FEMALE FIGURE IDENTIFICATION TECHNIQUE (FFIT) FOR APPAREL

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ABSTRACT

Sizing standards used in the United States that identify the body measurements used in the design and development of clothing were established from identified "best practices" of the apparel industry. 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. Regardless of the sizing systems used, however, almost all are based on the myth that humans have mathematically proportional bodies and that they grow in proportional ways. In addition, the shapes and proportions of today's American population differ greatly from the shapes of the generations before. So a variety of issues impact our inability to 'fit' the American customer of today. These fit issues continue to be a growing concern.

Mass customization methodologies appear to provide a "solution" by allowing customized fit of apparel. A significant underlying problem exists, however, when attempting to alter a garment for fit based on one standard shaped garment product. "Extreme" alterations seldom provide the desired fit in the final garment. This discovery has led us to understand that optimal customization can only occur if customization starts from the most correctly shaped garment for each customer's "figure type". Thus a system was developed to identify female figure types using 3D body scan data. Such categorization of body types will allow a more appropriate reorganization of sizing systems with more successful attempts at customization and mass customization. This information will allow researchers to analyze body scan data relative to target market sizing, develop new shape categories not possible with 2-dimensional systems, and characterize body types for today's market. This process allows us to use the most "correctly shaped" garment for the customization procedure that will better ensure satisfactory fit of the final garment.

Keywords: FFIT for Apparel, shape sorting, sizing standards, mass customization, fit, female figure types

1 Introduction

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.

2 Research Purpose and Methodology

The research of this study focused on one basic objective: 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 Best Fit software was created for comparison of 3D body scan data to recognized standards for body measurements. The FFIT for Apparel software was created to recognize body shape in conjunction with the 3D body scanner.

3 Literature Review

3.1 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 [1,2]. 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 [3]. 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 [4]."
- 'Simply a matter of length and width in each part of the pattern being correct for your figure [5]."

Much research has been conducted over the years on the topic of fit of apparel [6,7,8]. In general, consumers have been dissatisfied with fit for some time. 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 that 60 years old [9]. Dissatisfaction with fit can also be attributed to several factors that have changed the average body types: diets [10,11], physical exercise and activities [2,12], increased immigration [10], disproportionate growth rates in minority groups [10], sedentary lifestyles [13], and changes in ideals of masculinity and femininity [10].

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%.

For many years, the United States population has been a mixture of ethnic origins. 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 [14]. 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 [15,16,17,18]. The racial mixture in the United States is definitely different than in the 1940s when the body measurements used to develop the current standard were taken.

3.2 History of Figure Typing/Somatotyping

3.2.1 Early Physique Classifications

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 [19]. In the fourth century BC, Aristotle attempted to additionally elaborate and develop Hippocrates' ideas [20]. However, there would be many more years until further studies were conducted on the differing types of human body forms.

Around the seventeenth 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 [21].

The twentieth 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, began important scientific studies in the early 1920s. His findings grouped the human body-build in four basic categories. His bodily characteristics were, like those of most early physicians, associated with particular disease susceptibilities.

3.2.2 Twentieth Century Contributions to Figure Typing

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 bodies and temperaments. In 1940, Sheldon, with Stevens and Tucker, introduced the concept of "somatotype" in their book <u>The Varieties of Human Physique</u> [22] "The patterning of the morphological components as expressed by three numerals is called the somatotype" of the individual [22,p3]. Sheldon and his colleagues had worked out a system to measure these components and express them numerically [23]. These components were called endomorphy, mesomorphy, and ectomorphy. 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).

In the 1960s, the research team of Lindsay Carter and Barbara Heath collaborated on continuing the modification of Sheldon's somatype methodology [24]. Heath's 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 and the presentation of the Heath-Carter modified somatotype method were products of this joint effort[25].

Also 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.

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" [26]. 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.

Over the years, many researchers have used Douty's method of "graphic somatometry" in their studies of clothing. In 1977, Brinson [27] used the graphic somatometry method to evaluate the body characteristics of posture, general mass, proportion, contour, and balance and symmetry of similar body parts. She was successful in the satisfactory fit of her subjects by using body angle measurements to alter basic bodices and skirts.

Pouliot [28] 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.

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.

An Italian company called CAD Modeling 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 Modeling 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 [29]. 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).

3.2.3 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 [30].

The pattern industry then devised its own standard set of figure types and sizes. Figure 1 is a composite of the pattern industry figure types. Many pattern making and sewing books [31,32] reference these figure types as having differences in height and contour according to its designation. Table 1 describes each of the figure types. These figure types are in alignment with the groupings of the current ASTM classifications.

