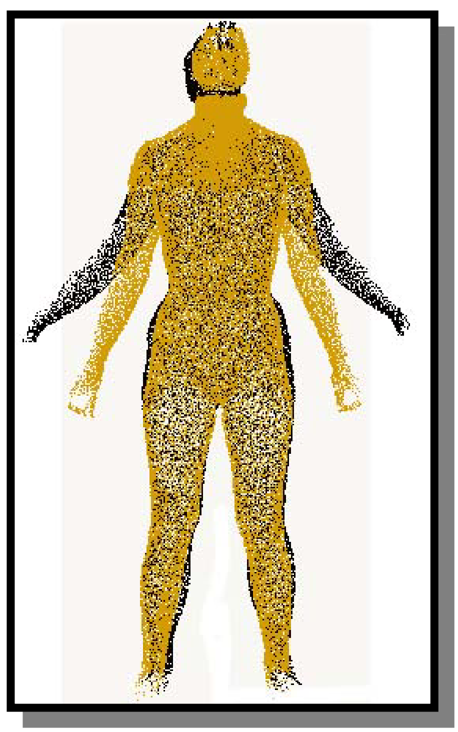


Figure 53. An Hourglass body shape (yellow) superimposed onto a Spoon body shape (black).

All of the 38 subjects with the Spoon shape were visually verified individually that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Spoon shaped subjects are found in Figure 54. Each is superimposed over the true Spoon shape example (Subject #SpoonTrue) to visually verify the proportionate body shape of the Spoon figure.

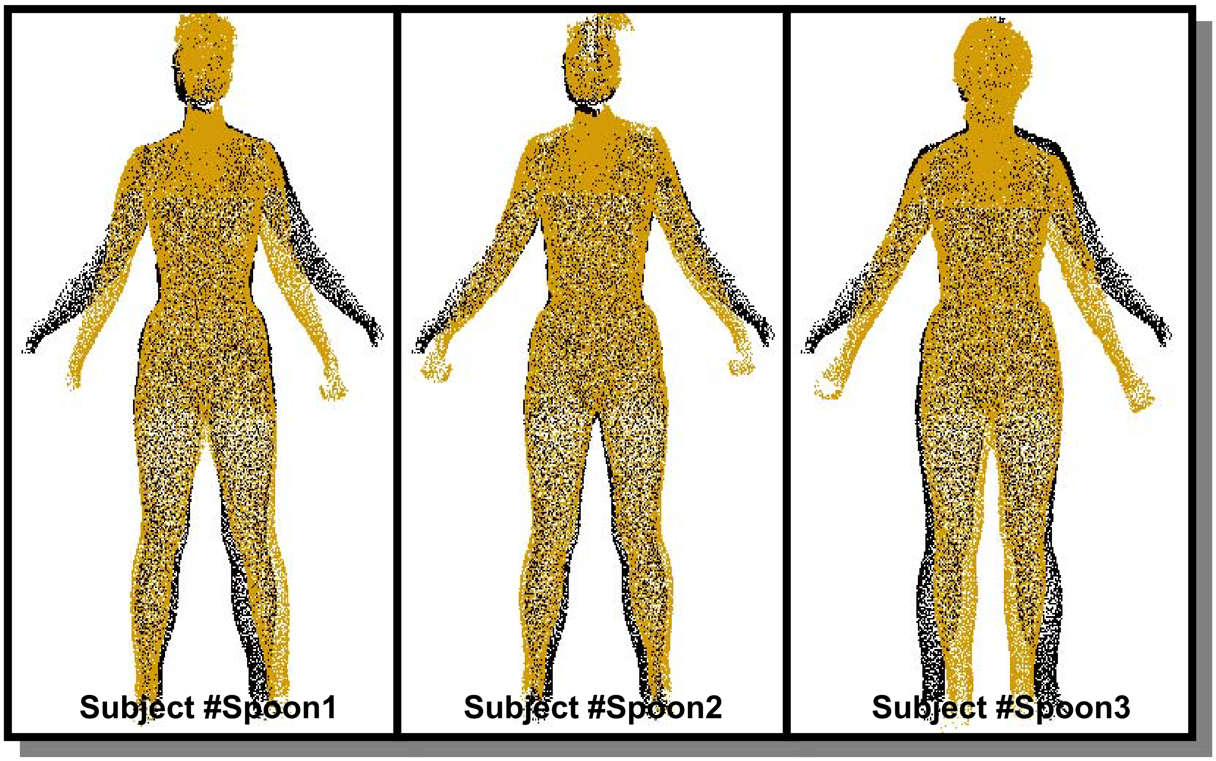


Figure 54. Subjects in the Spoon shape category superimposed on the example of a true Spoon shape.

Rectangle

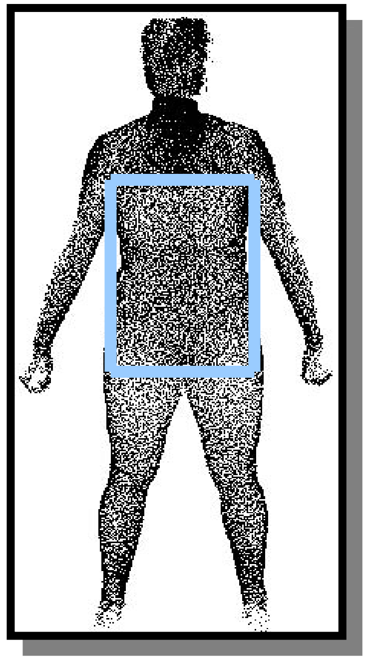
The Rectangle was the fourth largest shape category of this study with 15.8% of the subjects (35 of the 222). The racial mixture of the subjects was Caucasian (77.1%) with a few Asians (20%), and a single African-American

(2.9%). The average age for this category was 26 with a range of 18 to 66 years old. The average height was 65 inches (5'5") with a range of 60 inches (5') to 70 inches (5'10"). The average weight for the Spoon category was 140 pounds with a range of 99 to 237 pounds.

The Rectangle category was determined by utilizing the bust, waist, and hips circumference measures. The underlying premise for this category is that if the bust and hip measure are fairly equal AND bust-to-waist and hip-to-waist ratios are low, then it will fall into the shape category of Rectangle. The person with a Rectangle shape is characterized by not having a clearly discernible waistline. Therefore, the bust, waist, and hips are all inline with each other.

The FFIT for Apparel program searches for the Rectangle shape criteria last. If the subject's measurements fall within the range of values set for each measure of the Rectangle shape, then the program with give the subject a shape designation of Rectangle. If the subject's measurements DO NOT fall within the range of values set for each measure of the Rectangle shape, then the program will give the designation of "No Shape".

In Figure 55, subject #RectTrue has the circumferential measurements that meet the Rectangle shape criteria and is an example of a true Rectangle shape. Her bust, waist, and hips appear to be vertically aligned. A visual representation of the difference in the Hourglass and Rectangle shapes can be found in Figure 56.



<u>Figure 55</u>. **Example of a true Rectangle shape, Subject #RectTrue**

<u>Figure 56.</u> **An Hourglass body shape (black) superimposed onto a Rectangle body shape (yellow).**

All of the 35 subjects with the Rectangle shape were visually verified individually that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Rectangle shaped subjects are found in Figure 57. Each is superimposed over the true Rectangle shape example (Subject #RectTrue) to visually verify the proportionate body shape of the Rectangle figure. Note that Subject #Rect1 is behind the True Rectangle because her figure is larger and would hide the image.

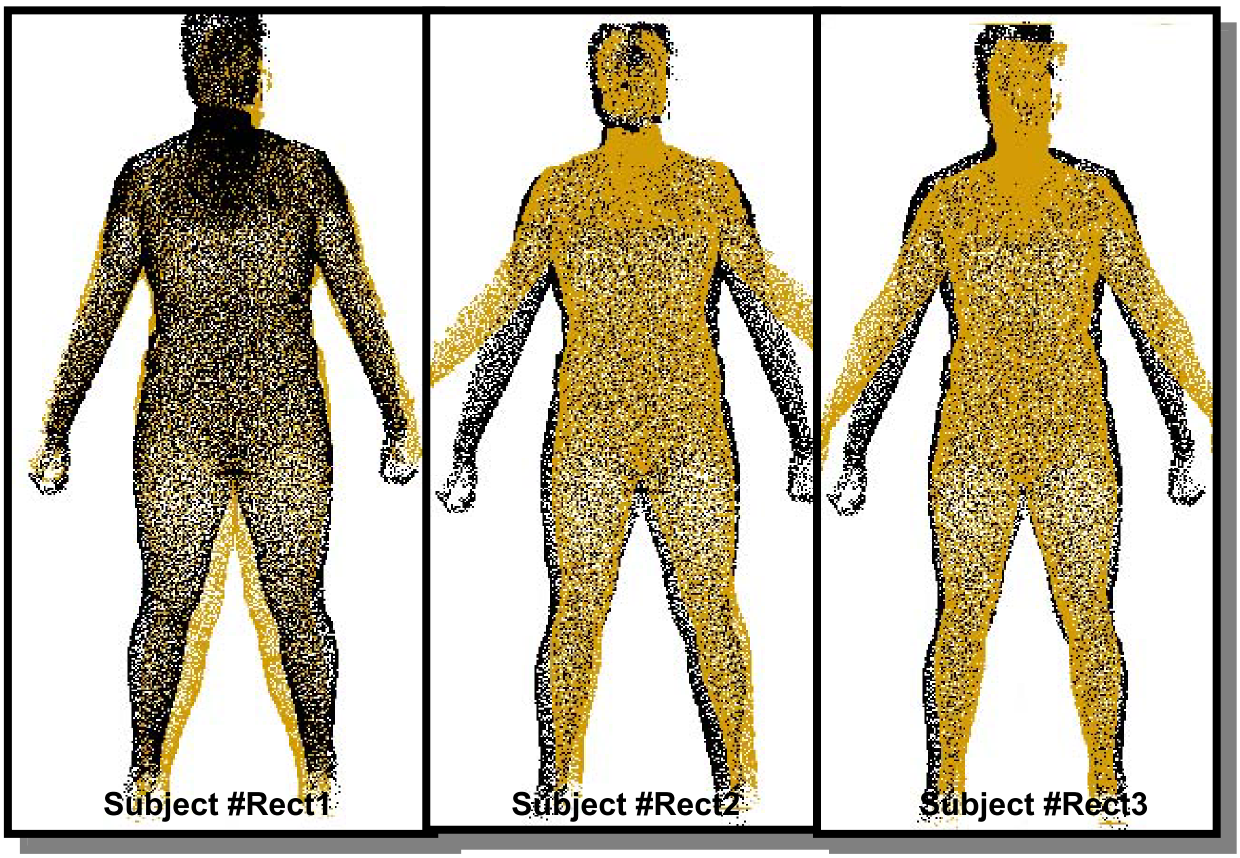


Figure 57. Subjects in the Rectangle shape category (yellow) superimposed on the example of a true Rectangle shape (black).

Diamond

The shape category of Diamond was determined by utilizing the body measurements of the bust, waist, hips, stomach, and abdomen, as in the Oval. However, there is a difference in the two categories. The Diamond shape category utilizes the underlying condition that if the average of the subject's stomach, waist, and abdomen measures are more than their bust measure, then it will fall into the shape category of Diamond. If the average is less than the bust, then it will fall into the shape category of Oval. The person with a Diamond shape is characterized by having several large rolls of flesh in the midsection of the body that protrude away from the body at the waist area. They appear to have a very large midsection (more so than the Oval) in comparison to the rest of their body, almost having a tube-like apparatus wrapped around their waist..

The FFIT for Apparel program searches for the Diamond shape criteria before the Oval. If the subject's measurements fall within the range of values set for each measure of the Diamond shape, then the program with give the subject a shape designation of Diamond. If the subject's measurements DO NOT fall within the range of values set for each measure of the Diamond shape, then the program will continue to search for a qualifying shape. Most subjects whose measurements slightly miss the Diamond shape category will usually end up being an Oval.

For this study, there were no subjects that fell into the Diamond category. In the control data set, there was a single subject who was characterized as having a Diamond shape. A simplistic representation of the shape without contrast of a body form is compared with the Oval shape in Figure 58.

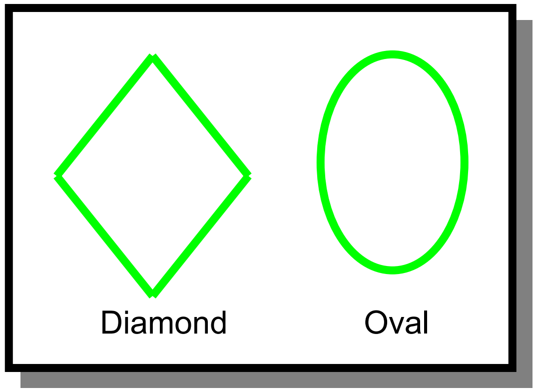


Figure 58. Comparison of the Diamond and Oval shapes.

