ABSTRACT

WILSON, ANTHONY FRANK. Body Shape Classifications of Males 26 to 35 Using Size USA Three-Dimensional Scan Data (Under the direction of Dr. Cynthia Istook.)

Literature reviewed showed that consumers are frustrated with the lack of consistency of fit in regards to apparel. More than half of male consumers have difficulty finding good fit in apparel. Among the factors contributing to the fit and sizing issues found in the apparel industry are the lack of consistency in sizing across brands and a currently outdated standardized sizing system. Current standardized sizing systems are based on averages and percentages that don't fully capture every size and shape in the population and does not take into consideration that two consumers that are the same height and weight can have very different body shapes due to factors such as age or ethnicity. At present, there is no ASTM sizing table available for men younger than 35 which demonstrated the void for a sizing standard that addressed the body size and shape needs for men younger than 35 years of age.

This research provides a method for using 3D scan data to determine shape categories for the male population between the ages of 26 and 35. Two different methods utilizing five drop values were used to determine shape clusters that identified the predominant shapes of male bodies in the US for males age 26 to 35 utilizing SizeUSA scan data. One set of clusters was based on the shape clusters identified by a cluster analysis and the other was based on shape clusters identified using a new shape identification software developed in Microsoft Excel called MSIT (Male Shape Identification Technique) for Apparel. Clustering the shapes using the MSIT proved to be better at identifying the various body shapes that existed than the cluster analysis. The shape clusters identified by each method were assigned a descriptive category label. The category labels were: Oval, Rectangle, Trapezoid, and

Inverted Trapezoid. There were subjects that could not be easily identified by the four shape categories. There were subjects whose body measurements did not fit within the broad shape categories, in addition to subjects that fell into more than one category.

Additionally, minimum and maximum values were identified for ASTM drop values that corresponded with the drop values generated from the SizeUSA measurement data for males age 26 to 35. The minimum and maximum values in each ASTM drop were used to create a range for each drop. These ranges were used in a formula to determine whether or not any of the ASTM sizing standards for males satisfied the measurement needs of the male subjects ages 26 to 35 in the SizeUSA data in each of the shape categories. This analysis showed that there were no subjects that had all five drops satisfied by the current ASTM D6240 sizing standard for males.

Body Shape Classifications of Males 26 to 35 Using Size USA Three-Dimensional Scan Data

by

Anthony Frank Wilson

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APPROVED BY:

Dr. Katherine Annett-Hitchcock	Dr. Marguerite Moore
Dr. Andre West	Dr. Cynthia Istook Chair of Advisory Committee

DEDICATION

To my parents,

Columbus and Mamie Wilson:

through the sacrifices you've made,

support and encouragement you've given,

and prayers you've lifted on my behalf,

I am achieving my goals.

BIOGRAPHY

Anthony Frank Wilson, son of Columbus Frank and Mamie (Rowe) Wilson, was born on September 22, 1973, in Taylorsville, North Carolina. He graduated from Alexander Central High School in Taylorsville, North Carolina in 1991. He then attended and graduated from Appalachian State University with a Bachelor of Science degree in Clothing and Textiles with a minor in Marketing in 1997. After obtaining his undergraduate degree, he worked for several years in the apparel industry with Sag Harbor Dresses (New York, NY) as a production pattern assistant, Liancarlo (Miami, FL) as a creative design assistant/ fabric purchaser, Andasimo (New York) as a technical designer, and Taylor Togs (Micaville, NC) as a sample coordinator. He has created a variety of commissioned design works for various occasions and has collaborated with companies as a freelance designer. Through his freelance work with Heatherette, Anthony was provided the opportunity to create designs that have been in magazines and worn by singing artists such as Pink, Brittany Spears, and Shirley Manson. Through his freelance work with Golden Age Motorcycles, he had the opportunity to create a motorcycle jacket for singer Billy Joel.

