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# FEMALE FIGURE IDENTIFICATION TECHNIQUE (FFIT) FOR APPAREL PART II: DEVELOPMENT OF SHAPE SORTING SOFTWARE

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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 3-D body scan data. This article, as Part Two of two, describes the process involved in the development of an expert shape sorting system using 3D body scan data. This software will enable the identification of personal body shapes, allowing the use of 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*

## 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.

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 (Cotton Inc., 2002a, 200b, 1998, 1997). Regardless of how one defines fit exactly, it must always start from basic human proportional truths. 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.

## Research Purpose and Methodology

The research of this study focused on one basic objective: to develop software that would use 3-D body scan data to define the body shape of women. The software code was created based on theoretical mathematical shape definitions developed in earlier research (reported in Part I). The FFIT for Apparel software was created to enable the development of new sizing systems and more effective and efficient customization strategies.

## Literature Review

### <u>Fit and Sizing Issues</u>

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)."
- 'Simply a matter of length and width in each part of the pattern being correct for your figure (Minott, 1978)."

Much research has been conducted over the years on the topic of fit of apparel (AAMA, 1975; Croney, 1977; O'Brien & Shelton, 1941). 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 (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), physical exercise and activities (LaBat, 1987; Tamburrino, 1992b), increased immigration (Meek, 1994), disproportionate growth rates in minority groups (Meek, 1994), sedentary lifestyles (CNN, 2001), and changes in ideals of masculinity and femininity (Meek, 1994).

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. 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 (LePechoux, 1998; US Census, 2000). 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. Projections for the number of multiracial Americans will be released in a report in 2005 (FOXNews, 2004). 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 definitely different than in the 1940s when the body measurements used to develop the current standard were taken.

## 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).

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).

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 (Satake, Morris, Hopfe, & Malina, 1993).



## Methodology

The first step in achieving the objective of this research was to develop a database of three-dimensional body scan data, from a variety of consumer markets, which included 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.

The second step in achieving the objective of this was to transform the theoretical mathematical body shape framework, reported in Part I, into software code that could use extracted 3-D body scan measures and automatically determine the shape defined by those measures.

## Database Development

A convenience sample of women was solicited primarily from the Triangle area of North Carolina (Raleigh, Durham, and Cary). Each subject was informed of the scanning procedure, possible risks, confidentiality, and contacts in accordance with the rules of a Human Subject Review Board at the university. Demographic information was also collected for each subject.

Subjects wore close fitting athletic gear to be scanned. Extracted measurements, 3D point cloud data, and reduced body data were stored and maintained entirely by the subject identification number given to each subject. No potential subject was excluded on the basis of race, size or shape. Women ages 18 and older, who had complete demographic data, good 3D body scans, and complete extracted measurement data were used for the sizing system evaluation in this study.

## Shape Sorting and Subgroup Identification

The primary 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.

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 expressions to aid in the determination of body shapes. The elements for shape classification determined from the literature search were used as a starting point for the shape descriptions. 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, a preliminary set of shapes with was defined with mathematical descriptors. This theoretical framework (described in Part I) was then implemented using Visual Basic to develop shape sorting software code.

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.



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. This new shape identification software was called FFIT© (Female Figure Identification Technique) for Apparel.

## Individual Shape Category Information

**Description.** Of the 222 subjects, over 40% 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 1. 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 2. Each shape category section will cover this information in detail.