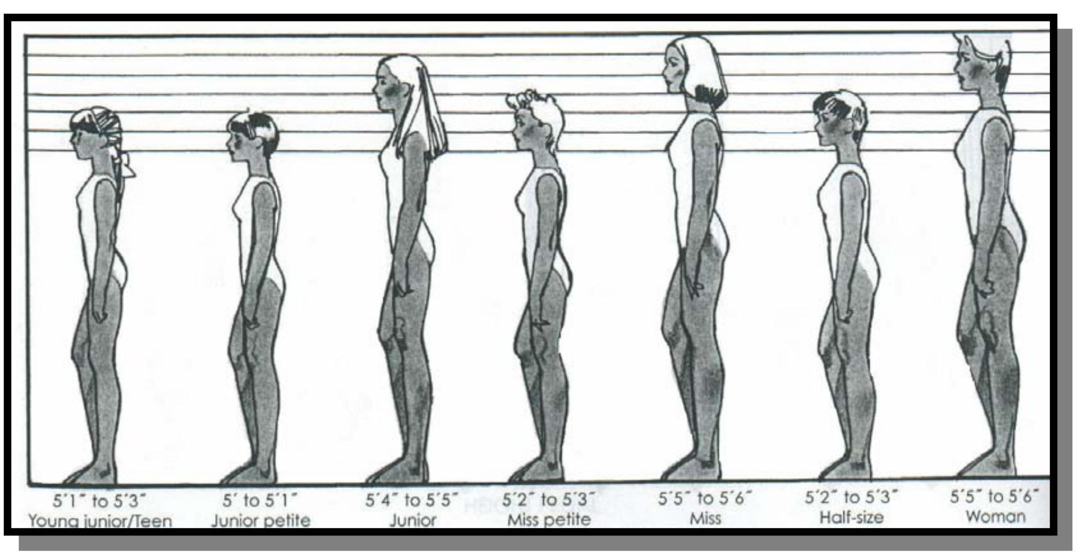


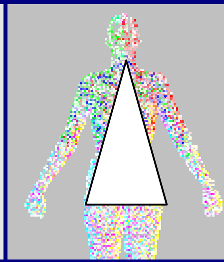
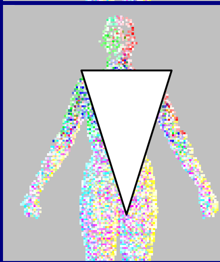
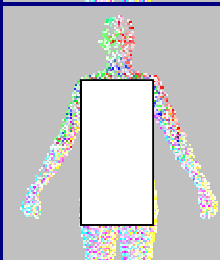
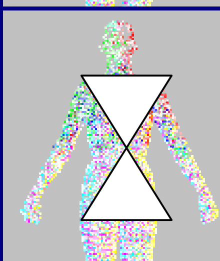
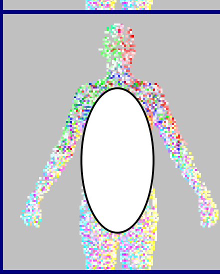
Figure 1. Compostion of pattern industry figure types. [31,p25]

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 2 characterizes these figure types.

Table 1. Pattern Industry Figure Type Characteristics [31]

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 2. Common Shape Groupings.

Figure Type	Traits	Illustration
Triangle[c, h, I, 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, I, 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, I, 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, I, 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, I, 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 [33] (b) iVillage.com, 2001 [34] (c) la.assortment.com, 2001 [35] (d) teraformahealth.com, 2001 [36] (e) tinajuanfitness.com, 1999 [37] (f) Farro, 1996 [38] (g) Jackowski, 1995 [39] (h)betterhalf.com, 2001[40] (i) carlamathis.com, 2001 [41] (j) Beauty Is, 2001[42] (k) exude.com, 2001 [43] (l) Duffy, 1987 [44] (m) Your Total Image, 2001 [45] (n) Palmer & Alto, 1998 [30] (o) Rasband, 1994 [46] (p) eswimmers.com, 2001 [47].

4 Results

4.1 Shape Sorting and Subgroup Identification

The 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 and then to develop preliminary subgroups for the female population that would aid in the development of better fitting clothing. 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. 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. Examples of the different shapes that were placed together by the cluster analysis can be found in Figure 2.

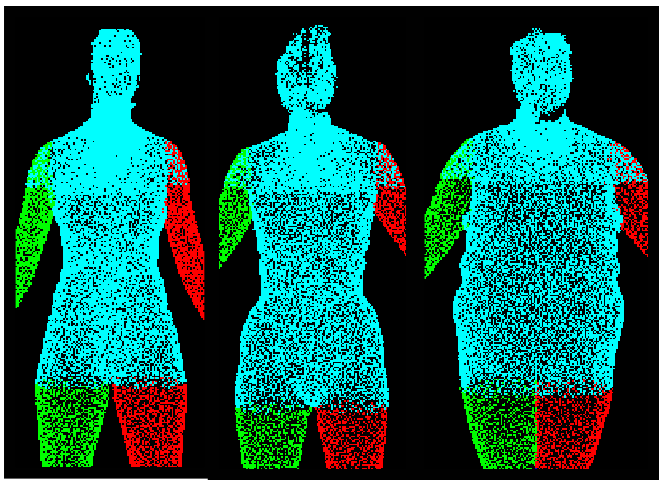


Figure 2. Cluster analysis of shapes within the same category.

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. 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 successfully identify shapes. Using mathematical criteria and 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 be more easily adjusted within each shape category for customized fit. After consideration of all of the available measurements that would describe the body, the 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 program code in 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. A visual check was made of each subject shape by our "expert panel" for verification that the shape labeled by the software was correct.

4.2 Individual Shape Category Information

4.2.1 Overall Description

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 3. None of our 222 subjects 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 4. Each shape category section will cover this information in detail.

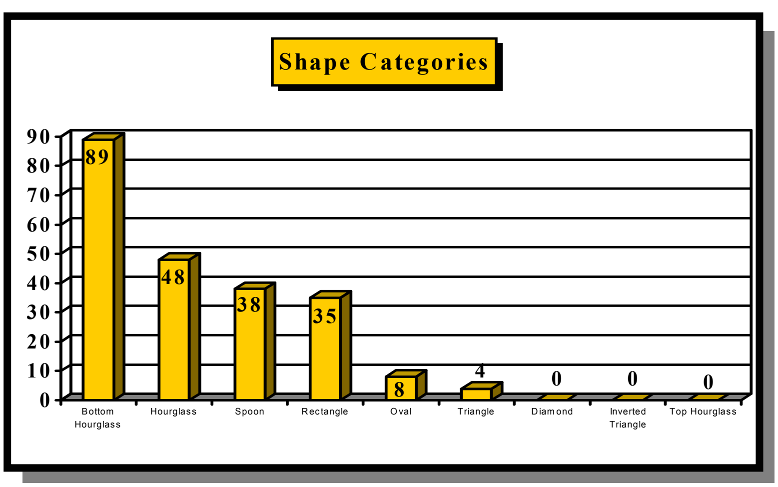


Figure 3. Sample distribution by shape.