Oval

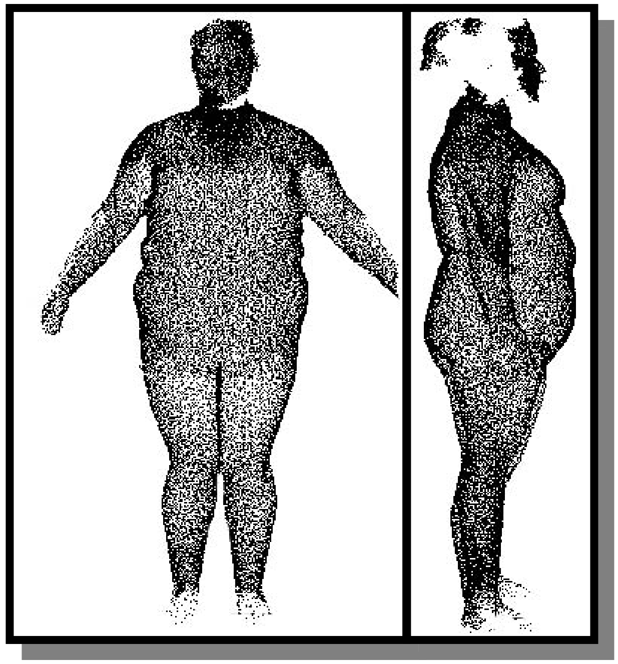
The Oval was the fifth largest shape category of this study with 3.6% of the subjects (8 of the 222). The racial breakdown of the subjects was Caucasian (62.5%) with a few Hispanics (25%), and a single Asian (12.5%). The average age for this category was 36 with a range of 18 to 53 years old. The average height was 63 inches (5’3”) with a range of 62 inches (5’2”) to 65 inches (5’5”). The average weight for the Oval category was 151 pounds with a range of 121 to 244 pounds.

The shape category of Oval was determined by utilizing the body measurements of the bust, waist, hips, stomach, and abdomen. The person with an Oval shape is characterized by having several rolls of flesh in the midsection of the body and appears to have a large midsection in comparison to the rest of their body. The shape from the front view can be different for each subject but the side view is where the true characteristics of the Oval shape are seen. The Oval shape category utilizes the underlying criteria that, if the average of the subject's stomach, waist, and abdomen measures are less than their bust measure, then the shape category would be an Oval.

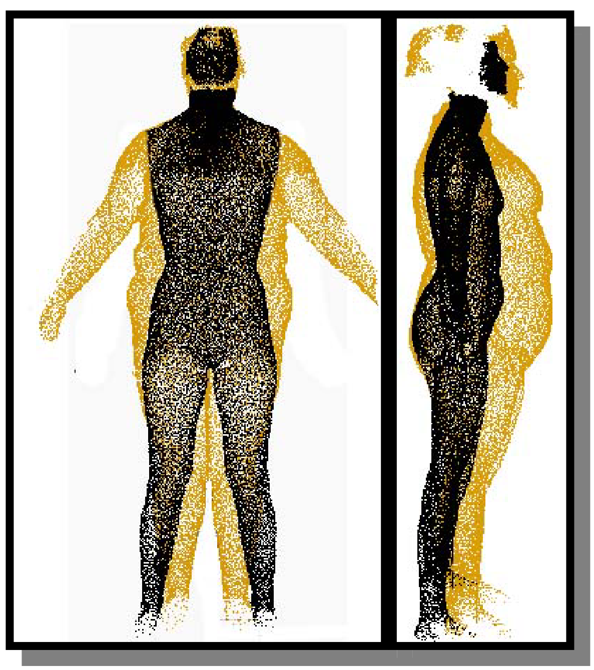
The FFIT for Apparel program searches for the Oval shape criteria after the Hourglass, Spoon, Diamond, Bottom Hourglass, and Top Hourglass. If the subject's measurements fall within the range of values set for each measure of the Oval shape, then the program will give the subject a shape designation of Oval. If the subject's measurements DO NOT fall within the range of values set for each measure of the Oval shape, then the program will continue to search for a qualifying shape. The critical identifier for this shape is the average of the waist, stomach, and abdomen measures.

In Figure 59, Subject #OvalTrue has the circumferential measurements that meet the Oval shape criteria and is an example of a true Oval shape. She appears to be much larger in her midsection than in any other region of her body. A visual representation of the difference in the Hourglass and Oval shapes can be found in Figure 60.

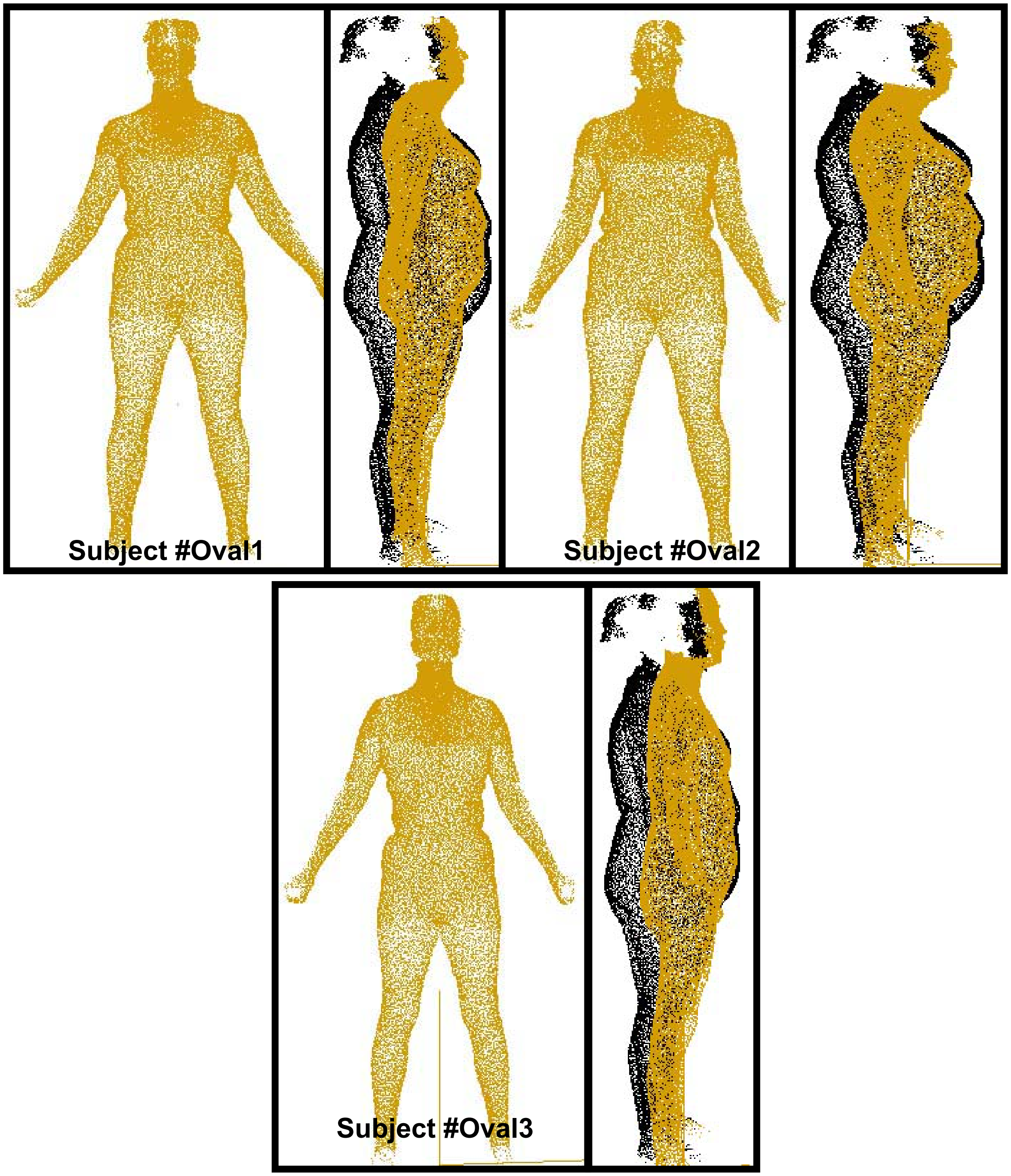
All of the 8 subjects with the Oval shape were visually verified individually that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Oval shaped subjects are found in Figure 61. Each is superimposed over the true Oval shape example (Subject #OvalTrue) to visually verify the proportionate body shape of the Rectangle figure.



<u>Figure 59</u>. Example of a true Oval shape with a front and side view, Subject #OvalTrue.



<u>Figure 60.</u> An Hourglass body shape (black) superimposed onto an Oval body shape (yellow).



<u>Figure 61.</u> Subjects in the Oval shape category (yellow) superimposed on the example of a true Oval shape (black) with front and side views.

Triangle

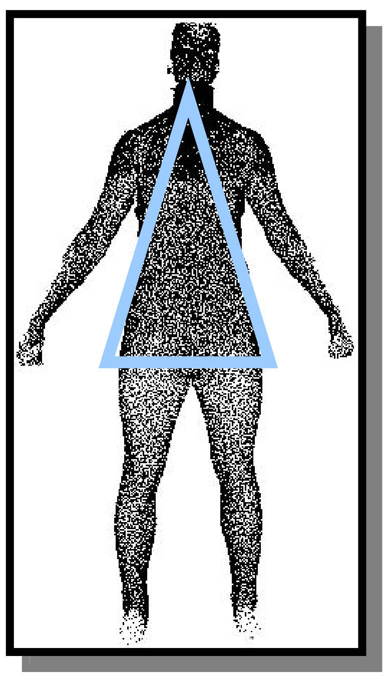
There were 4 subjects, or 18% of the sample, who fulfilled the criteria for the smallest shape category as the Triangle. The racial mix of the subjects was Caucasian (75%) with a single Asian (25%). The average age for this category was 20 with a range of 18 to 22 years old. The average height was 66.75 inches (5'6 3/4") with a range of 67 inches (5'7") to 68.5 inches (5'8½"). The average weight for the Triangle category was 143 pounds with a range of 131 to 162 pounds.

The shape category of Triangle was determined by utilizing the body measurements of the bust, waist, and hips. The Triangle shape category utilizes the underlying criteria that if a subject has a larger hip circumference than their bust AND if the ratio of their hips-to-waist is small, then the subject can be identified as having a Triangle shape. The person with a Triangle shape has the appearance of being larger in the hips than the bust without having a defined waistline.

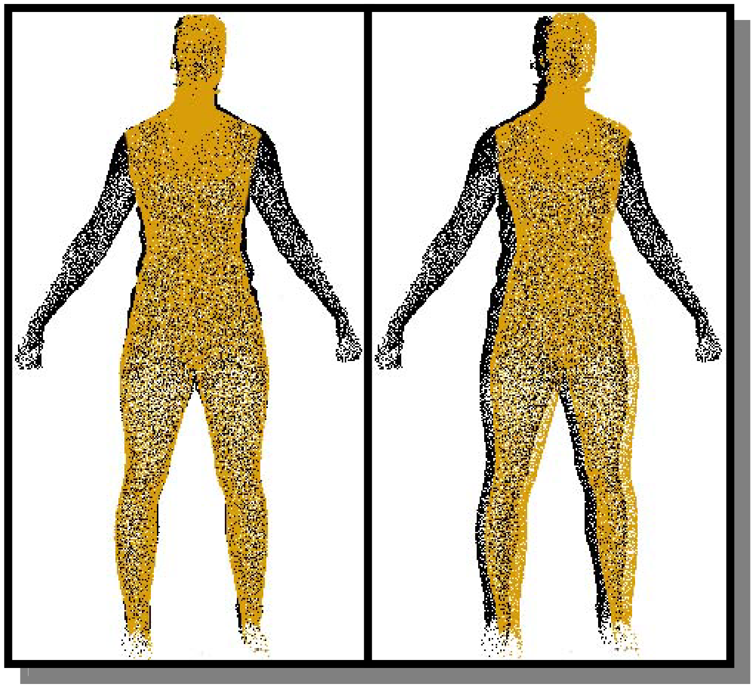
This shape differs from the Bottom Hourglass because the Triangle does not consider the bust-to-waist ratio where the Bottom Hourglass does. The FFIT for Apparel program searches for the Bottom Hourglass shape criteria before the Triangle. If the subject's measurements fall within the range of values set for each measure of the Bottom Hourglass shape, then the program with give the subject a shape designation of Bottom Hourglass. If the subject's measurements DO NOT fall within the range of values set for each measure of the Bottom

Hourglass shape, then the program will continue to search for a qualifying shape. Most subjects whose measurements slightly miss the Bottom Hourglass shape category will usually end up being a Triangle when there is no waist definition.