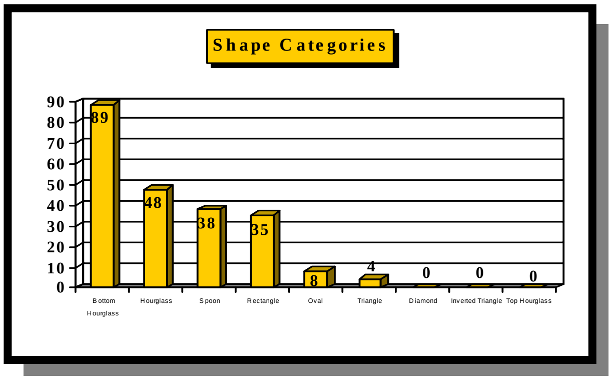


**Figure 1.** Sample distribution by shape.

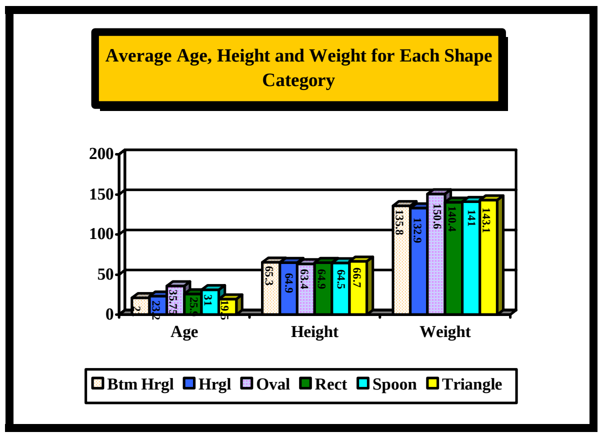


**Figure 2.** Average age, height, and weight for each shape category.

**<u>Hourglass Shape.</u>** 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 met the mathematical description previously defined. The Hourglass shape category was the second largest category, with 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 was that if a subject had 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 were about equal and significant, then the shape would be defined as Hourglass.

The <u>FFIT for Apparel</u> 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 will 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 3, 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.

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

**Bottom Hourglass**. The Bottom Hourglass was the largest shape category of this study with 40% or 89 of the subjects meeting that definition. The average age for this category was 21 with a range from 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.

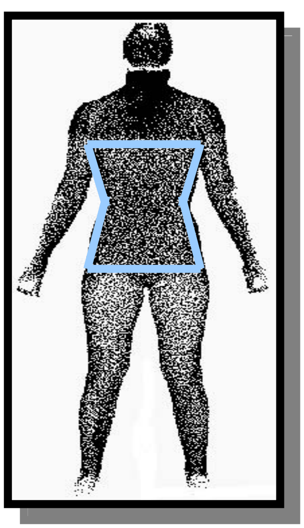

**Figure 3.** Example of a true Hourglass shape, Subject #HgTrue**.**



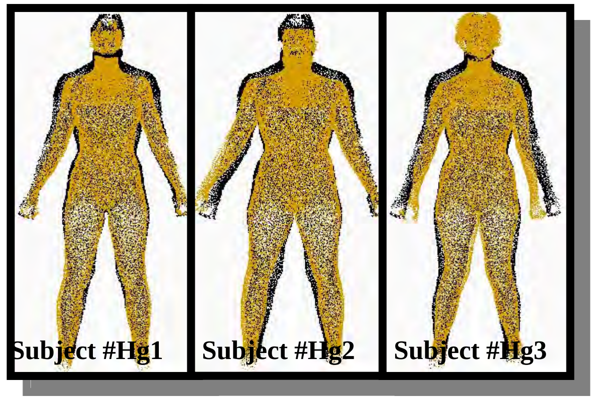


**Figure 4.** Hourglass subjects superimposed on the example of a true Hourglass shape.

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 shape will be defined as 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 will 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 5, 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 6.

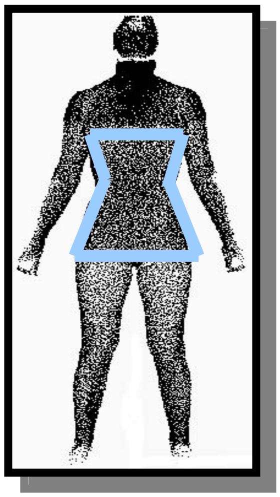

**Figure 5.** Example of a true Bottom Hourglass shape, Subject #BHgTrue.

**Figure 6.** An Hourglass shape (black) superimposed onto a Bottom Hourglass 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 7. Each is superimposed over the true Bottom Hourglass shape example (Subject #BHgTrue) to visually verify the proportionate body shape of the Bottom Hourglass figure.