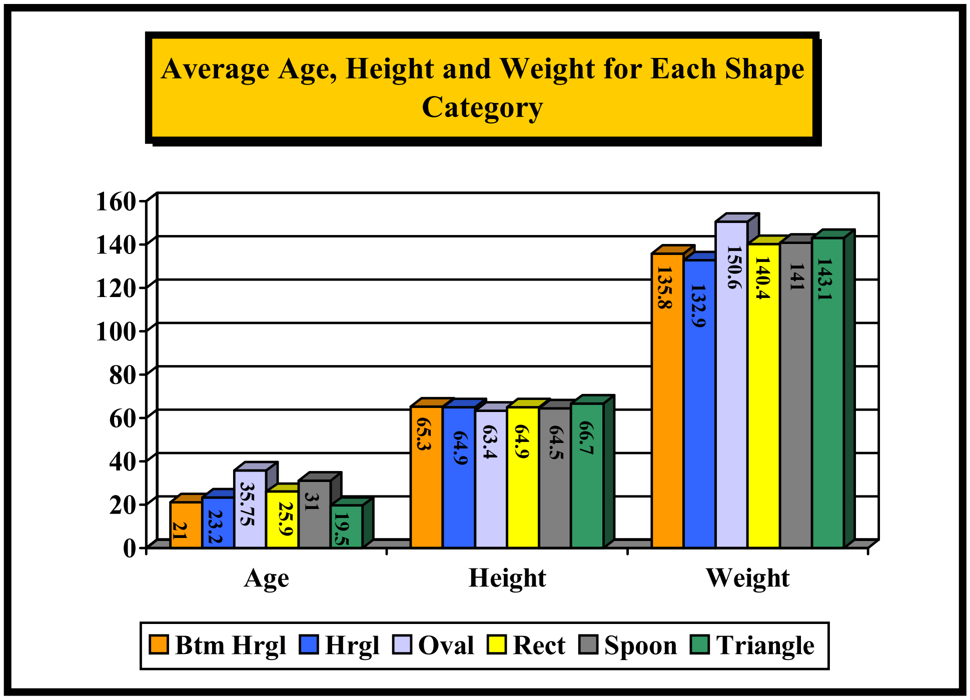


Figure 4. Average age, height, and weight for each shape category**.**

4.2.2 Hourglass Shape

Although 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 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 5, 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.

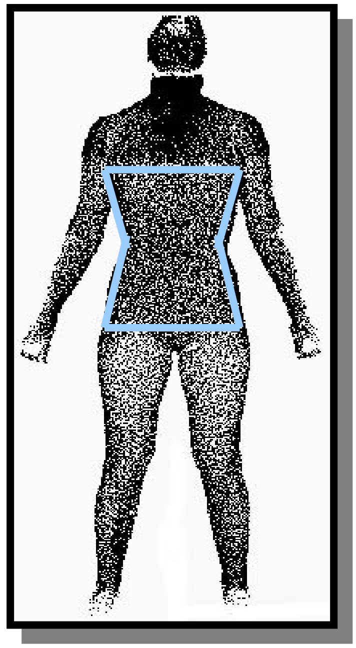


Figure 5. Example of a true Hourglass shape, Subject #HgTrue**.**

All of the 48 subjects with the Hourglass shape were visually verified individually to determine that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Hourglass shaped subjects are found in Figure 6. Each is superimposed over the true Hourglass shape example (Subject #HgTrue) to visually verify the proportionate body shape of the Hourglass figure.

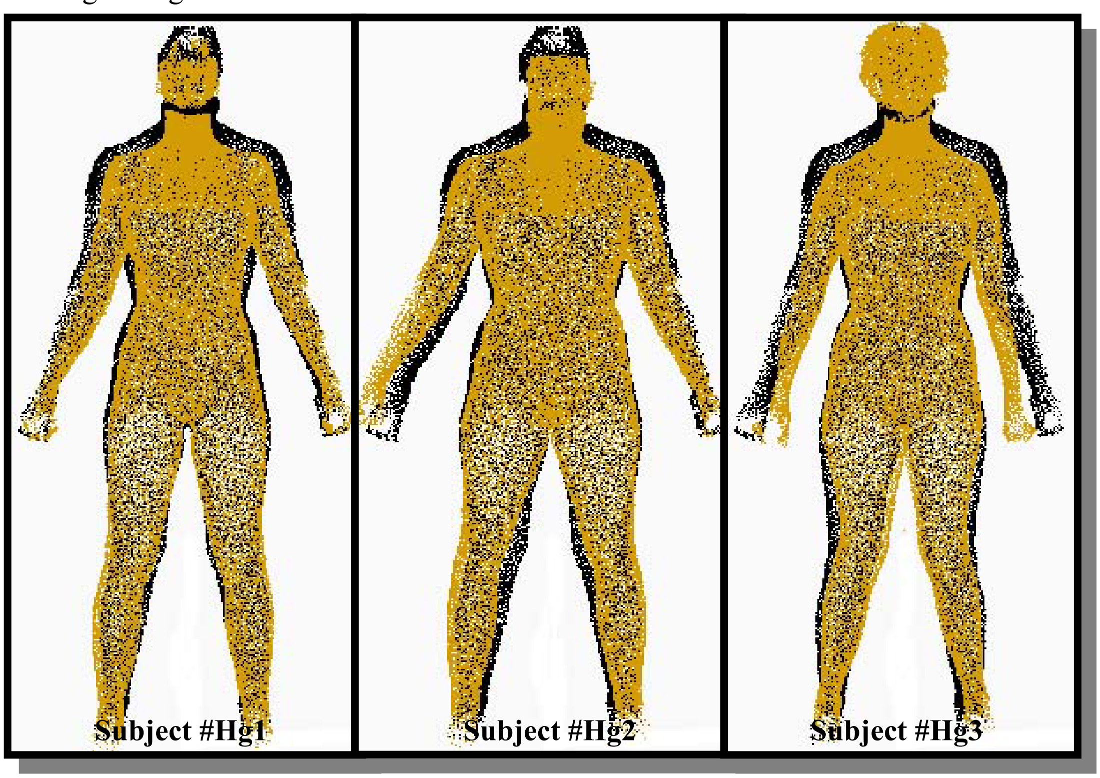


Figure 6. Subjects in the Hourglass shape category superimposed on the example of a true Hourglass shape.

4.2.3 Bottom Hourglass

The Bottom Hourglass was the largest shape category of this study with 40% of the subjects. There were 89 subjects with body shapes that were defined as Bottom Hourglass. 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, 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.

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 end up being a Triangle, primarily due to the lack of waist definition.

In Figure 7, 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 8.