In 2006, after returning to Appalachian State University and graduating with a Master of Science degree in Graphics and Imaging Technology, he opened a custom clothing design business called Anthony Wilson Designs, Inc. In 2009, in addition to his responsibilities with his design business, Anthony was offered the opportunity, via a nine month appointment position, to teach Textile and Apparel Merchandising courses at Appalachian State University. This position proved to be a rewarding experience that led to Anthony enrolling in the Textile Technology Management doctoral program at North Carolina State University. While enrolled in the doctoral program, he worked as the graduate teaching assistant to his advisor, Dr. Cynthia Istook, who encouraged him to become an active member of the International Textile and Apparel Association (ITAA) and to submit creative design works to various competitions for which he has received awards. Before graduating, Anthony began teaching full time at Appalachian State University in the Apparel Design and Merchandising program. In addition to his teaching responsibilities, Anthony continues to attend conferences and workshops to stay current with new technologies and techniques related to the apparel industry.

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have poured into me. I am so proud and feel blessed beyond measure to be able to say you are my parents. I love you to the moon and back!

- My family: It has been said that it takes a village to raise a child. I want to sincerely thank the members of my village for the love and encouragement you've given me throughout my life! Each of you have had a hand in helping me to become the man I am today (Grandparents: Charlie Rowe, Sr. and Ruth Wilson) (Extended family: Ola Sharpe, Mazo Linney, Myrtle Rowe, Helen Blanche Newland, Jim and Martha Richardson, Jean Flowers, Danny Rowe, Clifford Rowe, Hugh Rowe, Virginia McClain, Gina McClain, Sallie Carlton, Lynn Jones, and Carrie Stevenson).
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CHAPTER 1: INTRODUCTION

In the production of apparel products, it is commonplace that designers, tailors, sample makers, and manufacturers obtain information about the proportions, size, and shape of the human body. Regardless of the apparel items being produced, even the simplest garment can require the need to obtain multiple measurements. Knowledge of the dimensions of the bust/chest, waist, and hip are common for most garment production but in many cases additional information such as arm length, upper arm circumference, thigh circumference, waist to knee length, high hip circumference, or low hip circumference are required to achieve proper fit. Obtaining this information is an initial step in producing garments that fit properly.

In the past, dressmakers and/or tailors or consumers themselves would utilize the aforementioned information to achieve custom fit in clothing. As technological advances were made, apparel shifted from custom clothing for the individual to the method of mass production which provides clothing for the masses based on a standardized sizing system (Bye, DeLong, & Labat, 2006). Anthropometric studies conducted in 1941 for the purposes of producing military uniforms for World War II were used by the mail order apparel industry as a basis for establishing a sizing system to assist in grouping the most commonly occurring human body sizes into categories (O'Brien & Shelton, 1941). A downfall of the standardized sizing system used in the apparel industry is that it does not represent every body size and shape in the entire population nor does it represent the differences present in body size, shape, and proportion due to the demographic changes that have occurred in the population within the past 74 years (Ashdown, & Dunne, 2006; Giovis, 2007; Simmons, 2002; Simmons, & Ulrich, 2013).

The United Kingdom, The United States, Mexico, Korea, Thailand, and various other countries have conducted sizing surveys utilizing 3D scanning technology in addition to manual anthropometric measurements in an attempt to provide industry professionals with more accurate information regarding the size and shape of consumers (Deschamps, 2011; Lee, Istook, Nam, & Park, 2007; Shin, & Istook, 2007). Three dimensional scanning and the information it provides has been utilized and referenced in a wealth of studies conducted regarding body analysis and apparel fit for womenswear, however, there has been little to no significant research regarding body analysis and apparel fit for menswear (Chattaraman, Simmons, & Ulrich, 2013).

Rationale

Research has shown that consumers are frustrated with the lack of consistency of fit across apparel brands (Staples, 1995). More than half of male consumers have difficulty finding good fit in apparel (DesMarteau, 2000; Chattaraman, Simmons, & Ulrich, 2013). Among the factors contributing to the fit and sizing issues found in the apparel industry are the lack of consistency in sizing across brands and a currently outdated standardized sizing system. Current standardized sizing systems are based on averages and percentages that don’t fully capture every size and shape in the population and do not take into consideration that two consumers that are the same height and weight can have very different body shapes due to factors such as age, ethnicity, heredity, or health and fitness.

This research will provide a method for using 3D scan data to determine shape categories for the US male population between the ages of 26 and 35. Men in this age range make up approximately 14% of the US male population and earn an annual median income of upwards of $50,000 (http://census.gov/library/publications/2016/demo/p60-256.html).