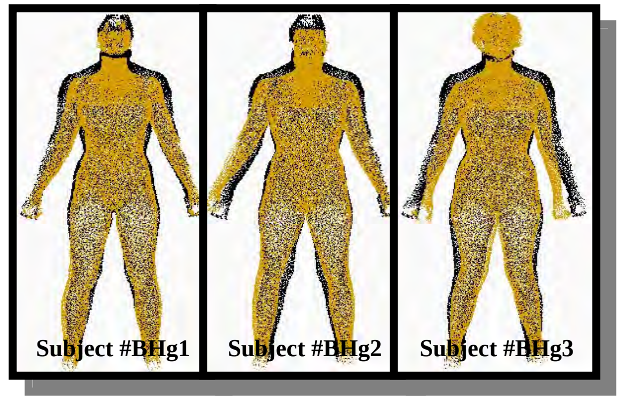


**Figure 7.** Bottom Hourglass shape comparison.

**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 shape will be defined as Top Hourglass.

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 will 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 8.

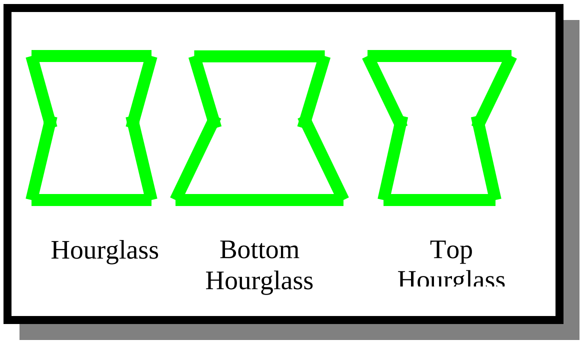


**Figure 8.** Comparison of the Hourglass, Bottom Hourglass, and Top Hourglass shapes.

**Spoon.** The Spoon was the third largest shape category of this study with 17% of the subjects or 38 of 222. The average age for this category was 30 with a range in age of 18 to 65 years. 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 will 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 9, 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 10.

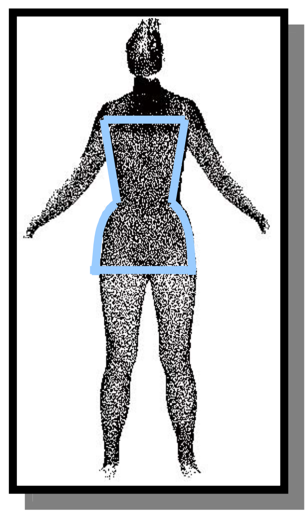

**Figure 9.** Example of a true Spoon shape, Subject #SpoonTrue.

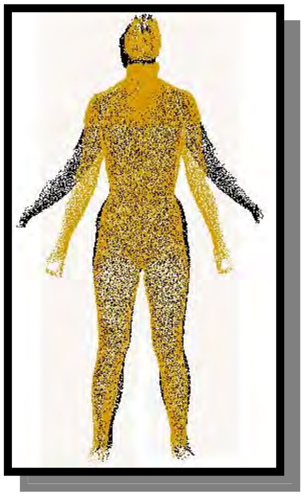

**Figure 10.** An Hourglass shape (yellow) superimposed onto a Spoon shape (black).

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

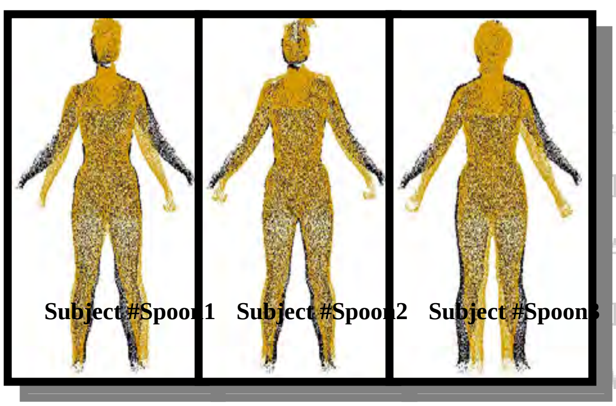


**Figure 11.** Subjects in the Spoon shape category superimposed on the example of a true Spoon shape.

Rectangle. The Rectangle was the fourth largest shape category of this study with 15.8% of the subjects (35 of the 222). The 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 relatively 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 will 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 12, 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 13.

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 14. 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.