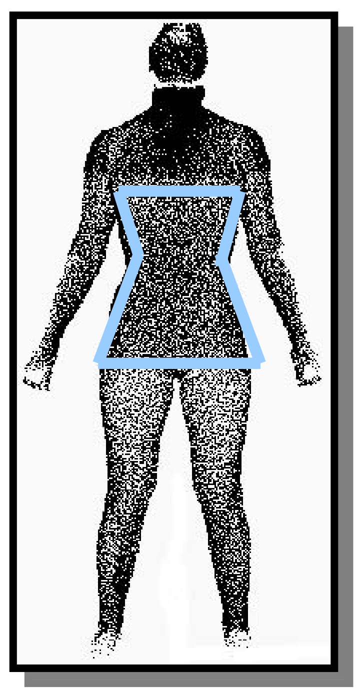


Figure 7. Example of a true Bottom Hourglass shape, Subject #BHgTrue.

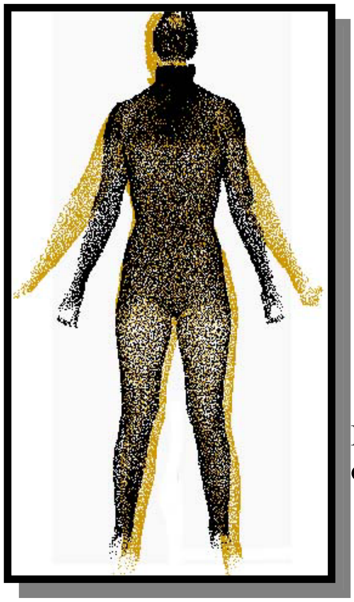


Figure 8. An Hourglass body shape (black) superimposed onto a Bottom Hourglass body shape (yellow).

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 9. Each is superimposed over the true Bottom Hourglass shape example (Subject #BHgTrue) to visually verify the proportionate body shape of the Bottom Hourglass figure.

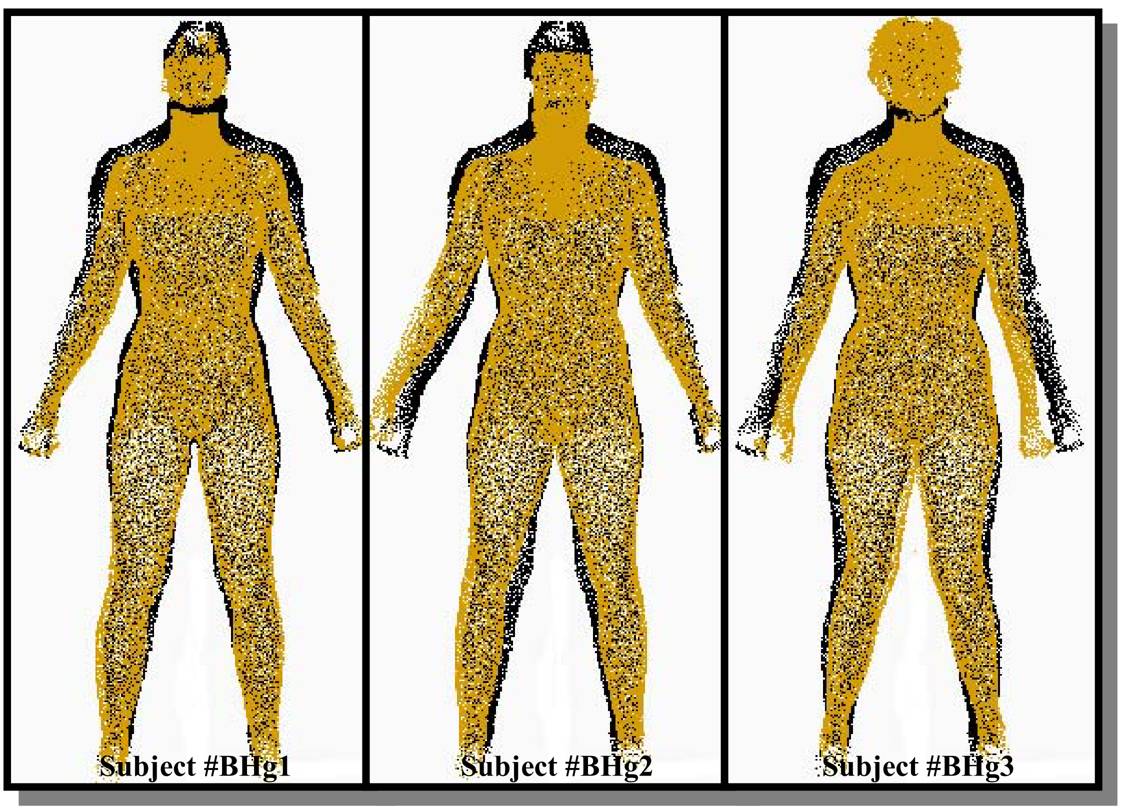


Figure 9. Bottom Hourglass shape comparison.

4.2.4 Top Hourglass

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. A simplistic representation of the shape without contrast of a body form is compared with the Hourglass and Bottom Hourglass shapes in Figure 10.

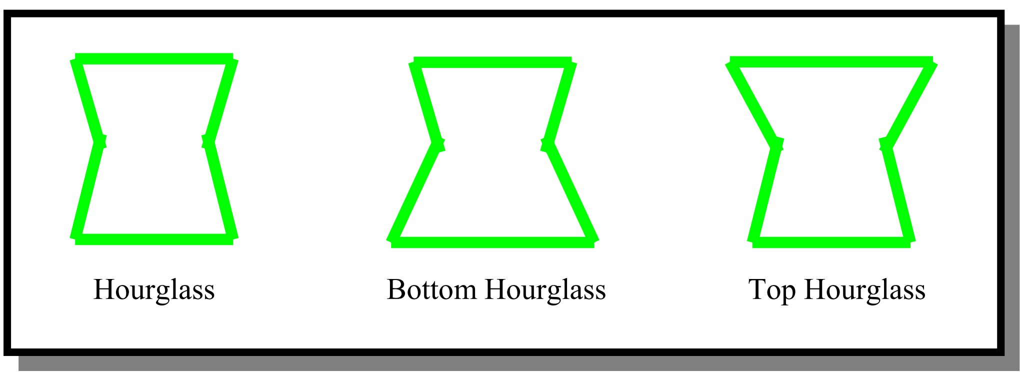


Figure 10. Comparison of the Hourglass, Bottom Hourglass, and Top Hourglass shapes.

4.2.5 Spoon

The Spoon was the third largest shape category of this study with 17% of the subjects or 38 of 222. 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 Hourglass shape AND the high hip-to-waist ratio is great, then that subject 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 defined 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 11, 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 12.