In Figure 62, Subject #TriTrue has the circumferential measurements that meet the Triangle shape criteria and is an example of a true Triangle shape. Her hips-to-waist ratio is small and her hips measurement is larger than her bust. She does not have a defined waistline. A visual representation of the difference in the Bottom Hourglass and Triangle shapes (primarily in the waist) can be found in Figure 63. Notice the image on the right in Figure 63 that the Bottom Hourglass body is offset slightly. This illustrates how the Bottom Hourglass shape is more tapered from the bust to the waist than the Triangle shape where the hips are equal in both shapes.



<u>Figure 62</u>. Example of a true Triangle shape, Subject #TriTrue.



<u>Figure 63.</u> An Bottom Hourglass body shape (yellow) superimposed onto a Triangle body shape (black).

All of the 4 subjects with the Triangle shape were visually verified individually that the shape designation given by <u>FFIT for Apparel</u> was correct. Examples of 3 random Triangle shaped subjects are found in Figure 64. Each is superimposed over the true Triangle shape example (Subject #TriTrue) to visually verify the proportionate body shape of the Triangle figure.

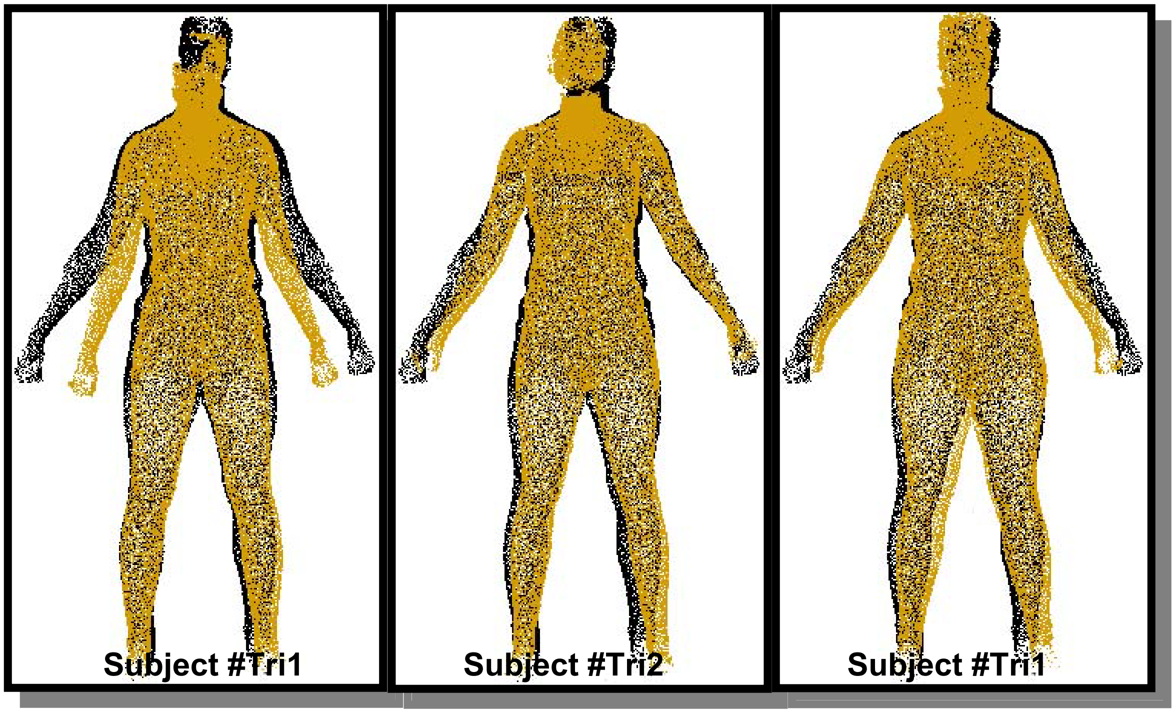


Figure 64. **Subjects in the Triangle shape category (yellow) superimposed on the example of a true Triangle shape (black).**

Inverted Triangle

The shape category of Inverted Triangle was determined by utilizing the same body measurements of the bust, waist, and hips just as in the Triangle. The Inverted Triangle shape category utilizes the underlying criteria that if a subject has a larger bust circumference than their hips AND if the ratio of their bust-to-waist is small, then it will fall into the shape category of Inverted Triangle. The person with an Inverted Triangle shape has the appearance of being heavy in the bust as compared to the hips but not having a defined waistline.

This shape differs from the Top Hourglass because the Inverted Triangle does not consider the hips-to-waist ratio where the Top Hourglass does. The

FFIT for Apparel program searches for the Inverted Triangle shape criteria before the Triangle but after the Top Hourglass. If the subject's measurements fall within the range of values set for each measure of the Top Hourglass shape, then the program with give the subject a shape designation of Bottom Hourglass. If the subject's measurements DO NOT fall within the range of values set for each measure of the Top Hourglass shape, then the program will continue to search for a qualifying shape. Most subjects whose measurements slightly miss the Top Hourglass shape category will end up being an Inverted Triangle because of the lack of waist definition.

For this study, no subjects fell into the Inverted Triangle category. A simplistic representation of the shape without contrast of a body form is compared with the Top Hourglass shape in Figure 65.

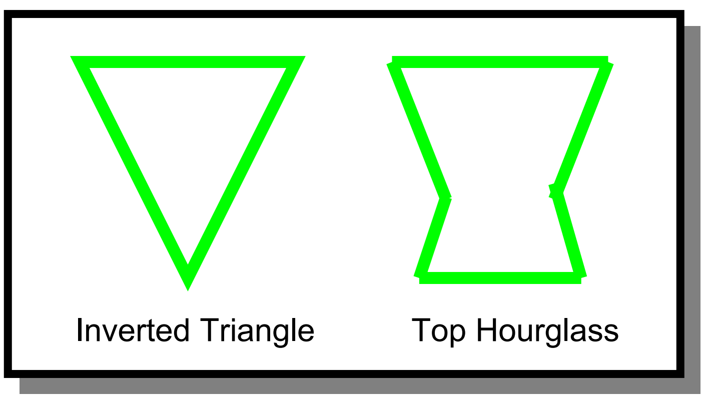


Figure 65. Comparison of the Inverted Triangle and Top Hourglass shapes.

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

Currently, clothing sizes are based on a biased study that is over 6 decades old. This method of sizing does not conform to the diversity of human shapes that currently exist in the United States. Attempts to classify body shapes into analogous types, in order to establish size standards, have resulted in the formation of several size groupings. However, the industry as a whole has not adopted a single system of clothing sizing.

Additionally, the shapes and proportions of today's American population differ greatly from the shapes of the generations before. Because the clothing sizing system is based on a study from the 1940s, many fit problems are occurring with consumers. These fit issues continue to be a growing concern. Consumers are not happy with clothing that does not provide good and desirable fit. Regardless of how one defines fit exactly, it must always start from basic human proportional truths. We are currently ill equipped to do this successfully with many products. This is a significant problem for retailers and manufacturers, alike.

New and improved technologies are now available that allow realistic images of human bodies to be classified into categories that will better reflect the differential proportions of the true American population. Mega-computing power, three-dimensional body scanning, dimensional design programs, and computer-aided-design software are allowing advances in the product development process that will lead to a seamless technology of customized clothing and ready-to-wear garments that can provide fit, as they have been designed to do. Some attempts have been made to chart the body in two dimensions but they do not yield a satisfactory illustration of true body shape. There is currently no means of viewing, categorizing, and/or comparing the body three-dimensionally. No attempts have been made to study body shapes and sizes using the 3D body scanner until this pilot study.

The research of this study focused on four basic objectives: 1) To develop a database of 3D body scan data, from a variety of consumer markets, that included measurement data, 3D point cloud data, and demographic data; 2) To demonstrate that the current sizing system is insufficient and to determine where significant deficiencies exist; 3) To utilize software that could take 3D data and "sort" it into congruous and related shape categories (body or shape sort) based on measurements, proportion, and shape; and 4) To develop preliminary subgroups for the female population that will aid in the better fit of clothing. The methodology involved software creation that was based on tacit and implicit knowledge. A database of 3D body scan data was established. The <u>Best Fit</u> software was created for comparison of 3D body scan data to recognized standards for body measurements. The <u>FFIT for Apparel</u> software was created to recognize body shape in conjunction with the 3D body scanner.

Summary and Implications

3D Database

The first objective of this pilot study was to develop a database of 3D body scan data, from a variety of consumer markets, that included measurement data and 3D point cloud data. This objective was met by establishing the database that resides at the College of Textile at North Carolina State University.

A total of 499 subjects were scanned and their data entered into the database, including demographic information (age, race, sex, height, and weight) on both males and females. The data is managed through the use of Microsoft Access 2000. Due to the nature of the university setting, this pilot study consisted entirely of a convenience sample, where the majority of the subjects were students. The goal of future work will be to expand the market base.

Sample

A subset of the 3D database was selected for the objectives 2 and 3. A sample of 222 female subjects was chosen on the basis of age, complete demographic data, good 3D body scan data, and a complete set of measurement data. The race was predominately Caucasian with Asians, African-Americans, Hispanics and Native-Americans also present. The average age of the subjects was 25. The average height of the subjects was 5’5”. The average weight of the subjects was 137 pounds.

Best Fit software

The second objective of this pilot study was to demonstrate that the current sizing system is insufficient and to determine where significant deficiencies exist. This objective was met by the development and application of the Best Fit software.

A computer program was developed in Microsoft Access 2000 to derive a numerical difference in body measurements between those of the subjects and those defined by all current and past sizing standards. Three methods were developed in the Best Fit software to ascertain the sufficiency of the standards: percentage difference, tolerance difference, and weighted tolerance difference. In this pilot study, the standard that was the most compatible with the majority of subjects, concerning the percentage difference, was the CS215-58 database. Even though the CS215-58 was the most chosen standard for the best fit in the percentage difference, 30% of the measures in that standard were greater than 5% different than the subject's measurements. While the percentage difference is a common mathematical formula that is recognized and understood by the general public, this formula has little application to the garment industry.

Whether clothing meets specifications and is in-tolerance are important issues to the garment industry. Therefore, a method to detect tolerance would be significant. A good example of tolerance would be a pair of pants that met specifications and was +/- ½ inch in the waist. In this pilot study, the standard that was the most compatible with the majority of subjects, concerning the tolerance difference, was the ASTM 5586-95 (women over 55) database.

The ASTM5586-95 is the current standard for women over the age of 55. There were only 9 women over the age of 55 in this study and yet this standard provided the best fit for using the tolerance difference method. Even so, the ASTM5586-95 had an average of 14 measurements (out of 23) that were out-of-tolerance as compared to the subject's measurements. This tolerance difference would not indicate the extent to which the measurement was out of specification. The smallest number of measurements out-of-tolerance was 9 and the largest was 17.

What if the pant waist was out-of-tolerance? In this case, the weighted tolerance would be used. For each increment that the measure was out-of-tolerance, a weight is assigned: a larger number represents greater deviation of the measurement. In this pilot study, the standard that was the most compatible with the majority of subjects, concerning the weighted tolerance difference, was the ASTM 5586-95 (women over 55) database. If each of the 23 measurements for a subject were out-of-tolerance to the greatest degree, then the subject would get a score of 69. This study had an average score of 20 with a range of 11-28.

The analysis of the current and past standards for body type classification revealed that the two standards that most closely fit the sample of 3D body scans were the CS215-58 and the ASTM5586-95 (women over 55). Keep in mind that the current standards are the ASTM5585-95 (Missy) and ASTM5586-95(women over 55). The CS215-58 was released in 1958 and was the first iteration of the original study by O'Brien and Shelton (1941). It was replaced in 1970 with the PS42-70 and eventually replaced by our current standards, which were established in 1995 by ASTM.

The ASTM5586-95 data was collected on women over the age of 55. This data is presented in the standard as raw data, not standardized data as in the other standards, which renders the data inconsistent. The ASTM5586-95 standard has measurements that are common to females of all ages but it also has measurements that are only for women over the age of 55 and are not indicative to this study.

This analysis indicates that the current standard of ASTM5585-95, for Missy, is worse than the CS215-58 which has been obsolete for over 32 years. As the garment industry has come forward over the last few decades, our standards for clothing sizes and fit have not improved. This suggests that the optimal standard has not been devised and that the current one is not providing a good fit in clothing. These statements indicate even though there were standards (CS215-58 and the ASTM5586-95) that gave a best fit among those provided, they are obsolete or for a different population that will still not produce well-fitting garment for the consumer. If any manufacturers actually follow these standards based on our findings, customers have little chance of finding something that fits well. They will make do with what is available. This example demonstrates that manufacturers may not be meeting the needs of the customers.