This market segment contributed to the $125.6 billion of revenue generated in the US menswear market in 2014 and is predicted to increase to $147.9 billion by 2019 (http://www.marketresearch.com/MarketLine-v3883/Menswear-United-States-9043151/).

The current ASTM sizing table is for mature men 35 years of age or older (https://www.astm.org/Standards/D6240.htm). At present, there is no ASTM sizing table available for men younger than 35 demonstrating the void for a sizing standard that addresses the body size and shape needs for men 26 to 35 years of age. Comparing the information generated in this study to current sizing standards will result in providing information to assist in meeting the needs of male consumers ages 26 to 35 more proficiently.

Research Objectives

The objective of this research was to determine male body shape classifications for men ages 26 to 35 utilizing 3D scan data. While there is research regarding female body shape classifications, research regarding men's body shape classifications are lacking. This research will assist in establishing a baseline for further studies in this area.

Specific research questions include:

1. Can SizeUSA data collected for men be used to identify the predominant shapes of male bodies in the US for men ages 26 to 35?
2. Based on literature review and the visual properties of the bodies within each shape, can a descriptive label be identified that would aid in an understanding of the shape differentiators?

3. Does the ASTM D6240 sizing system developed for males meet the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey?

Study Limitations

This study will be limited by the following factors:

1. Measurement data used in this study was from the SizeUSA 3D scanning survey completed in 2003. However, it is the most current and largest sizing survey conducted in the United States to date.
2. Without expert human intervention, measurements extracted from 3D body scans may not be obtained at the exact location on the body, as would be necessary for accurate comparisons. This is an issue because the computer software does not have the tacit knowledge or the physical ability to determine specific body landmarks that might be hidden or indeterminate by muscle, fat, or other inhibitors.
3. SizeUSA 3D data does not include stomach and abdomen measurements for male subjects.

Assumptions

The following assumptions will be made:

1. The SizeUSA data obtained from [TC]^2 scanners has an accuracy within an 1/8" when the measurements have been obtained at the correct location on the body.

2. Size USA point cloud images generated from 3D scan data accurately represent the predominant shapes of the male population in the US.

Definition of Terms

Anthropometry: Refers to the measurement and proportions of the human body.

ASTM, formerly the American Society of Testing and Materials International: A not-for-profit organization that provides a forum for the development and publication of international voluntary consensus standards for materials, products, systems, and services (ASTM.org, 2015).

Civilian American and European Surface Anthropometry Resource Project (CAESAR): A sizing study conducted to generate 3-D data to update current anthropometric databases of civilian males and females age 18-65 of a variety of shapes and sizes (http://www.sae.org/technicalcommittees/caesarhome.htm).

Mass Customization: A business strategy to produce a good or service that meets a specific customer's need while maintaining the efficiency associated with mass production (Christy, 1993; Duray, Ward, Milligan, & Berry, 2000; Jiao &Tseng, 2001; Pine, B., Davis, & Pine II, B., 1999; Pine II, B., Victor, & Boynton, 1993).

Somatotype: The category of a person's body structure or build in relation to how fat, muscular, or lean they are (Sheldon, 1954).

Ectomorph – Characterized as linear, thin, flat chested, and having lean muscles.

Endomorph – Characterized as round and soft, having a large abdominal region, stocky, and muscles are not well defined.

Mesomorph – Characterized as athletic and strong, having well defined muscles.

Three Dimensional (3D) Body Scanning: In general, most 3D body scanning systems use non-invasive optical techniques and light sensitive devices to obtain body size and shape information in addition to generating a virtual model of the human body (Istook & Hwang, 2001; Treleaven & Wells, 2007).

CHAPTER 2: REVIEW OF LITERATURE

While there is a wealth of information and research surrounding body size and shape classifications for women, research in these areas for men is lacking. Literature was reviewed in the following areas:

- Fit and Sizing Issues
- Figure classification for males
- Body evaluation techniques
- Body shape and age
- Three dimensional body scanning technology
- Data analysis techniques

Fit and Sizing Issues

Apparel fit is an area of major concern for apparel industry professionals and consumers alike. One industry study reported that 62% of male consumers have difficulty finding good fit in apparel (LaBat, & Delong, 1990; DesMarteau, 2000; Chattaraman, Simmons, & Ulrich, 2013). This dissatisfaction contributes to loss revenue in retail sales of apparel and apparel products (LaBat, 2007). There are a variety of factors that contribute to the fit and sizing issues found in the apparel industry. Among these factors are the lack of consistency in sizing across brands and a currently outdated standardized sizing system.