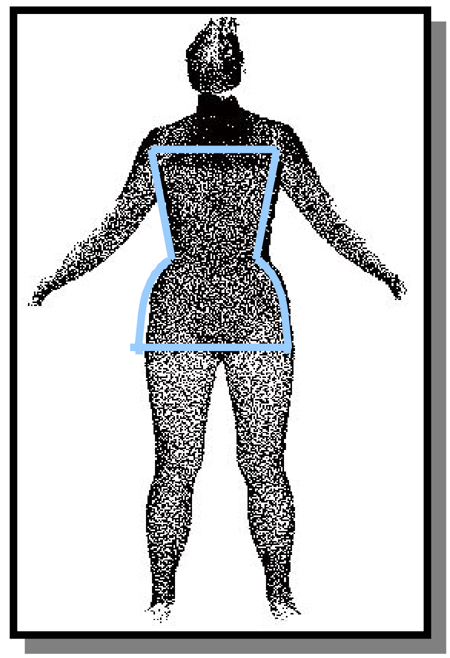


Figure 11. Example of a true Spoon shape, Subject #SpoonTrue.

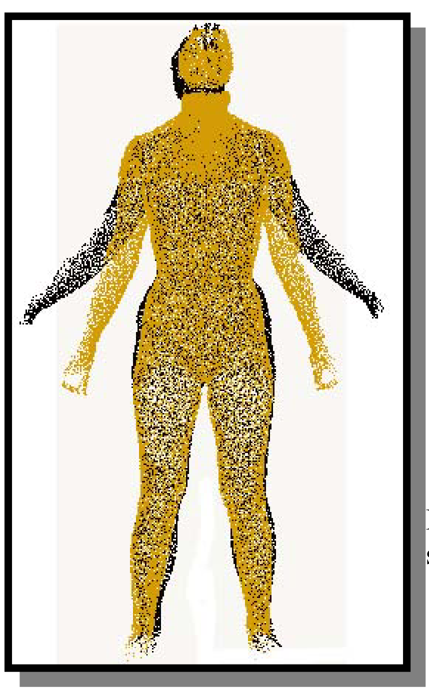


Figure 12. An Hourglass body shape (yellow) superimposed onto a Spoon body shape (black).

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 13. Each is superimposed over the true Spoon shape example (Subject #SpoonTrue) to visually verify the proportionate body shape of the Spoon figure.

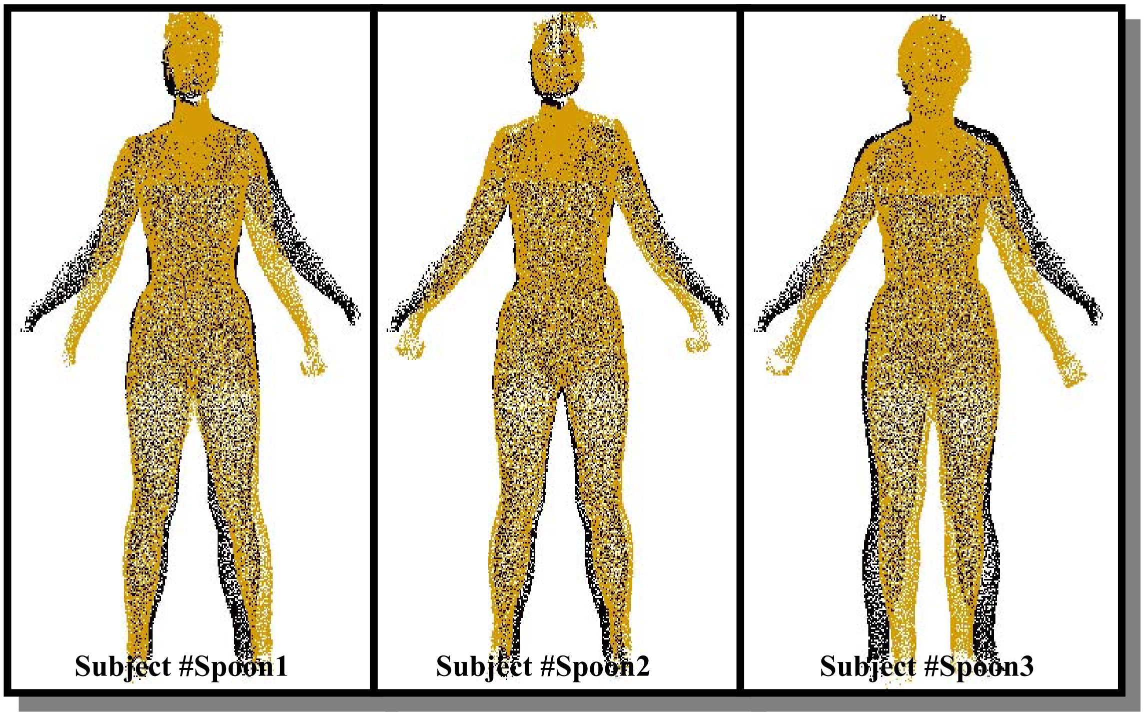


Figure 13. Subjects in the Spoon shape category superimposed on the example of a true Spoon shape.

4.2.6 Rectangle

The Rectangle was the fourth largest shape category of this study with 15.8% of the subjects (35 of the 222). 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 14, 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 15.

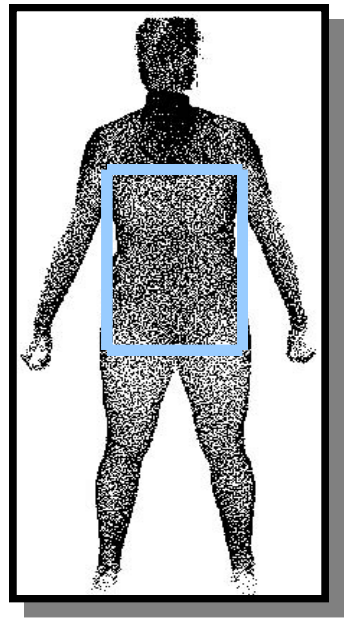


Figure 14. Example of a true Rectangle shape, Subject #RectTrue.