Shape Sorting software

The third and fourth objectives were to utilize software that could take 3D data and "sort" it into congruous and related shape categories (body or shape sort) based on measurements, proportion, and shape, and to develop preliminary subgroups for the female population that will aid in the better fit of clothing. The third objective was met by using the rudimentary shape sorting software from [TC^2] as a structural base to create a new shape identification software. The new software was developed using the computer program of Visual Basic Pro, Version 6.0. The name of the shape identification software is FFIT (Female Figure Identification Technique) for Apparel.

In the first draft of the software, five shape categories were identified, "hourglass", "oval", "triangle", "inverted triangle", and "rectangle", based on common terms in the literature and through tacit knowledge. A control data set of 31 females, not part of the subject sample group, was obtained from $[TC]^2$ with unknown height, weight, and age information. The code was initially tested on this group and yielded a subject in every shape group. When the 222 subject measurements were evaluated using the software for the first time, many subjects fell into no category. The categories were further divided based on the previous results and the knowledge of the researcher in fit of garments. Four new categories were created that resembled shapes of a "spoon", "diamond", "bottom hourglass", and "top hourglass". Each shape category was then given a range of numerical values that corresponded to the body measurements that were significant for that shape. The “bust”, “waist”, “hip”, “stomach”, and “abdomen” circumferences were used in combination to describe each shape.

The development of the shape sorting code required a stringent evaluation of all the variables that could potentially impact a person’s shape and thus impact the fit of a garment. Combinations of variables were studied to determine their value in the development of new sizing systems or in the customization of clothing. We determined that the most benefit would be achieved by defining body shapes at the most elemental level.

Based on the premise that mass customization efforts will only be successful if customization starts from the most correctly shaped garment patterns, determining elemental, basic body shapes was vital. Any additional alterations that might be needed (based on other fit variables such as torso length, posture, bust development, knee skewedness, and others) could be fairly easily achieved using customization methods available in pattern development software. Inclusion of these additional variables in the definition of body shapes would have increased the number of body shapes exponentially and decreased the value of this research to the apparel industry and, ultimately, the consumer. The complication of the process would decrease its likelihood of adoption.

Why is the FFIT for Apparel software so important? In this study, we have proven that the basic sizing systems are not adequate. To further the effectiveness of this research, we ran all of the current and previous standards used in this pilot study (CS215-58, PS42-70, ASTM5585-95, and ASTM5586-95) through the FFIT for Apparel software to determine what shape categories the standards apply(applied) to. The CS215-58 measurements, found to be most closest to a best fit for the subjects in this study, were almost 50% comprised of the Spoon category. The ASTM5586-95(55+) measurements, found to be the second closest to a best fit for the subjects in this study, were over 95% comprised of the Rectangle category. Through the FFIT for Apparel software, each standard, except the ASTM5585-95, consisted of differing shapes for its population. In this pilot study, the frequency of subjects in each category was the Bottom Hourglass (40%), Hourglass (21.6%), Spoon (17%), Rectangle (15.8%), Oval (3.6%), and Triangle (1.8%).

People always talk about the Hourglass figure and it is visually defined in people minds as being the “perfect” shape. With our sample being comprised of mostly college students, aged 18-24, one would think that, if anyone, they would have this “perfect” body. Surprisingly, the Hourglass shape was not the majority of our population. A significant number of the sample fit into other categories (over 78%). When ran through the FFIT for Apparel software, the current standard from which all of these college students clothing is based (ASTM5585-Missy) had all of its measurements fall into the Spoon category. This is also contradictory to our results. Therefore, there is no way that the current Missy standard (ASTM5585-95) could meet the needs of all the different body shapes today.

Recommendations

There is little information about the sorting of body shapes into congruous categories as is relates to the fit of clothing. Therefore, future research should include:

1. A full-scale replication of this study to determine if the body shape categories in the FFIT for Apparel software are adequate to define the entire population by shape. This full-scale study should consider:
    a. A much larger sample. This would possible allow for a statistical method such as data mining to occur to aid in statistical validity.
    b. A greater age assortment.
    c. More ethnic diversity.
2. Specific consumer groups could be targeted using the FFIT for Apparel software to define how to better meet the needs of that consumer market with respect to clothing fit.
3. This body shape identification system could be used to develop slopers that are based on these body shapes. This would make the alteration process of garments less laborious. It would also make the automation of alterations more expedient. In addition, slopers based on body shapes would aid in the integration of technologies for the application of Mass Customization.

4. This body shape data could be used in conjunction with organizations such as ASTM to help reorganize the current sizing system for mass-produced apparel.
5. The FFIT for Apparel software could be adapted so that different versions would apply to specific age or gender groups.
6. Research should be conducted on 3D body scanning and the methods available to interpret 3D data.
7. Further research should be performed regarding consumer attitudes with 3D body scanning. The consumer's willingness to be scanned is the core of 3D body scanning research. Investigation can't be done without human bodies.

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Appendices

Appendix A: CS 215-58, Body Measurements for the Sizing of Women's Patterns and Apparel, 1958

MISSES SIZING-REGULAR HEIGHT, AVERAGE HIP - CS215-58

Measurement	8	10	12	14	16	18	20	22
GIRTH:								
Bust	31	32.5	34	35.5	37	39	41	43
Waist	23.5	24.5	25.5	27	28.5	30.5	32.5	34.5
High hip								
Hip	32.5	34	36	38	40	42	44	46
Neck Base	14.25	14.5	14.75	15	15.25	15.625	16	16.375
Upper arm	9	9.625	10.25	10.875	11.5	12.25	13	13.75
Thigh, Max	18.25	19.5	20.75	22	23.25	24.5	25.75	27
Total Crotch	26.25	27.25	28.25	29.25	30.25	31.25	32.25	33.25
VERTICAL								
Cervical height	54	54.5	55	55.5	56	56.5	57	57.5
Waist height	39.125	39.5	39.875	40.25	40.625	41	41.375	41.75
Hip height	31.625	31.75	31.875	32	32.125	32.25	32.375	32.5
Crotch height	28.5	28.625	28.75	28.875	29	29.125	29.25	29.375
Ft waist length (necktowaist)	13.125	13.25	13.5	13.625	13.875	14	14.25	14.375
Bk waist length (necktowaist	15.125	15.25	15.5	15.625	15.875	16	16.25	16.375
Rise								
WIDTH & LENGTH								
Across Schoulder								
Cross-back width	11.875	12.25	12.625	13	13.375	13.875	14.375	14.875
Cross-chest width	11.5	11.75	12	12.2	12.5	12.875	13.25	13.625
Shoulder length	4.25	4.375	4.375	4.5	4.5	4.625	4.625	4.75
Shoulder slope (degrees)	23	23	23	23	23	23	23	23
Arm length (shlder to wrist)	22.75	23	23.25	23.5	23.75	24	24.25	24.5
Bust point to bust point	6.75	6.875	7	7.125	7.25	7.375	7.5	7.625

MISSY SIZING - TALL HEIGHT, AVERAGE HIP - CS215-58

Measurement	10	12	14	16	18	20
GIRTH:						
Bust	32.5	34	35.5	37	38.5	40
Waist	24	25.5	27	28.5	30	31.5
High hip						
Hip	34.5	36	38	40	42	44
Neck Base	14.625	14.875	15.125	15.375	15.625	15.875
Upper arm	9.5	10.125	10.75	11.375	12	12.625
Thigh, Max	19.5	20.75	22	23.25	24.5	25.75
Total Crotch	29	30	31	32	33	34
VERTICAL						
Cervical height	58.5	59	59.5	60	60.5	61
Waist height	42.5	42.875	43.25	43.625	44	44.375
Hip height	34.125	34.25	34.375	34.5	34.625	34.75
Crotch height	30.875	31	31.125	31.25	31.375	31.5
Ft. waist length (neck to waist)	13.875	14.125	14.25	14.5	14.625	15.875
Bk waist length (neck to waist)	16.125	16.375	16.5	16.75	16.875	17.125
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	12.375	12.75	13.125	13.5	13.875	14.25
Cross-chest width	12	12.25	12.5	12.75	13	13.25
Shoulder length	4.5	4.5	4.625	4.625	4.75	4.75
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	24.375	24.625	24.875	25.125	25.375	25.625
Bust point to bust point	7	7.125	7.25	7.375	7.5	7.625

MISSY SIZING SHORT HEIGHT, AVERAGE HIP - CS215-58

Measurement	8	10	12	14	16	18
GIRTH:						
Bust	31	32.5	34	35.5	37.5	39.5
Waist	23	24	25.5	27	29	31
High hip						
Hip	32.5	34	36	38	40	42
Neck Base	14.125	14.375	14.625	14.875	15.25	15.625
Upper arm	9.125	9.75	10.375	11	11.75	12.5
Thigh, Max	18.5	19.34	21	22.25	23.5	24.75
Total Crotch	25.25	26	26.75	27.5	28.5	29.5
VERTICAL						
Cervical height	50.5	51	51.5	52	52.5	53
Waist height	36.625	37	37.375	37.75	38.125	38.5
Hip height	29.625	29.75	29.875	30	30.125	30.25
Crotch height	26.625	26.75	26.875	27	27.125	27.25
Ft. waist length (neck to waist)	12.375	12.5	12.75	12.875	13.125	13.25
Bk waist length (neck to waist)	14.125	14.25	14.5	14.625	14.875	15
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	11.75	12.125	12.5	12.875	13.375	13.875
Cross-chest width	11.25	11.5	11.75	12	12.375	12.75
Shoulder length	4.125	4.25	4.25	4.375	4.375	4.5
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	21.25	21.5	21.75	22	22.25	22.5
Bust point to bust point	6.625	6.75	6.875	7	7.125	7.25

MISSY SIZING - REGULAR HEIGHT, SLENDER HIP - CS215-58

Measurement	10	12	14	16	18	20	22
GIRTH:							
Bust	32.5	34	35.5	37	39	41	43
Waist	24.5	25.5	27	28.5	30.5	32.5	34.5
High hip							
Hip	32.5	34	36	38	40	42	44
Neck Base	14.5	24.75	15	15.25	15.625	16	16.375
Upper arm	9.625	10.25	10.875	11.5	12.25	13	13.75
Thigh, Max	18.5	19.75	21	22.25	23.5	24.75	26
Total Crotch	26.5	27.5	28.5	29.5	30.5	31.5	32.5
VERTICAL							
Cervical height	54.5	55	55.5	56	56.5	57	57.5
Waist height	39.5	39.875	40.25	40.625	41	41.375	41.75
Hip height	31.75	31.875	32	32.125	32.25	32.375	32.5
Crotch height	28.625	28.75	28.875	29	29.125	29.25	29.375
Ft. waist length (neck to waist)	13.25	13.5	13.625	13.875	14	14.25	14.375
Bk waist length (neck to waist)	15.25	15.5	15.625	15.875	16	16.25	16.375
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	12.25	12.625	13	13.375	13.875	14.375	14.875
Cross-chest width	11.75	12	12.25	12.5	12.875	13.25	13.625
Shoulder length	4.375	4.375	4.5	4.5	4.625	4.625	4.75
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	23	23.25	23.5	23.75	24	24.25	24.5
Bust point to bust point	6.875	7	7.125	7.25	7.375	7.5	7.625

MISSY SIZING - TALL HEIGHT, SLENDER HIP - CS215-58

Measurement	12	14	16	18
GIRTH:				
Bust	34	35.5	37	38.5
Waist	25.5	27	28.5	30.5
High hip				
Hip	34.5	36	38	40
Neck Base	14.875	15.125	15.375	15.625
Upper arm	10.125	10.75	11.375	12
Thigh, Max	19.75	21	22.25	23.5
Total Crotch	29.25	30.25	31.25	32.25
VERTICAL				
Cervical height	59	59.5	60	60.5
Waist height	42.875	43.25	43.625	44
Hip height	34.25	34.375	34.5	34.625
Crotch height	31	3.125	31.25	31.375
Ft. waist length (neck to waist)	14.125	14.25	14.5	14.625
Bk waist length (neck to waist)	16.375	16.5	16.75	16.875
Rise				
WIDTH & LENGTH				
Across Schoulder				
Cross-back width	12.75	13.125	13.5	13.875
Cross-chest width	12.25	12.5	12.75	13
Shoulder length	4.5	4.625	4.625	4.75
Shoulder slope (degrees)	23	23	23	23
Arm length (shoulder to wrist)	24.625	24.875	25.125	25.375
Bust point to bust point	7.125	7.25	7.375	7.5