Research has shown that consumers are frustrated with the lack of consistency of fit across apparel brands (Staples, 1995; Sindicich, & Black, 2011). It is common for consumers to find good fit with a size medium in one brand but will find if necessary to go up or down a size for the same garment in another brand. Retailers and manufacturers have not all adopted one standard method of sizing apparel, instead many attempt to appeal to consumer's egos opting to attach a smaller size label to a larger garment as a strategy used to boost sales by helping consumers feel better about themselves when they're able to wear a smaller size (Goldsberry, 1994; DesMarteau, 2000).

Brands such as Gap and Levi Strauss have attempted to address sizing issues in the sale of their jeans. Many of the style category names used by both brands give consumers an indication of how a particular jean style is going to fit in a fashion sense. In addition to providing descriptive style category names such as Skinny, Slim, Bootcut, Straight, Relaxed, and Standard, these brands also provide consumers with additional general information regarding the fit of each style category (see Table 1) (http://www.gap.com/; http://www.levi.com/US/en_US/). While the fit of each style category is described relative to the body (size and shape) that the garment has been designed for, it does not identify what the perfect measurements would be to achieve that fit.

Table 1. Examples of Garment Style and Fit Descriptions

Jean Style	Gap Fit Description	Levi Fit Description
Bootcut	• A classic fit with a flared leg • Mid rise	• Slim through the thigh with a classic boot-cut
Relaxed	• Ample room throughout • Mid rise	• For guys who like their jeans with a little more room
Skinny	• Fashion-forward and fitted • Low rise	• Slimmest from hip to ankle
Slim	• Not too tight, not too baggy • Low rise	• Cut close, but not too skinny, for a modern look
Standard	• Straightforward fit with a little more room • Mid rise	• N/A
Straight	• The happy medium of all fits • Mid rise	• A straight up classic, great for every guy

Note: Information obtained from the following: (gap.com, 2015; levi.com, 2015)

Another contributing factor to issues in fit and sizing is the outdated standardized sizing system currently used as the basis for sizing apparel. A study by Ruth O'Brien and William Shelton in 1941 was used as a basis for a commercial standard which led to the development of the American Society of Testing and Materials International (ASTM) apparel sizing system currently used for women in the US today (O'Brien & Shelton, 1941; Devarajan, 2003). This sizing system was developed to assist in grouping the most commonly occurring human body sizes into categories. Because this system was based on a study comprised primarily of young Caucasian women in the 1940s, it is not a true representation of every body size, shape, and proportion that was present in the entire population in regards to demographic factors such as age and race in the 1940s and likewise does not represent the differences present in body size, shape, and proportion in the current population due to the demographic changes that have occurred within the past 74 years (Ashdown, & Dunne, 2006; Devarajan, 2003; Giovis, 2007; Simmons, 2002; Simmons, & Ulrich, 2013). In addition, the grade rules for the current standards are based on averages and percentages that don't fully capture every size and shape in the population and does not take into consideration that two consumers that are the same height and weight can have very different body shapes.

The limited literature regarding the fit and sizing in men's apparel indicates that standardized sizing for men evolved from measurements taken of soldiers during the American Civil War for the mass production of military uniforms (http://museum.nist.gov/exhibits/apparel/ history.htm; [TC]², 2004; Zernike, 2004). Because of the racial climate prevalent during this time period and the fact that measurements were obtained from soldiers, it is safe to assume that much like the female study conducted in

1941, these male sizing standards are comprised primarily of young Caucasian male soldiers resulting in body size, shape, and proportion information that did not represent the entirety of the population of its time nor does it represent the differences present in body size, shape, and proportion in the current population due to the demographic changes that have occurred since the 1800s.