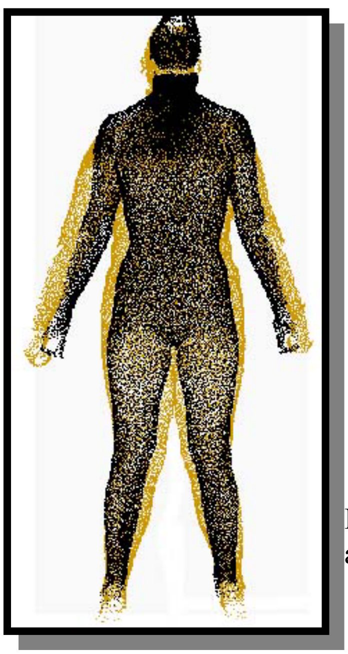


Figure 15. An Hourglass body shape (black) superimposed onto a Rectangle body shape (yellow).

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 16. 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.

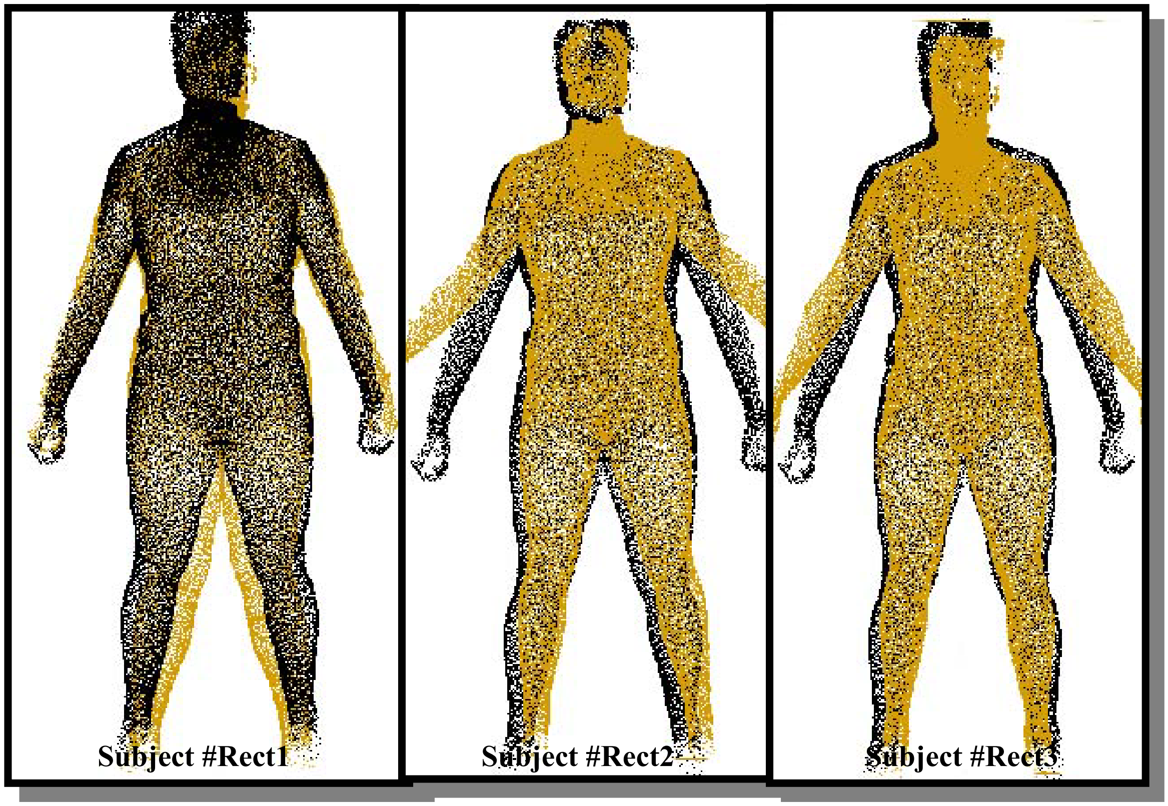


Figure 16. Subjects in the Rectangle shape category (yellow) superimposed on the example of a true Rectangle shape (black).

4.2.7 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 <u>FFIT for Apparel</u> 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, none of the 222 subjects fell into the Diamond shaped 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 17.

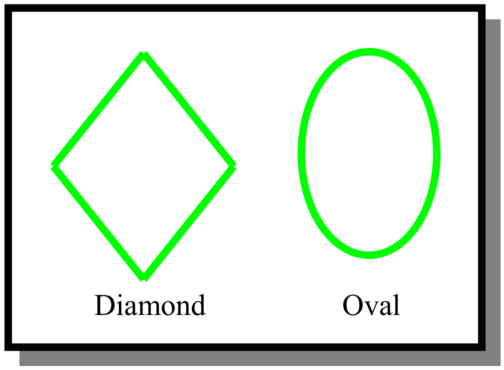


Figure 17. Comparison of the Diamond and Oval shapes.

4.2.8 Oval

The Oval was the fifth largest shape category of this study with 3.6% of the subjects (8 of the 222). 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 , 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 .

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 . Each is superimposed over the true Oval shape example (Subject #OvalTrue) to visually verify the proportionate body shape of the Rectangle figure.

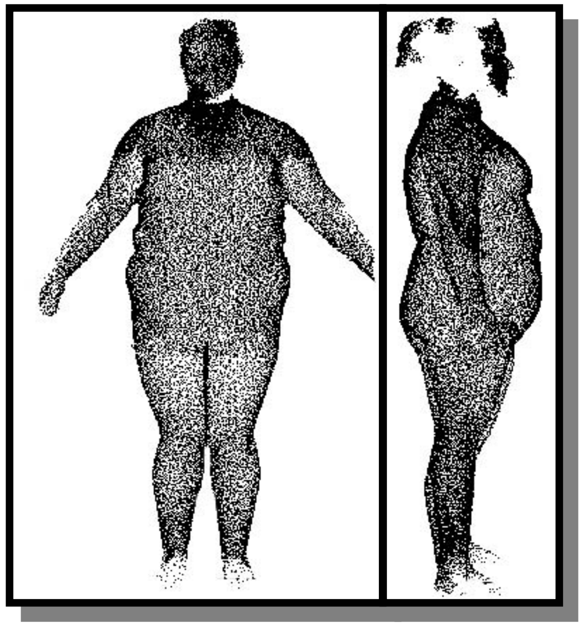


Figure 18. Example of a true Oval shape with a front and side view, Subject #OvalTrue.