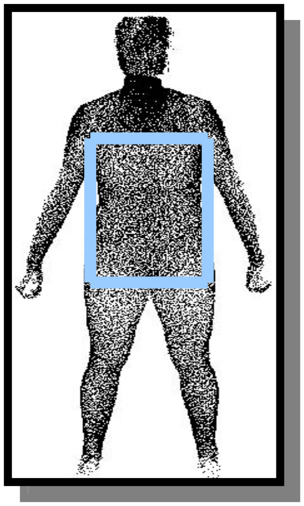

**Figure 12.** Example of a true Rectangle shape, Subject #RectTrue.

**Figure 13.** An Hourglass shape (black) superimposed onto a Rectangle shape (yellow).

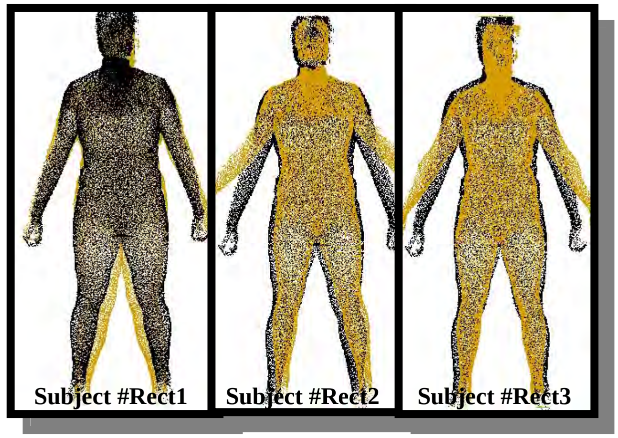


**Figure 14**. Rectangle subjects (yellow) superimposed on the true Rectangle shape example (black).

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 utilized the underlying condition that if the average of the subject's stomach, waist, and abdomen measures was more than their bust measure, then it will fall into the shape category of Diamond. If the average was less than the bust, then it would 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 will 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 15.

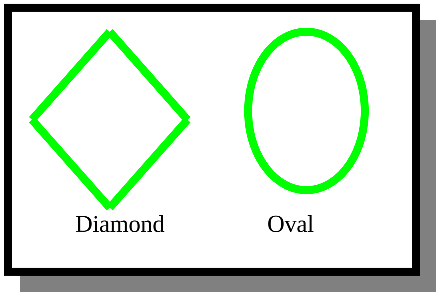


**Figure 15.** Comparison of the Diamond and Oval shapes.

**Oval.** The Oval was the fifth largest shape category of this study with 3.6% of the subjects (8 of the 222). The average age for this category was 36 with a range in age of 18 to 53 years. 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 utilized the underlying criteria that, if the average of the subject’s stomach, waist, and abdomen measures was 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 Figure16, 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 17.