In an attempt to gain more current anthropometric data there have been a variety of sizing surveys conducted in the United Kingdom, the United States, Mexico, Korea, and Thailand utilizing 3D scanning technology in addition to manual anthropometric measurements (Deschamps, 2011; Lee, Istook, Nam, & Park, 2007; Shin, & Istook, 2007). The CAESAR study, a sizing study organized and conducted by the Society of Automotive Engineers and the U.S. Air Force from 1998 to early 2000, utilized 3D scanning technology to collect anthropometric data from a diverse sample of men and women, ages 18 to 65 of various sizes and shapes. The sample consisted of 2,500 subjects from the United States and 2,500 subjects from Europe. Data collection methods were standardized to ensure the database could be consistently updated and expanded (http://www.sae.org/technicalcommittees/caesarhome.htm, 2015; [TC]², 2004).

Another study, the SizeUSA National Sizing Survey, partially funded by the U.S. Department of Commerce and additionally supported by apparel industry companies, the Army, Navy, and academic universities, was organized and conducted by [TC]² from 2002 to 2003 utilizing white light 3D scanning technology (more emphasis will be placed on this study because the data obtained on its males subjects will be used to address the research objectives of this paper). The purpose of the SizeUSA survey was to obtain more current anthropometric data of the U.S. population that was not possible previously because of the time and cost associated with taking on such a task manually. A sample was selected consisting of over 10,000 adults of which approximately 37% were men and 63% were women from 13 U.S. cities. The sampling strategy used modelled approximate height and weight distribution of a previously valid study by the National Health and Nutrition Examination Survey III. Prior to being scanned, subjects completed a questionnaire that identified their age, sex, ethnicity, zip code, annual household income, marital status, body structure, lifestyle, education, employment, preferred clothing sizes, preferred stores, and types of clothing worn ([TC]², 2004; Zernike, 2004). Demographic data obtained from the questionnaire is shown in Figure 1. A description of the primary measurements obtained from subjects 3D scans in comparison the ASTM measurement descriptions are shown in Table 2.

SizeUSA Demographics – Females and Males

	Scan Location	Subjects Scanned		Scan Location	Subjects Scanned
13%	1. Cary, NC	1338	7%	7. Los Angeles, CA	685
11%	2. Columbia, MO	1105	4%	8. San Francisco, CA	396
17%	3. Dallas, TX	1750	5%	9. Portland, OR	499
1%	4. Miami, FL	99	6%	10. Lawrence,MA	557
4%	5. New York, NY	447	1%	11. Winston-Salem, NC	132
7%	6. Chattanooga,TN	667	10%	12. Buford, GA	1002
			13%	13. Glendale, CA	1324
				Total:	**10,001**

Ethnicity:		**Age:**	
51%	Non-Hispanic White	25%	18-25
18%	Non-Hispanic Black	22%	26-35
8%	Hispanic	22%	36-45
8%	Other	18%	46-55
		9%	56-65
		4%	66+

Income:		**Lifestyle:**	
36%	Under $25,000	29%	Very Active
26%	$25,000 - $49,999	47%	About as active as others
16%	$50,000 – $74,999	19%	A little less active
9%	$75,000 - $99,999	5%	Much less active
9%	$100,000 or more		

Figure 1: Size USA Demographics ([TC]², 2004).

Table 2. ASTM vs. Size USA Measurement Descriptions

Measurement	ASTM Specification	SizeUSA Scanner Measurement
Bust	Measure the bust circumference horizontally around the body under the arms, across the nipples, and parallel to the floor.	Same as ASTM.
Waist	Measure the waist circumference horizontally around the body at waist level.	Circumference measured around the body at the waist level following the pant waist
High-Hip	Measure the high hip circumference of the body at high-hip level, approximately 3 inches below the waist level and parallel to the floor.	Same as ASTM
Hip	Measure the maximum hip circumference of the body at the hip level and parallel to the floor.	Maximum circumference of the body measured between the waist and crotch, parallel to the floor.
Mid-Neck	Measure the mid neck circumference of the neck approximately 1 inch above the neck base.	Circumference of the neck measured above the neck base as for a shirt collar.
Neck Base	With tape measure standing on edge, measure the circumference of the neck base crossing the cervicale at the back, shoulder line/neck base at the side, and hollow at center front.	Circumference of the neck base crossing the cervicale (Back Neck Point) at the back, shoulder/neck base at side, and sternum/neck base at the front (Front Neck Point).
Armscye	With the arm hanging down, measure from the shoulder joint down through the front-break point, the armpit, up to the back-break point, and up to the starting point.	With the arm hanging down, measure from shoulder point down the front to armpit level, horizontally under the armpit, and back up to the starting point.
Upper Arm	With the arm down, measure the maximum upper arm circumference parallel to the floor between the shoulder joint and elbow.	Measure the maximum arm circumference between the shoulder point and the elbow.
Elbow	With the arm bent, measure the elbow circumference.	Measure the circumference of the elbow.