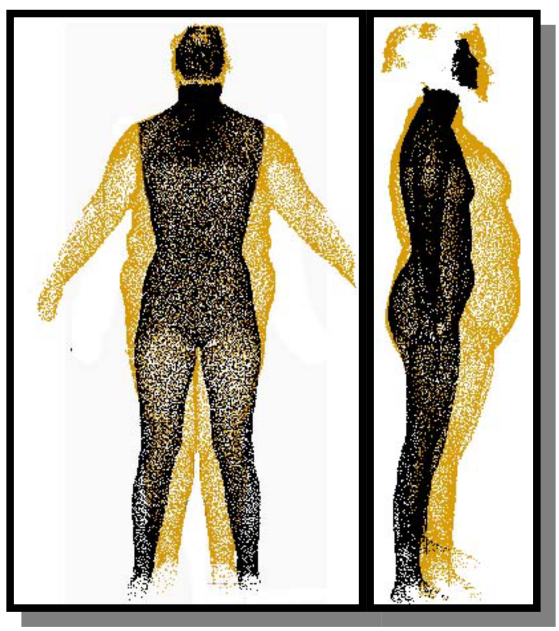


Figure 19. An Hourglass body shape (black) superimposed onto an Oval body shape (yellow).

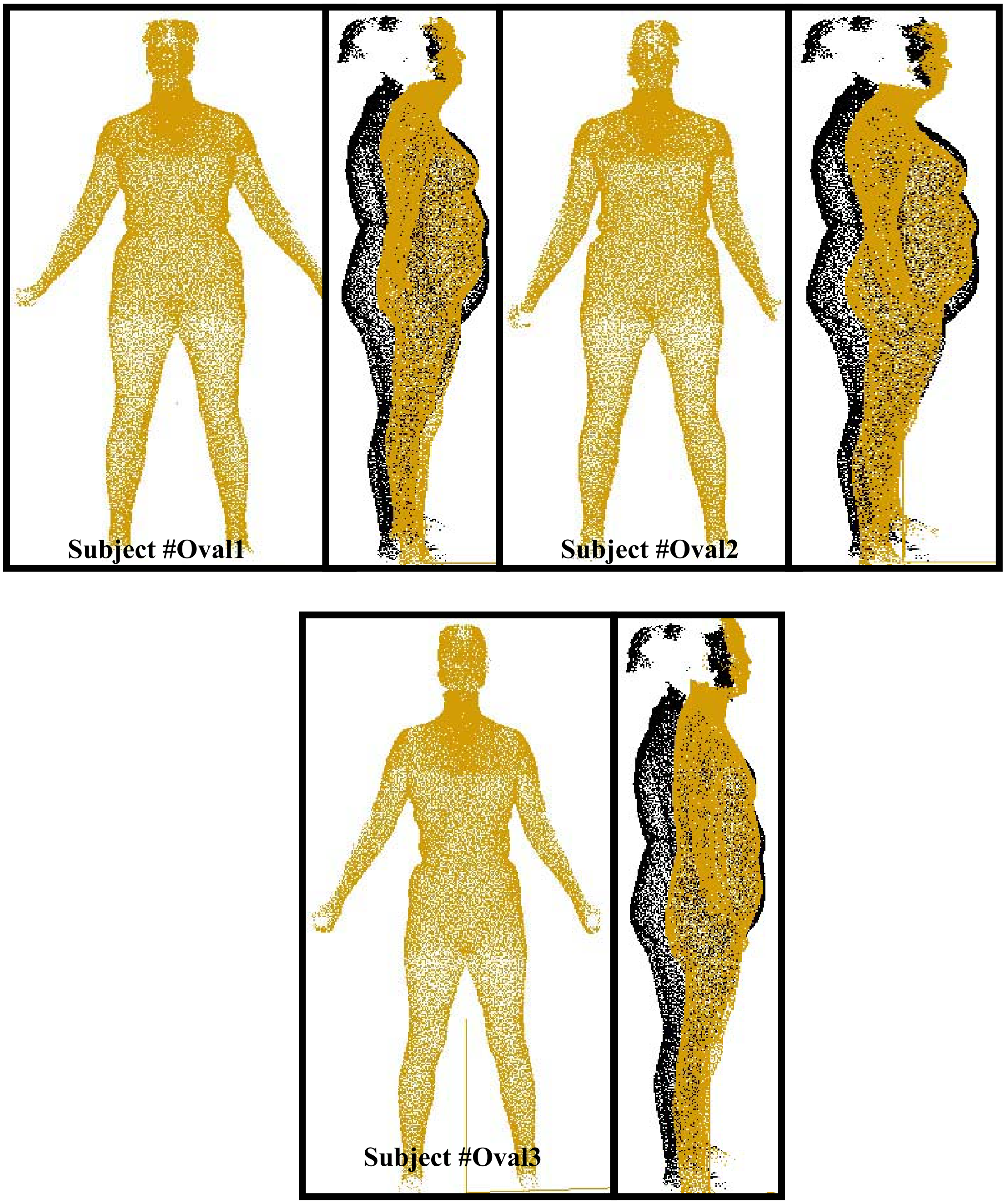


Figure 20. Subjects in the Oval shape category (yellow) superimposed on the example of a true Oval shape (black) with front and side views.

4.2.9 Triangle

There were 4 subjects, or 18% of the sample, who fulfilled the criteria for the smallest shape category as the Triangle. 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 21, 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 22Figure . Notice the image on the right in Figure 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.

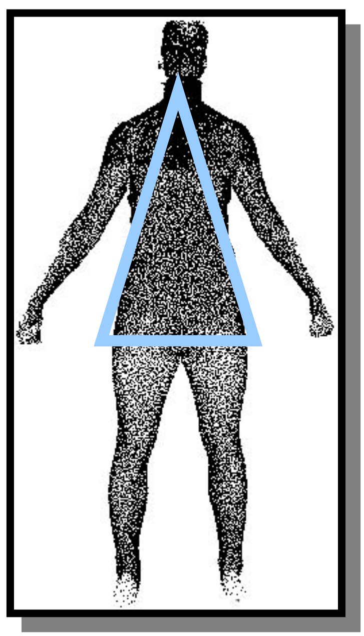


Figure 21. Example of a true Triangle shape, Subject #TriTrue.