MISSY FIGURE TYPE SIZING- SHORT HEIGHT, SLENDER HIP - CS215-58

Measurement	12	14	16	18
GIRTH:				
Bust	34	35.5	37.5	39.5
Waist	25.5	27	29	31
High hip				
Hip	34.5	36	38	40
Neck Base	14.625	14.875	15.25	15.625
Upper arm	10.375	11	11.75	12.5
Thigh, Max	20	21.25	22.5	23.75
Total Crotch	26.25	27.75	29.25	30.75
VERTICAL				
Cervical height	51.5	52	52.5	53
Waist height	37.375	37.5	38.125	38.5
Hip height	29.875	30	30.125	30.25
Crotch height	26.875	27	27.125	27.25
Ft. waist length (neck to waist)	12.75	12.875	13.125	13.25
Bk waist length (neck to waist)	14.5	14.625	14.875	15
Rise				
WIDTH & LENGTH				
Across Schoulder				
Cross-back width	12.5	12.875	13.375	13.875
Cross-chest width	11.75	12	12.375	12.75
Shoulder length	4.25	4.375	4.375	4.5
Shoulder slope (degrees)	23	23	23	23
Arm length (shoulder to wrist)	21.75	22	22.25	22.5
Bust point to bust point	6.875	7	7.125	7.25

MISSY SIZING - REGULAR HEIGHT, FULL HIP - CS215-58

Measurement	8	10	12	14	16
GIRTH:					
Bust	31	32.5	34	35.5	37
Waist	23.5	24.5	25.5	27	28.5
High hip					
Hip	34	36	38	40	42
Neck Base	14.25	14.5	14.75	15	15.25
Upper arm	9	9.625	10.25	10.875	11.5
Thigh, Max	19.25	20.5	21.75	23	24.25
Total Crotch	27	28	29	30	31
VERTICAL					
Cervical height	54	54.5	55	55.5	56
Waist height	39.125	39.5	39.875	40.25	40.625
Hip height	31.625	31.75	31.875	32	32.125
Crotch height	28.5	28.625	28.75	28.875	29
Ft waist length (neck to waist)	13.125	13.25	13.5	13.625	13.875
Bk waist length (neckto waist)	15.125	15.25	15.5	15.625	15.875
Rise					
WIDTH & LENGTH					
Across Schoulder					
Cross-back width	11.875	12.25	12.625	13	13.375
Cross-chest width	11.5	11.75	12	12.25	12.5
Shoulder length	4.25	4.375	4.375	4.5	4.5
Shoulder slope (degrees)	23	23	23	23	23
Arm length (shoulder to wrist)	22.75	23	23.25	23.5	23.75
Bust point to bust point	6.75	6.875	7	7.125	7.25

MISSY FIGURE TYPE SIZING - TALL HEIGHT, FULL HIP - CS215-58

Measurement	10	12	14
GIRTH:			
Bust	32.5	34	35.5
Waist	24	25.5	27
High hip			
Hip	36	38	40
Neck Base	14.625	14.875	15.125
Upper arm	9.5	10.125	10.75
Thigh, Max	20.5	21.75	23
Total Crotch	29.75	30.75	31.75
VERTICAL			
Cervical height	58.5	59	59.5
Waist height	42.5	42.875	43.25
Hip height	34.125	34.25	34.375
Crotch height	30.875	31	31.125
Ft waist length (neck to waist)	13.875	14.125	14.25
Bk waist length (neckto waist)	16.125	16.375	16.5
Rise			
WIDTH & LENGTH			
Across Schoulder			
Cross-back width	12.375	12.75	13.125
Cross-chest width	12	12.25	12.5
Shoulder length	4.5	4.5	4.625
Shoulder slope (degrees)	23	23	23
Arm length (shoulder to wrist)	24.375	24.625	24.875
Bust point to bust point	7	7.125	7.25

MISSY SIZING - SHORT HEIGHT, FULL HIP - CS215-58

Measurement	8	10	12
GIRTH:			
Bust	31	32.5	34
Waist	23	24	25.5
High hip			
Hip	34	36	38
Neck Base	14.125	14.375	14.625
Upper arm	9.125	9.75	10.375
Thigh, Max	19.25	20.5	21.75
Total Crotch	25.75	26.5	27.25
VERTICAL			
Cervical height	50.5	51	51.5
Waist height	36.625	37	37.375
Hip height	28.625	29.75	29.875
Crotch height	25.75	26.5	27.25
Ft. waist length (neck to waist)	12.375	12.5	12.75
Bk waist length (neck to waist)	14.125	14.25	14.5
Rise			
WIDTH & LENGTH			
Across Schoulder			
Cross-back width	11.75	12.125	12.5
Cross-chest width	11.25	11.5	11.75
Shoulder length	4.125	4.25	4.25
Shoulder slope (degrees)	23	23	23
Arm length (shoulder to wrist)	21.25	21.5	21.75
Bust point to bust point	6.625	6.75	6.875

WOMEN'S FIGURE TYPE SIZING - REGULAR HEIGHT, AVERAGE HIP - CS215-58

Measurement	30	32	34	36	38	40	42
GIRTH:							
Bust	33	35	37	39	41	43	45
Waist	25	27	29	31	33.5	36	38.5
High hip							
Hip	34	36	38	40	42	44	46
Neck Base	14.5	14.75	15	15.25	15.625	16	16.375
Upper arm	9.875	10.625	11.375	12.125	12.875	13.625	14.375
Thigh, Max	19.5	20.75	22	23.25	24.5	25.75	27
Total Crotch	28	29	30	31	32	33.5	35
VERTICAL							
Cervical height	54.5	55	55.5	56	56.5	57	57.5
Waist height	39.625	40	40.375	40.75	41.125	41.5	41.875
Hip height	31.75	31.875	32	32.125	32.25	32.375	32.5
Crotch height	28.375	28.5	28.625	28.75	28.875	29	29.125
Ft. waist length (neck to waist)	13.375	13.5	13.75	13.875	14.125	14.25	14.5
Bk waist length (neck to waist)	15.5	15.625	15.875	16	16.25	16.375	16.625
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	12.25	12.75	13.25	13.75	14.25	14.75	15.25
Cross-chest width	11.5	11.875	12.25	12.625	13	13.375	13.75
Shoulder length	4.375	4.375	4.5	4.5	4.625	4.625	4.75
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	23	23.25	23.5	23.75	24	24.25	24.5
Bust point to bust point	6.75	7	7.25	7.5	7.75	8	8.25

WOMEN'S SIZING - TALL HEIGHT, AVERAGE HIP - CS215-58

Measurement	32	34	36	38	40
GIRTH:					
Bust	35	37	39	41	43
Waist	27	29	31	33	35
High hip					
Hip	36	38	40	42	44
Neck Base	14.875	15.25	15.625	16	16.375
Upper arm	10.625	11.375	12.125	12.875	13.625
Thigh, Max	20.75	22	23.25	24.5	25.75
Total Crotch	30	31	32	33	34
VERTICAL					
Cervical height	59	59.5	60	60.5	61
Waist height	43.125	43.5	43.875	44.25	44.625
Hip height	34.375	34.5	34.625	34.75	34.875
Crotch height	31.625	31.5	31.625	31.75	31.875
Ft. waist length (neck to waist)	14.375	14.625	14.875	15.125	15.375
Bk waist length (neck to waist)	16.75	17	17.25	17.5	17.75
Rise					
WIDTH & LENGTH					
Across Schoulder					
Cross-back width	12.875	13.375	13.875	14.375	14.875
Cross-chest width	12.125	12.5	12.875	13.25	13.375
Shoulder length	4.5	4.625	4.625	4.75	4.75
Shoulder slope (degrees)	24	24	24	24	24
Arm length (shoulder to wrist)	24.5	24.75	25	25.25	25.5
Bust point to bust point	7.25	7.5	7.75	8	8.25

WOMEN'S FIGURE TYPE SIZING -REGULAR HEIGHT, SLENDER HIP - CS215-58

Measurement	32	34	36	38	40	42
GIRTH:						
Bust	35	37	39	41	43	45
Waist	27	29	31	33.5	36	38.5
High hip						
Hip	34	36	38	40	42	44
Neck Base	14.75	15	15.25	15.625	16	16.375
Upper arm	10.625	11.375	12.125	12.875	13.625	14.375
Thigh, Max	19.75	21	22.25	23.5	24.75	26
Total Crotch	28.5	29.5	30.5	31.5	33	34.5
VERTICAL						
Cervical height	55	55.5	56	56.5	57	57.5
Waist height	40	40.375	40.75	41.125	41.5	41.875
Hip height	31.875	32	32.125	32.25	32.375	32.5
Crotch height	28.5	28.625	28.75	28.875	29	29.125
Ft waist length (neck to waist)	13.5	13.75	13.875	14.125	14.25	14.5
Bk waist length (neck to waist)	15.625	15.875	16	16.25	16.375	16.625
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	12.75	13.25	13.75	14.25	14.75	15.25
Cross-chest width	11.875	12.25	12.625	13	13.375	13.75
Shoulder length	4.375	4.5	4.5	4.625	4.625	4.75
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	23.25	23.5	23.75	24	24.25	24.5
Bust point to bust point	7	7.25	7.5	7.75	8	8.25

WOMEN'S SIZING - REGULAR HEIGHT, FULL HIP - CS215-58

Measurement	28	30	32	34	36	38
GIRTH:						
Bust	31	33	35	37	39	41
Waist	24	25	27	29	31	33.5
High hip						
Hip	34	36	38	40	42	44
Neck Base	14.25	14.5	14.75	15	15.25	15.625
Upper arm	9.125	9.875	10.625	11.375	12.125	12.875
Thigh, Max	19.25	20.5	21.75	23	24.25	25.5
Total Crotch	27.75	28.75	29.75	30.75	31.75	32.75
VERTICAL						
Cervical height	54	54.5	55	55.5	56	56.5
Waist height	39.25	39.625	40	40.375	40.75	41.125
Hip height	31.625	31.75	31.875	32	32.125	32.25
Crotch height	28.25	28.375	28.5	28.625	28.75	28.875
Ft. waist length (neck to waist)	13.125	13.375	13.5	13.75	13.875	14.125
Bk waist length (neck to waist)	15.25	15.5	15.625	15.875	16	16.25
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	11.75	12.25	12.75	13.25	13.75	14.25
Cross-chest width	11.125	11.5	11.875	12.25	12.625	13
Shoulder length	4.25	4.375	4.375	4.5	4.5	4.625
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	22.75	23	23.25	23.5	23.75	24
Bust point to bust point	6.5	6.75	7	7.25	7.5	7.75

WOMEN'S FIGURE TYPE SIZING - TALL HEIGHT, FULL HIP - CS215-58

Measurement	30	32	34	36
GIRTH:				
Bust	33	35	37	39
Waist	25	27	29	31
High hip				
Hip	36	38	40	42
Neck Base	14.5	14.875	15.25	15.625
Upper arm	9.875	10.625	11.375	12.125
Thigh, Max	20.5	21.75	23	24.25
Total Crotch	29	30	31	32
VERTICAL				
Cervical height	58.5	59	59.5	60
Waist height	42.75	43.125	43.5	43.875
Hip height	34.25	34.375	34.5	34.625
Crotch height	31.25	31.375	31.5	31.625
Ft.waist length (neck to waist)	14.125	14.375	14.625	14.875
Bk waist length (neck to waist)	16.5	16.75	17	17.25
Rise				
WIDTH & LENGTH				
Across Schoulder				
Cross-back width	12.375	12.875	13.375	13.875
Cross-chest width	11.75	12.125	12.5	12.875
Shoulder length	4.5	4.5	4.625	4.625
Shoulder slope (degrees)	24	24	24	24
Arm length (shoulder to wrist)	24.25	24.5	24.75	25
Bust point to bust point	7	7.25	7.5	7.75

HALFSIZE FIGURE TYPE SIZING - SHORT HEIGHT, AVERAGE HIP - CS215-58

Measurement	10.5	12.5	14.5	16.5	18.5	20.5	22.5	24.5
GIRTH:								
Bust	33	35	37	39	41	43	45	47
Waist	25.5	27.5	29.5	31.5	33.5	36	38.5	41
High hip								
Hip	34	36	38	40	42	44	46	48
Neck Base	14.375	14.625	14.875	15.25	15.625	16	16.375	16.75
Upper arm	10	10.75	11.5	12.25	13	13.75	14.5	15.25
Thigh, Max	19.5	20.75	22	23.25	24.5	25.75	27	28.25
Total Crotch	27.5	28.5	29.5	30.5	32	33.5	35	36.5
VERTICAL								
Cervical height	51	51.5	52	52.5	53	53.5	54	54.5
Waist height	37	37.375	37.75	38.125	38.5	38.875	39.25	39.625
Hip height	29.75	29.875	30	30.125	30.25	30.375	30.5	30.625
Crotch height	26.5	26.625	26.75	26.875	27	27.125	27.25	27.375
Ft. waist length (neck to waist)	12.5	12.75	13	13.25	13.5	13.75	14	14.25
Bk waist length (neck to waist)	14.375	14.625	14.875	15.125	15.375	15.625	15.875	16.125
Rise								
WIDTH & LENGTH								
Across Schoulder								
Cross-back width	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75
Cross-chest width	11.375	11.75	12.125	12.5	12.875	13.25	13.625	14
Shoulder length	4.25	4.25	4.375	4.375	4.5	4.5	4.625	4.625
Shoulder slope (degrees)	23	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	21.5	21.75	22	22.25	22.5	22.75	23	23.25
Bust point to bust point	6.625	6.875	7.125	7.375	7.625	7.875	8.125	8.375