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

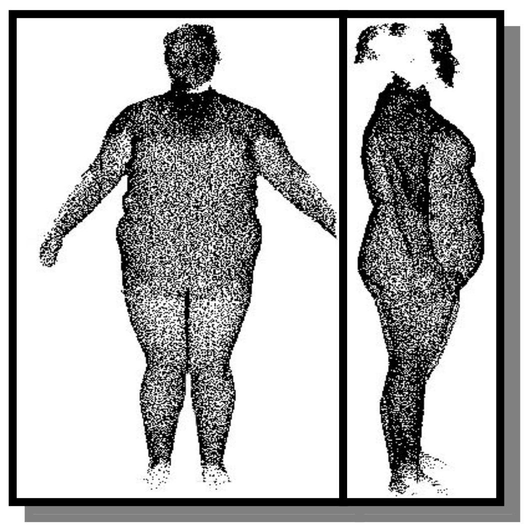

**Figure 16.** Example of a true Oval shape with a front and side view, Subject #OvalTrue.

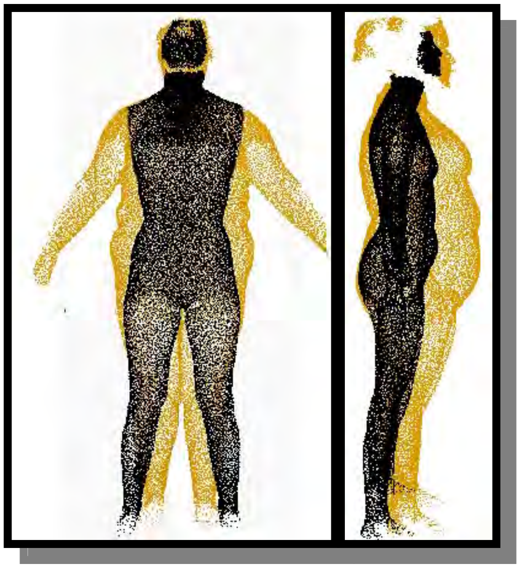

**Figure 17.** An Hourglass shape (black) superimposed onto an Oval shape (yellow).

**Triangle.** There were 4 subjects, or 18% of the sample, who fulfilled the criteria for the smallest shape category of 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 will 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 18, 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 19. Notice the image on the right in Figure 19 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. All of the 4 subjects with the Triangle shape were visually verified individually that the shape designation given by FFIT for Apparel was correct.

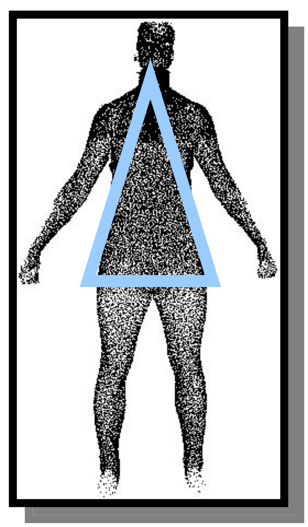

**Figure 18.** Example of a true Triangle shape, Subject #TriTrue.

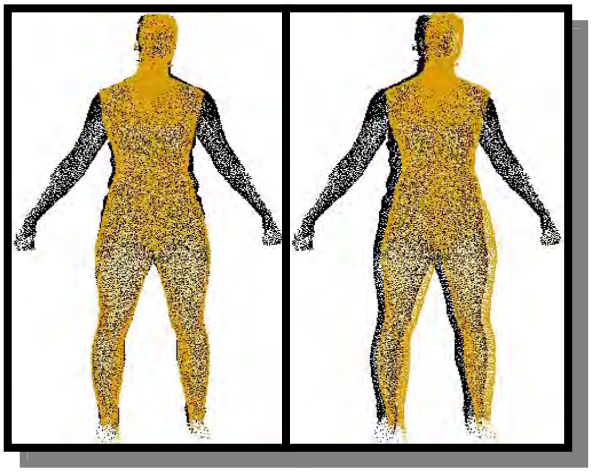

**Figure 19.** A Bottom Hourglass shape (yellow) superimposed onto a Triangle shape (black).

**__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 utilized 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 will 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 20.

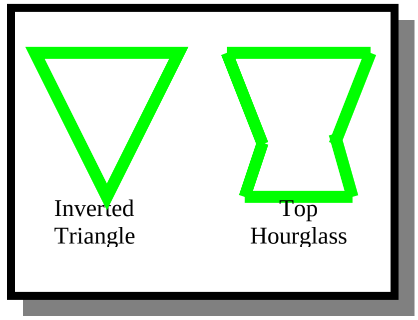


**Figure 20.** Comparison of the Inverted Triangle and Top Hourglass shapes**.**

**Discussion**

The development of the shape sorting code required a stringent evaluation of the theoretical framework of mathematical shape definitions that were previously developed and reported in *Female Figure Identification Technique (FFIT) For Apparel, Part I: Describing Female Shapes (*Simmons & Istook, 2004). The code development and analysis process allowed a rigorous appraisal of each of the mathematical definitions. In some cases, where subjects were defined as having no shape, further refinement of the mathematical definitions were required. Ultimately, the objective was to be able to define every shape, using the least number of shape definitions. With the knowledge that every female shape can not be served using standard sizing systems, it became vital to create definitions that could be logically described and hopefully adopted by the industry.

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 Part I of this study, we proved 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 the 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 the previous 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 the previous 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%).

FFIT for Apparel allows the opportunity for greater study of the female population. Ultimately, it may supply the framework for the development of new sizing systems, as well as slopers created to better fit the shapes of females today.



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