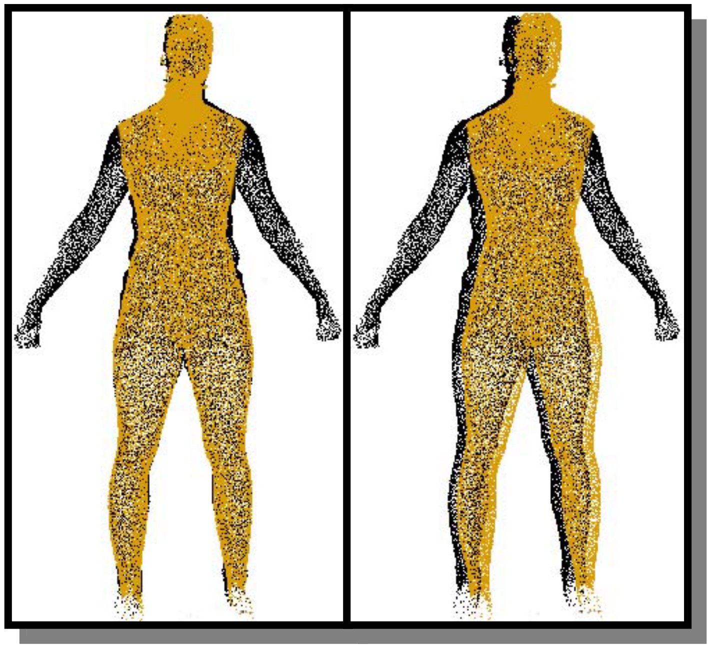


Figure 22. A Bottom Hourglass body shape (yellow) superimposed onto a Triangle body shape (black).

All of the 4 subjects with the Triangle shape were visually verified individually that the shape designation given by FFIT for Apparel was correct. Examples of 3 random Triangle shaped subjects are found in Figure 23Figure . Each is superimposed over the true Triangle shape example (Subject #TriTrue) to visually verify the proportionate body shape of the Triangle figure.

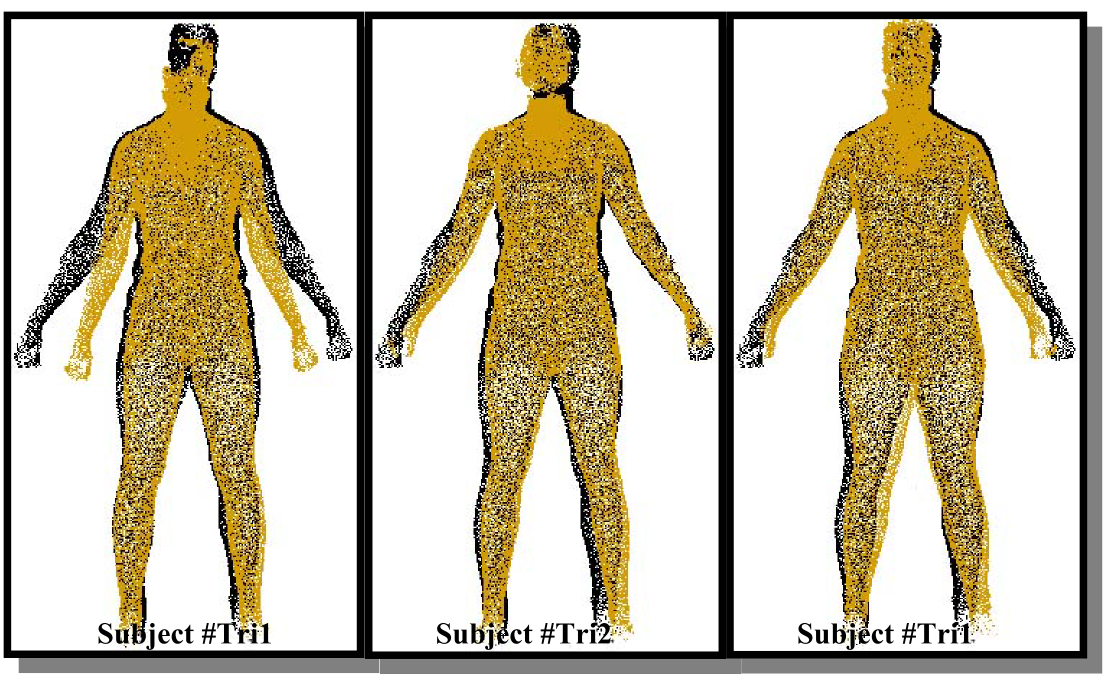


Figure 23. Subjects in the Triangle shape category (yellow) superimposed on the example of a true Triangle shape (black).

4.2.10 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 24.

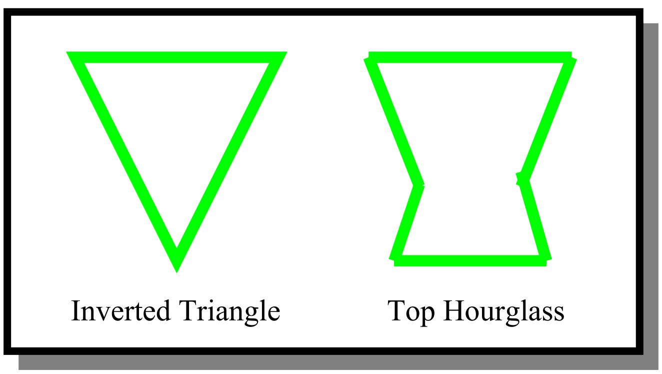


Figure 24. Comparison of the Inverted Triangle and Top Hourglass shapes**.**

5 Discussion

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 applied to. The CS215-58 measurements, found to provide the best fit for the majority of the subjects in this study, were almost 50% comprised of the Spoon category. The ASTM5586-95 (55+) measurements, found to provide the second 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's 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.

6 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:

- 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 much larger sample. This would possible allow for a statistical method such as data mining to occur to aid in statistical validity.
- A greater age assortment.
- More ethnic diversity. 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.
- 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.
- 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.
- The FFIT for Apparel software could be adapted so that different versions would apply to specific age or gender groups.

- Research should be conducted on 3D body scanning and the methods available to interpret 3D data.
- 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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