HALFSIZE FIGURE SIZING - SHORT HEIGHT, SLENDER HIP - CS215-58

Measurement	12.5	14.5	16.5	18.5	20.5	22.5
GIRTH:						
Bust	35	37	39	41	43	45
Waist	27.5	29.5	31.5	33.5	36	38.5
High hip						
Hip	34	36	38	40	42	44
Neck Base	14.625	14.875	15.25	15.625	16	16.375
Upper arm	10.75	11.5	12.25	13	13.75	14.5
Thigh, Max	19.75	21	22.25	23.5	24.75	26
Total Crotch	27.75	28.75	29.75	31.25	32.75	34.25
VERTICAL						
Cervical height	51.25	52	52.5	53	53.5	54
Waist height	37.375	37.75	38.125	38.5	38.875	39.25
Hip height	29.875	30	30.125	30.25	30.375	30.5
Crotch height	26.625	26.75	26.875	27	27.125	27.25
Ft. waist length (neck to waist)	12.75	13	13.25	13.5	13.75	14
Bk waist length (neck to waist)	14.625	14.875	15.125	15.375	15.625	15.875
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	12.75	13.25	13.75	14.25	14.75	15.25
Cross-chest width	11.75	12.125	12.5	12.875	13.25	13.625
Shoulder length	4.25	4.375	4.375	4.5	4.5	4.625
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	21.75	22	22.25	22.5	22.75	23
Bust point to bust point	6.875	7.125	7.375	7.625	7.875	8.125

HALFSIZE FIGURE TYPE SIZING - SHORT HEIGHT, FULL HIP - CS215-58

Measurement	8.5	10.5	12.5	14.5	16.5	18.5	20.5
GIRTH:							
Bust	31	33	35	37	39	41	43
Waist	24	25.5	27.5	29.5	31.5	33.5	36
High hip							
Hip	34	36	38	40	42	44	46
Neck Base	14.125	14.375	14.625	14.875	15.25	15.625	16
Upper arm	9.25	10	10.75	11.5	12.25	13	13.75
Thigh, Max	19.25	20.5	21.75	23	24.25	25.5	26.75
Total Crotch	27.25	28.25	29.25	30.25	31.25	32.75	34.25
VERTICAL							
Cervical height	50.5	51	51.5	52	52.5	53	53.5
Waist height	36.625	37	37.375	37.75	38.125	38.5	38.875
Hip height	29.625	29.75	29.875	30	30.125	30.25	30.375
Crotch height	26.375	26.5	26.625	26.75	26.875	27	27.125
Ft. waist length (neck to waist)	12.25	12.5	12.75	13	13.25	13.5	13.75
Bk waist length (neck to waist)	14.125	14.375	14.625	14.875	15.125	15.375	15.625
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	11.75	12.25	12.75	13.25	13.75	14.25	14.75
Cross-chest width	11	11.375	11.75	12.125	12.5	12.875	13.25
Shoulder length	4.125	4.25	4.25	4.375	4.375	4.5	4.5
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	21.25	21.5	21.75	22	22.25	22.5	22.75
Bust point to bust point	6.375	6.625	6.875	7.125	7.375	7.625	7.875

JUNIOR FIGURE TYPE SIZING - REGULAR HEIGHT, AVERAGE HIP - CS215-58

Measurement	7	9	11	13	15	17	19
GIRTH:							
Bust	30.5	32	33.5	35	36.5	38	39.5
Waist	22.5	23.5	24.5	26	27.5	29	30.5
High hip							
Hip	32	33.5	35	37	39	41	43
Neck Base	14.125	14.375	14.625	14.875	15.125	15.375	15.625
Upper arm	8.75	9.375	10	10.625	11.25	11.875	12.5
Thigh, Max	17.75	19	20.25	21.5	22.75	24	25.25
Total Crotch	25.25	26.25	27.25	28.25	29.25	30.25	31.25
VERTICAL							
Cervical height	53.5	54	54.5	55	55.5	56	56.5
Waist height	38.875	39.25	39.625	40	40.375	40.75	41.125
Hip height	31.5	31.625	31.75	31.875	32	32.125	32.25
Crotch height	28.5	28.625	28.75	28.875	29	29.125	29.25
Ft. waist length (neck to waist)	12.875	13.125	13.25	13.5	13.625	13.875	14
Bk waist length (neck to waist)	14.875	15.125	15.25	15.5	15.625	15.875	16
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	11.75	12.125	12.5	12.875	13.25	13.625	14
Cross-chest width	11.375	11.625	11.875	12.125	12.375	12.625	12.875
Shoulder length	4.25	4.375	4.375	4.5	4.5	4.625	4.625
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	22.625	22.875	23.125	23.375	23.625	23.875	24.125
Bust point to bust point	6.625	6.75	6.875	7	7.125	7.25	7.375

JUNIOR FIGURE TYPE SIZING - TALL HEIGHT, AVERAGE HIP - CS215-58

Measurement	9	11	13	15	17
GIRTH:					
Bust	32	33.5	35	36.5	38
Waist	23	24.5	26	27.5	29
High hip					
Hip	34	35.5	37	39	41
Neck Base	14.5	14.75	15	15.25	15.5
Upper arm	9.25	9.875	10.5	11.125	11.75
Thigh, Max	19	20.25	21.5	22.75	24
Total Crotch	27.5	28.5	29.5	30.5	31.5
VERTICAL					
Cervical height	58	58.5	59	59.5	60
Waist height	42.5	42.625	43	43.375	43.75
Hip height	34.125	34.25	34.375	34.5	34.625
Crotch height	30.875	31	31.125	31.25	31.375
Ft. waist length (neck to waist)	13.75	13.875	14.125	14.25	14.5
Bk waist length (neck to waist)	16	16.125	16.375	16.5	16.75
Rise					
WIDTH & LENGTH					
Across Schoulder					
Cross-back width	12.25	12.625	13	13.375	13.75
Cross-chest width	11.875	12.125	12.375	12.625	12.875
Shoulder length	4.5	4.625	4.625	4.75	4.75
Shoulder slope (degrees)	23	23	23	23	23
Arm length (shoulder to wrist)	24.25	24.5	24.75	25	25.25
Bust point to bust point	6.875	7	7.125	7.25	7.375

JUNIOR FIGURE TYPE SIZING - SHORT HEIGHT, AVERAGE HIP - CS215-58

Measurement	9	11	13	15
GIRTH:				
Bust	32	33.5	35	36.5
Waist	23.5	24.5	26	27.5
High hip				
Hip	33.5	35	37	39
Neck Base	14.25	14.5	14.75	15
Upper arm	9.5	10.125	10.75	11.375
Thigh, Max	19.25	20.5	21.75	23
Total Crotch	25.75	26.5	27.25	28
VERTICAL				
Cervical height	50.5	51	51.5	52
Waist height	36.75	37.125	37.5	37.875
Hip height	29.625	29.75	29.875	30
Crotch height	26.75	26.875	27	27.125
Ft waist length (neck to waist)	12.5	12.625	12.875	13
Bk waist length (neck to waist)	14.125	14.25	14.5	14.625
Rise				
WIDTH & LENGTH				
Across Schoulder				
Cross-back width	12	12.375	12.75	13.125
Cross-chest width	11.375	11.625	11.875	12.125
Shoulder length	4.25	4.375	4.375	4.5
Shoulder slope (degrees)	23	23	23	23
Arm length (shoulder to wrist)	21.375	21.625	21.875	22.125
Bust point to bust point	6.625	6.75	6.875	7

Appendix B: PS 42-70, Body Measurements for the Sizing of Women's Patterns and Apparel, 1970

JUNIOR SIZING - NBSVPS

Measurement	3	5	7	9	11	13	15	17
GIRTH:								
Bust	30	31	32	33	34.5	36	37.5	39
Waist	20.5	21.5	22.5	23.5	25	26.5	28	29.5
High hip	27.625	28.625	29.625	30.625	32.625	33.625	35.125	36.625
Hip	32	33	34	35	36.5	38	39.5	41
Neck Base								
Upper arm	9.125	9.375	9.625	9.875	10.25	10.625	11	11.375
Thigh, Max	17.5	18.25	19	19.75	20.75	21.75	22.75	23.75
Total Crotch	24.5	25.25	26	26.75	27.5	28.25	29	29.75
VERTICAL								
Cervical height	52.5	53	53.5	54	54.5	55	55.5	56
Waist height	38.125	38.5	38.875	39.25	39.625	40	40.375	40.75
Hip height	31.25	31.375	31.5	31.625	31.75	31.875	32	32.125
Crotch height	28.25	28.375	28.5	28.625	28.75	28.875	29	29.5
Ft. waist length (neck to waist)	12.25	12.5	12.75	13	13.25	13.5	13.75	14
Bk waist length (neck to waist)	14.25	14.5	14.75	15	15.25	15.5	15.75	16
Rise								
WIDTH & LENGTH								
Across Schoulder								
Cross-back width	11.625	11.875	12.125	12.375	12.75	13.125	13.5	13.875
Cross-chest width	11.625	11.75	11.875	12	12.25	12.5	12.75	13
Shoulder length	4	4.0625	4.125	4.1875	4.25	4.3125	4.375	4.4375
Shoulder slope (degrees)	23	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	22.375	22.5625	22.75	22.9375	23.125	23.3125	23.5	23.6875
Bust point to bust point	6.375	6.625	6.875	7.125	7.375	7.625	7.875	8.125

JUNIOR PETITE FIGURE TYPE SIZING- NBSVPS

Measurement	3	5	7	9	11	13	15
GIRTH:							
Bust	30	31	32	33	34.5	36	37.5
Waist	20.5	21.5	22.5	23.5	25	26.5	28
High hip	27.625	28.625	29.625	30.625	32.125	33.625	35.125
Hip	32	33	34	35	36.5	38	39.5
Neck Base							
Upper arm	9.125	9.375	9.625	9.875	10.25	10.625	11
Thigh, Max	17.5	18.25	19	19.75	20.75	21.75	22.75
Total Crotch	23.5	24.25	25	25.75	26.5	27.25	28
VERTICAL							
Cervical height	49	49.5	50	50.5	51	51.5	52
Waist height	35.625	36	36.375	36.75	37.125	37.5	37.875
Hip height	29.25	29.375	29.5	29.625	29.75	29.875	30
Crotch height	26.375	26.5	26.625	26.75	26.875	27	27.125
Ft. waist length (neck to waist)	11.5	11.75	12	12.25	12.5	12.75	13
Bk waist length (neck to waist)	13.5	12.75	14	14.25	14.5	14.75	15
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	11.625	11.875	12.125	12.375	12.75	13.125	13.5
Cross-chest width	11.625	11.75	11.875	12	12.25	12.5	12.75
Shoulder length	4	4.0625	4.125	4.1875	4.25	4.3125	4.375
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	20.875	21.0625	21.25	21.4375	21.625	21.8125	22
Bust point to bust point	6.375	6.625	6.875	7.125	7.375	7.625	7.875

MISSY SIZING - NBSVPS

Measurement	6	8	10	12	14	16	18	20	22
GIRTH:									
Bust	31.5	32.5	33.5	35	36.5	38	40	42	44
Waist	22.5	23.5	24.5	26	27.5	29	31	33	35
High hip	29.625	30.625	31.625	33.125	34.625	36.125	38.125	40.125	42.125
Hip	33.5	34.5	35.5	37	38.5	40	42	44	46
Neck Base									
Upper arm	9.625	9.875	10.125	10.5	10.875	11.25	11.875	12.5	13.125
Thigh, Max	18.75	19.5	20.25	21.25	22.25	23.25	24.5	25.75	27
Total Crotch	26.375	27.125	27.875	28.625	29.375	30.125	30.875	31.625	32.375
VERTICAL									
Cervical height	53.5	54	54.5	55	55.5	56	56.5	57	57.5
Waist height	38.75	39.125	39.5	39.875	40.25	40.625	41	41.375	41.75
Hip height	31.5	31.625	31.75	31.875	32	32.125	32.25	32.375	32.5
Crotch height	26.375	27.125	27.875	28.625	29.375	30.125	30.875	31.625	32.375
Ft. waist length	12.75	13	13.25	13.5	13.75	14	14.25	14.5	14.75
Bk waist length	14.75	15	15.25	15.5	15.75	16	16.25	16.5	16.75
Rise									
WIDTH & LENGTH									
Across Schoulder									
Cross-back width	12	12.25	12.5	12.875	13.25	13.625	14.125	14.625	15.125
Cross-chest width	11.875	12	12.125	12.375	12.625	12.875	13.25	13.625	14
Shoulder length	4.1875	4.25	4.3125	4.375	4.4375	4.5	4.5625	4.625	4.6875
Shoulder slope (degrees)	23	23	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	22.687 5	22.875	23.062 5	23.25	23.437 5	23.625	23.812 5	24	24.187 5
Bust point to bust point	6.75	7	7.25	7.5	7.75	8	8.25	8.5	8.75

MISSY PETITE SIZING - NBSVPS

Measurement	8	10	12	14	16	18
GIRTH:						
Bust	32.5	33.5	35	36.5	38	40
Waist	23.5	24.5	26	27.5	29	31
High hip	30.625	31.625	33.125	34.625	36.125	38.125
Hip	34.5	35.5	37	38.5	40	42
Neck Base						
Upper arm	9.875	10.125	10.5	10.875	11.25	11.875
Thigh, Max	19.5	20.25	21.25	22.25	23.25	24.5
Total Crotch	25.625	26,375	27.125	27.875	28.625	28.375
VERTICAL						
Cervical height	50.5	51	51.5	52	52.5	53
Waist height	36.625	37	37.375	37.75	38.125	38.5
Hip height	29.625	29.75	29.875	30	30.125	30.25
Crotch height	26.625	26.75	26.875	27	27.125	27.25
Ft. waist length (neck to waist)	12.25	12.5	12.75	13	13.25	13.5
Bk waist length (neck to waist)	14.25	14.5	14.75	15	15.25	15.5
Rise						
WIDTH & LENGTH						
Across Schoulder						
Cross-back width	12.25	12.5	12.875	13.25	13.625	14.125
Cross-chest width	12	12.125	12.375	12.625	12.875	13.25
Shoulder length	4.25	4.3125	4.375	4.4375	4.5	4.5625
Shoulder slope (degrees)	23	23	23	23	23	23
Arm length (shoulder to wrist)	21.375	21.5625	21.75	21.9375	22.125	22.3125
Bust point to bust point	7	7.25	7.5	7.75	8	8.25

MISSY SIZING - TALLS - NBSVPS

Measurement	10	12	14	16	18	20	22
GIRTH:							
Bust	33.5	35	36.5	38	40	42	44
Waist	24.5	26	27.5	29	31	33	35
High hip	31.625	33.125	34.625	36.125	38.125	40.125	42.125
Hip	35.5	37	38.5	40	42	44	46
Neck Base							
Upper arm	10.125	10.5	10.875	11.25	11.875	12.5	13.125
Thigh, Max	20.25	21.25	22.25	23.25	24.5	25.75	27
Total Crotch	29.625	30.375	31.125	31.875	32.625	33.375	34.125
VERTICAL							
Cervical height	58.5	59	59.5	60	60.5	61	61.5
Waist height	42.5	42.875	43.25	43.625	44	44.375	44.75
Hip height	34.125	34.25	34.625	34.5	34.625	34.75	34.875
Crotch height	30.875	31	31.125	31.25	31.375	31.5	31.625
Ft. waist length (neck to waist)	14	14.25	14.5	14.75	15	15.25	15.5
Bk waist length (neck to waist)	16	16.25	16.5	16.75	17	17.25	17.5
Rise							
WIDTH & LENGTH							
Across Schoulder							
Cross-back width	12.5	12.875	13.25	13.625	14.125	14.625	15.125
Cross-chest width	12.125	12.375	12.625	12.875	13.25	13.625	14
Shoulder length	4.3125	4.375	4.4375	4.5	4.5625	4.625	4.6875
Shoulder slope (degrees)	23	23	23	23	23	23	23
Arm length (shoulder to wrist)	24.4375	24.625	24.8125	25	25.1875	25.375	25.5625
Bust point to bust point	7.25	7.5	7.75	8	8.25	8.5	8.75

WOMEN'S SIZING - NBSVPS

Measurement	34	36	38	40	42	44	46	48	50	52
GIRTH:										
Bust	38	40	42	44	46	48	50	52	54	56
Waist	30	32.5	34	36.5	39	41.5	44	46.5	49	51.5
High hip	37	39	41	43.25	45.5	47.75	50	52.25	54.5	56.75
Hip	39	41	43	45	47	49	51	53	55	57
Neck Base										
Upper arm	12	12.625	13.25	13.875	14.5	15.125	15.75	16.375	17	17.625
Thigh, Max	22.5	23.75	25	26.25	27.5	28.75	30	31.25	32.5	33.75
Total Crotch	30.625	31.375	32.125	32.875	33.625	34	34.375	34.75	35.125	35.5
VERTICAL										
Cervical height	55.5	56	56.5	57	57.5	57.5	57.5	57.5	57.5	57.5
Waist height	40.375	40.75	41.125	41.5	41.875	41.875	41.875	41.875	41.875	41.875
Hip height	32	32.125	32.25	32.375	32.5	32.5	32.5	32.5	32.5	32.5
Crotch height	28.625	28.75	28.875	29	29.125	29.125	29.125	29.125	29.125	29.125
Ft. waist length	13.625	13.875	14.125	14.375	14.625	14.875	15.125	15.375	15.625	15.875
Bk waist length	15.75	16	16.25	16.5	16.75	16.75	16.75	16.75	16.75	16.75
Rise										
WIDTH & LENGTH										
Across Schoulder										
Cross-back width	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18
Cross-chest width	12.5	12.875	13.25	13.625	14	14.375	14.75	15.125	15.5	15.875
Shoulder length	4.3125	4.375	4.4375	4.5	4.5625	4.5625	4.5625	4.5625	4.5625	4.5625
Shoulder slope (degrees)	24	24	24	24	24	24	24	24	24	24
Arm length	23.5625	23.75	23.9375	24.125	24.3125	24.3125	24.3125	24.3125	24.3125	24.3125
Bust point to bust point	8	8.25	8.5	8.75	9	9.25	9.5	9.75	10	10.25

HALF SIZE FIGURE TYPE SIZING - NBSVPS

Measurement	12.5	14.5	16.5	18.5	20.5	22.5	24.5	26.5
GIRTH:								
Bust	36	38	40	42	44	46	48	50
Waist	28	30	32	34	36.5	39	41.5	44
High hip	35	37	39	41	43.25	45.5	47.75	50
Hip	37	39	41	43	45	47	49	51
Neck Base								
Upper arm	11.375	12	12.625	13.25	13.875	14.5	15.125	15.75
Thigh, Max	21.25	22.5	23.75	25	26.25	27.5	28.75	30
Total Crotch	29.375	30.125	30.875	31.625	32.375	33.125	33.875	34.625
VERTICAL								
Cervical height	51.5	52	52.5	53	53.5	54	54.5	55
Waist height	37.375	37.75	38.125	38.5	38.875	39.25	39.625	40
Hip height	29.875	30	30.125	30.25	30.375	30.5	30.625	30.75
Crotch height	26.625	26.75	26.875	27	27.125	27.25	27.375	27.5
Ft. waist length (neck to waist)	12.75	13	13.25	13.5	13.75	14	14.25	14.5
Bk waist length (neck to waist)	14.625	14.875	15.125	15.375	15.625	15.875	16.125	16.375
Rise								
WIDTH & LENGTH								
Across Schoulder								
Cross-back width	13	13.5	14	14.5	15	15.5	16	16.5
Cross-chest width	12.125	12.5	12.875	13.25	14	14.375	14.375	14.75
Shoulder length	4.25	4.3125	4.375	4.4375	4.5	4.5625	4.625	4.6875
Shoulder slope (degrees)	24	24	24	24	24	24	24	24
Arm length (shoulder to wrist)	21.875	22.0625	22.25	22.4375	22.625	22.8125	23	23.1875
Bust point to bust point	7.75	8	8.25	8.5	8.75	9	9.25	9.5

Appendix C: ASTM# d5585-95, Standard Table of Body Measurements for Adult Misses Figure Type, Sizes 2-20, 1995

MISSY SIZING--ASTM 5585

Measurement	2	4	6	8	10	12	14	16	18	20
GIRTH:										
Bust	32.00	33.00	34.00	35.00	36.00	37.50	39.00	40.50	42.50	44.50
Waist	24.00	25.00	26.00	27.00	28.00	29.50	31.00	32.50	34.50	36.50
High hip	31.50	32.50	33.50	34.50	35.50	37.00	38.50	40.00	42.00	44.00
Hip	34.50	35.50	36.50	37.50	38.50	40.00	41.50	43.00	45.00	47.00
Neck Base	13.50	13.75	14.00	14.25	14.50	14.88	15.25	15.63	16.13	16.63
Upper arm	10.00	10.25	10.50	10.75	11.00	11.38	11.75	12.13	12.75	13.38
Thigh, Max	19.50	20.25	21.00	21.75	22.50	23.50	24.50	25.50	26.75	28.00
Total Crotch	25.00	25.75	26.50	27.25	28.00	28.75	29.50	30.25	31.00	31.75
VERTICAL										
Cervical height	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00
Waist height	39.25	39.50	39.75	40.00	40.25	40.50	40.75	41.00	41.25	41.50
Hip height	31.25	31.50	31.75	32.00	32.25	32.50	32.75	33.00	33.25	33.50
Crotch height	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50
Ft waist length	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75
Bk waist length (necktowaist)	15.50	15.75	16.00	16.25	16.50	16.75	17.00	17.25	17.50	17.75
Rise	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75	12.00
WIDTH & LENGTH										
Across Schoulder	14.38	14.63	14.88	15.13	15.38	15.75	16.13	16.50	17.00	17.50
Cross-back width	13.88	14.13	14.38	14.63	14.88	15.25	15.63	16.00	16.50	17.00
Cross-chest width	12.88	13.13	13.38	13.63	13.88	14.25	14.63	15.00	15.50	16.00
Shoulder length	4.94	5.00	5.06	5.13	5.19	5.31	5.44	5.56	5.75	5.93
Shoulder slope (degrees)	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Arm length (shlder to wrist)	22.94	23.13	23.31	23.50	23.69	23.88	24.06	24.25	24.44	24.63
Bust point to bust point	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25

Appendix D: ASTM# d5586-95, Standard Tables of Body Measurements for Women Aged 55 and Older (All Figure Types), 1995

55+ JUNIOR FIGURE TYPE SIZING- -ASTM 5586

Measurement	3	5	7	9	11	13	15
GIRTH:							
Bust	29.84	31.43	32.52	33.60	35.02	36.54	37.28
Waist	26.20	27.28	28.21	29.26	30.44	32.05	32.95
High hip							
Hip	34.20	35.18	36.39	36.81	38.18	39.19	40.50
Neck Base	14.52	14.99	15.44	15.10	15.32	15.66	16.00
Upper arm	9.79	10.15	10.72	11.05	11.57	11.99	12.36
Thigh, Max	19.15	19.84	21.09	21.11	22.11	22.64	23.75
Total Crotch	26.15	26.42	27.20	27.61	28.06	28.86	29.53
VERTICAL							
Cervical height	53.11	53.91	54.18	54.68	55.13	55.79	56.30
Waist height	37.87	38.59	38.74	39.06	39.36	39.78	40.22
Hip height	31.86	32.35	32.68	32.89	33.12	33.36	33.44
Crotch height	27.76	28.57	28.53	28.63	28.84	28.92	29.08
Ft. waist length (neck to waist)	12.60	12.82	13.11	13.09	13.39	13.63	13.80
Bk waist length (neck to waist)	15.24	15.32	15.38	15.62	15.78	15.99	16.12
Rise							
WIDTH & LENGTH							
Across Shoulder	14.64	14.62	14.95	15.07	15.33	15.67	15.64
Cross-back width	14.00	14.12	14.20	14.31	14.52	15.09	15.48
Cross-chest width	13.37	14.00	13.80	13.83	14.14	14.30	14.58
Shoulder length	4.86	5.02	5.07	5.06	5.09	5.19	5.21
Shoulder slope (degrees)	21.61	22.57	21.04	22.54	22.08	21.95	21.31
Arm length (shlder to wrist)	22.10	22.38	22.31	22.64	22.93	23.15	23.21
Bust point to bust point	6.51	6.91	7.08	7.17	7.34	7.62	7.77

55+ JUNIOR PETITE FIGURE TYPE SIZING--ASTM 5586

Measurement	3	5	7	9	11	13	15
GIRTH:							
Bust	33.58	33.25	33.83	35.42	35.93	37.66	37.29
Waist	29.61	29.52	29.61	31.29	31.61	33.49	33.21
High hip							
Hip	36.05	35.99	36.09	37.50	37.90	39.50	40.53
Neck Base	14.79	15.52	14.84	15.29	15.42	15.86	15.86
Upper arm	11.02	10.38	10.82	11.42	11.69	12.29	12.46
Thigh, Max	20.64	19.93	20.36	21.11	21.75	22.58	23.52
Total Crotch	27.06	26.81	26.78	27.62	27.91	28.61	29.38
VERTICAL							
Cervical height	56.75	57.16	58.03	58.33	59.12	59.51	60.52
Waist height	35.94	36.04	36.08	36.62	37.10	37.28	38.34
Hip height	29.22	29.72	30.05	30.09	30.78	30.68	31.69
Crotch height	25.56	26.08	26.36	26.14	26.65	26.74	27.57
Ft. waist length (neck to waist)	11.90	11.78	12.26	12.49	12.70	13.13	13.14
Bk waist length (neck to waist)	14.45	14.72	14.89	15.10	15.08	15.18	15.38
Rise							
WIDTH & LENGTH							
Across Schoulder	14.57	14.35	14.59	14.88	15.21	15.40	15.35
Cross-back width	13.33	14.15	14.09	14.48	14.83	15.12	15.38
Cross-chest width	13.75	13.23	13.48	13.66	14.03	14.36	14.55
Shoulder length	4.89	4.63	4.87	4.91	5.02	5.07	4.92
Shoulder slope (degrees)	22.71	24.02	20.62	20.98	22.23	22.26	22.04
Arm length (shlder to wrist)	21.43	21.70	21.34	21.72	21.85	22.06	22.52
Bust point to bust point	7.11	7.22	7.19	7.45	7.57	7.83	7.74

55+ MISSES PETITE FIGURE TYPE SIZING--ASTM 5586

Measurement	8	10	12	14	16	18
GIRTH:						
Bust	31.45	32.79	34.36	35.74	37.57	39.56
Waist	27.55	28.77	29.89	31.18	32.98	35.19
High hip						
Hip	34.85	36.01	37.28	38.44	39.71	41.55
Neck Base	14.87	15.09	15.19	15.68	15.70	16.32
Upper arm	10.11	10.62	11.10	11.73	12.29	12.96
Thigh, Max	19.88	20.66	21.40	22.12	22.94	23.88
Total Crotch	26.10	26.91	27.40	28.15	28.84	30.07
VERTICAL						
Cervical height	52.41	52.96	53.44	53.57	54.71	55.39
Waist height	37.35	37.70	38.08	38.33	38.83	39.42
Hip height	31.26	31.50	31.79	32.09	32.44	32.51
Crotch height	27.73	27.64	27.76	27.79	28.04	28.20
Ft. waist length (neck to waist)	12.42	12.51	13.03	13.38	13.58	13.87
Bk waist length (neck to waist)	15.06	15.26	15.36	15.53	15.85	15.97
Rise						
WIDTH & LENGTH						
Across Schoulder	14.40	14.85	15.10	15.37	15.58	16.04
Cross-back width	13.88	14.01	14.76	14.97	15.23	15.95
Cross-chest width	13.29	13.45	13.81	14.22	14.41	14.97
Shoulder length	4.95	4.91	4.98	5.07	5.13	5.21
Shoulder slope (degrees)	21.12	20.41	21.12	22.09	21.82	20.94
Arm length (shlder to wrist)	21.69	21.94	22.27	22.33	22.74	23.01
Bust point to bust point	6.96	7.06	7.41	7.55	7.83	8.25

55+ MISSES SIZING--ASTM 5586

Measurement	6	8	10	12	14	16	18	20	22
GIRTH:									
Bust	30.66	31.45	32.60	34.18	35.68	37.22	39.13	41.01	43.23
Waist	26.64	27.22	28.40	29.81	31.06	32.57	34.48	36.97	39.32
High hip									
Hip	35.67	35.51	36.40	37.79	38.92	40.03	41.61	43.46	44.82
Neck Base	14.96	15.13	15.33	15.49	15.88	16.30	16.53	17.17	17.22
Upper arm	10.08	10.26	10.66	11.27	11.73	12.27	12.85	13.64	14.08
Thigh, Max	20.17	20.21	21.01	21.99	22.52	23.10	23.92	25.05	25.64
Total Crotch	27.72	27.17	27.34	28.02	29.04	29.38	30.55	30.20	31.85
VERTICAL									
Cervical height	55.11	55.26	55.79	56.37	57.09	57.64	58.28	58.76	59.42
Waist height	39.38	39.54	39.80	40.43	40.84	41.17	41.53	41.96	42.45
Hip height	32.57	33.27	33.70	34.15	34.34	34.63	34.61	34.78	34.96
Crotch height	28.91	29.19	29.52	29.76	29.82	30.19	30.18	30.23	30.65
Ft. waist length (neck to waist)	12.94	13.09	13.28	13.44	13.69	13.96	14.17	14.56	14.88
Bk waist length (neck to waist)	15.72	15.71	15.98	15.95	16.24	16.47	16.57	16.80	16.98
Rise									
WIDTH & LENGTH									
Across Schoulder	14.62	14.80	15.18	15.45	15.84	16.01	16.28	16.66	17.19
Cross-back width	14.21	14.20	14.28	14.57	14.86	15.44	15.95	16.62	17.32
Cross-chest width	13.54	13.53	13.52	14.00	14.23	14.56	15.02	15.75	16.00
Shoulder length	4.78	5.09	5.08	5.25	5.15	5.31	5.31	5.39	5.47
Shoulder slope (degrees)	21.40	22.02	22.34	21.98	22.54	22.51	21.76	20.51	20.86
Arm length (shoulder to wrist)	22.41	22.70	23.02	23.23	23.54	23.86	24.08	24.24	24.73
Bust point to bust point	6.67	6.82	7.03	7.29	7.51	7.73	8.24	8.64	8.84

55+ MISSES TALL SIZING--ASTM 5586

Measurement	10	12	14	16	18	20	22
GIRTH:							
Bust	33.19	35.48	36.9	38.17	39.94	41.92	44.85
Waist	28.48	30.67	32.3	33.74	35.43	37.83	41.17
High hip							
Hip	37.42	38.88	40.08	41.49	42.58	44.18	47.87
Neck Base	15.62	15.84	16.15	16.55	17.25	17.22	17.9
Upper arm	10.95	11.57	12.13	12.81	13.26	14.07	14.83
Thigh, Max	21.46	22.35	23.24	24.2	24.61	25.95	27.33
Total Crotch	28.19	29.06	29.53	30.6	31.14	32.9	33.41
VERTICAL							
Cervical height	58.01	58.93	59.43	59.82	60.69	61.36	61.75
Waist height	41.59	42.22	42.72	41.14	43.58	43.95	44.35
Hip height	35.46	35.83	36.04	36.1	36.53	35.83	36.29
Crotch height	30.95	31.2	31.55	31.63	31.9	31.47	31.81
Ft. waist length (neck to waist)	13.96	13.96	13.94	14.28	14.74	14.86	15.64
Bk waist length (neck towaist)	16.43	16.71	16.71	16.76	17.1	17.36	17.37
Rise							
WIDTH & LENGTH							
Across Schoulder	15.47	15.86	16.04	16.31	16.71	16.83	17.38
Cross-back width	14.71	15.4	15.69	15.88	16.21	16.6	17.55
Cross-chest width	14.37	14.47	14.83	15.42	15.71	15.94	17.04
Shoulder length	5.15	5.32	5.37	5.43	5.42	5.44	5.48
Shoulder slope (degrees)	22.57	22.08	20.57	21.68	19.64	20.6	20.96
Arm length (shoulder to wrist)	23.92	24.05	24.41	24.85	25.06	25.03	25.62
Bust point to bust point	7.13	7.44	7.73	7.89	8.45	8.77	9.28

55+ HALF-SIZE FIGURE TYPE SIZING--ASTM 5586

Measurement	12.5	14.5	16.5	18.5	20.5	22.5	24.5	26.5
GIRTH:								
Bust	20.03	21.39	22.08	22.76	23.56	24.44	25.87	26.39
Waist	32.29	34.86	37.01	38.47	39.91	42.01	43.16	45.75
High hip								
Hip	38.04	40.31	42.43	43.79	45.33	47.34	49.09	50.7
Neck Base	15.63	15.95	16.44	16.86	17.55	17.9	18.08	18.42
Upper arm	11.84	12.6	13.22	13.82	14.37	15.11	15.47	16.13
Thigh, Max	21.34	22.93	23.9	24.66	25.39	26.28	27.08	27.65
Total Crotch	27.49	28.99	29.93	31.07	31.97	33	34.25	35.04
VERTICAL								
Cervical height	59.9	60.16	60.62	61.78	62.58	62.96	63.47	64
Waist height	37.24	37.74	38.2	38.94	39.56	39.77	40.42	40.56
Hip height	31.12	31.27	31.29	31.77	32.09	32	32.7	32.39
Crotch height	27.13	27.2	27.07	27.42	27.72	27.63	28.05	27.77
Ft waist length (necktowaist)	13.01	13.67	14.01	14.26	14.49	14.78	14.79	15.42
Bkwaist length (necktowaist)	15.31	15.61	15.72	16	16.25	16.45	16.48	16.8
Rise								
WIDTH & LENGTH								
Across Schoulder	15.18	15.51	15.98	16.33	16.72	16.89	17.51	17.54
Cross-back width	14.82	15.65	16.12	16.7	16.94	17.51	18.14	18.83
Cross-chest width	13.8	14.75	15.1	15.55	15.76	16.19	16.52	17.03
Shoulder length	5.02	5.11	5.1	5.18	5.24	5.3	5.5	5.34
Shoulder slope (degrees)	21.83	21.12	20.31	19.92	20.49	20.09	19.13	20.34
Arm length (shlder to wrist)	22.02	22.35	22.6	22.93	23.24	23.53	23.68	24.18
Bust point to bust point	7.8	8.14	8.53	8.73	9.02	9.19	9.69	9.78

55+ WOMEN'S FIGURE TYPE SIZING--ASTM 5586

Measurement	34	36	38	40	42	44	46	48	50	52
GIRTH:										
Bust	38.92	40.59	42.5	44.12	45.85	46.92	49.99	50.98	54.99	58.27
Waist	34.26	36.33	38.45	40.24	41.76	43.52	45.56	49.63	49.02	51.97
High hip										
Hip	40.47	42.47	44.13	46.08	46.39	49.98	50.49	53.72	52.82	62.2
Neck Base	16.17	16.73	17.15	17.5	17.66	18.01	17.65	18.53	18.86	17.5
Upper arm	12.65	13.35	13.82	14.47	14.93	15.48	15.54	16.58	16.08	16.14
Thigh, Max	23.34	24.31	25.24	26.31	26.13	27.98	27.26	28.54	30.71	29.13
Total Crotch	29.49	30.78	31.62	32.72	33.12	33.8	35.25	34.54	36.55	37.8
VERTICAL										
Cervical height	56.42	56.87	57.46	58.04	59.23	59.43	59.78	60.08	58.66	57.48
Waist height	40.16	40.66	40.94	41.56	42.34	42.56	42.85	42.17	41.93	39.17
Hip height	33.49	33.4	33.42	33.72	34.19	34.83	34.84	33.62	34.32	32.09
Crotch height	29.07	29.08	29.12	29.23	29.92	29.72	29.77	28.76	28.02	25.39
Ft.waist length (necktowaist)	14.04	14.24	14.52	15.03	15.27	16.07	15.86	17.37	14.96	15.75
Bkwaist length (necktowaist)	16.23	16.25	16.51	16.5	16.92	16.87	16.92	17.91	16.73	18.31
Rise										
WIDTH & LENGTH										
Across Schoulder	15.95	16.29	16.62	17.03	17.24	17.4	18.54	18.18	18.18	19.69
Cross-back width	15.77	16.16	16.67	17.27	17.38	17.69	6.93	19.18	20.08	22.44
Cross-chest width	14.81	15.26	15.53	16.48	16.1	16.74	17.64	18.22	17.26	16.14
Shoulder length	5.25	5.22	5.27	5.36	5.49	5.57	5.64	5.73	5.45	6.5
Shoulder slope (degrees)	20.93	20.74	20.76	20.42	19.52	20.27	20.19	18.33	18.33	15
Arm length	23.29	23.72	23.81	23.95	24.57	24.65	24.57	25.46	24.67	22.24
Bust point to bust point	8.06	8.38	8.75	9.06	9.5	9.45	10.04	10.32	10.56	11.4