Note: Taken from ([TC]², 2004).

Table 2: ASTM vs. Size USA Measurement Descriptions (continued)

Wrist	Measure the wrist circumference over the inner and outer prominence at the end of the forearm.	Measure the circumference at the wrist joint.
Thigh, Maximum	Measure the circumference of the upper leg close to the crotch.	Measure the circumference of the upper leg 1 inch below the crotch.
Thigh, Mid	Measure the circumference of the upper leg midway between the hip and the knee.	Circumference of the upper leg measured midway between the knee and crotch.
Knee	With the leg straight, measure the knee circumference over the kneecap and parallel to the floor.	Same as ASTM.
Calf	Measure the maximum circumference of the lower leg between the knee and ankle and parallel to the floor.	Same as ASTM.
Ankle	Measure the ankle circumference over the inner and outer bony prominence at the lower end of the lower leg.	Same as ASTM.
Vertical Trunk	Measure from a point on the right shoulder midway between the neck base and shoulder joint, down the back, through the crotch, and up over the prominence of the right breast to the starting point, taking care to avoid constriction at the crotch.	Measure the Center Trunk from the Front Neck Point down the front, through the crotch and up the back to the Back Neck Point.
Total Crotch Length	Measure from the center front waist level through the crotch to the center back waist level	Same as ASTM.
Cervicale Height	Measure from the cervicale following the contour of the spinal column to the level of the hips, then vertically to the soles of the feet.	Same as ASTM.
Waist Height	Measure from the waist level at the side of the body following the contour of the body to the hip level, then vertically to the soles of the feet.	Same as ASTM.

Note: Taken from ([TC]², 2004).

Table 2: ASTM vs. Size USA Measurement Descriptions (continued)

High-hip Height	At the side of the body, measure from the level of the prominent high-hip (abdominal extension) following the contour of the body to the soles of the feet.	Measured from the high-hip circumference level vertically to the floor.
Hip Height	At the side of the body, measure from the full hip level to the soles of the feet.	Same as ASTM.
Crotch Height	While standing erect without shoes and with feet slightly apart, measure from the crotch straight down to the soles of the feet.	Same as ASTM.
Knee Height	Measure from the crease in the back of the knee to the soles of the feet.	Measured from the knee circumference level vertically to the floor.
Ankle Height	Measure from the middle of the outer ankle bone to the soles of the feet.	Same as ASTM.
Waist Length (Front)	Measure from the center front neck base line to the center front waist level.	Same as ASTM.
Waist Length (Back)	Measure from the cervicale following the contour of the spinal column to the center back waist level.	Same as ASTM.
Across Shoulder	While standing erect with the arms hanging down, measure across the back from one shoulder joint to the other.	Measure across the back from one shoulder point to the other on a line at approximately 45 degrees.
Cross-Back Width	Measure across the back from armscye to armscye at the back-break point level.	Same as ASTM.
Cross-Chest Width	Measure across the front from armscye to armscye at the front-break point level.	Same as ASTM.
Shoulder Length	With the arm hanging down, measure from the side of the neck base to the armscye line at the shoulder joint.	Measured from the side neck points to the armscye line at the shoulder points.

Note: Taken from ([TC]², 2004).

Table 2: ASTM vs. Size USA Measurement Descriptions (continued)

Shoulder Slope	Using a goniometer, position the measure on the shoulder and move the baseline until it is parallel to the floor; identify on the dial the degrees of difference between the shoulder slant and the horizontal measure of the goniometer.	The degree of shoulder slant from horizontal. The measurement given is the vertical drop of the shoulder point from horizontal. The slope must be calculated post-scan.
Arm Length (Shoulder to Wrist)	With the arm bent at 90 degrees and the hand placed on the hip, measure from the shoulder joint down along the outside of the arm over the elbow to the prominent wrist bone.	With the arm hanging in the scan position, measure from the shoulder point along the outside of the arm to the wrist joint.
Arm Length (Center Back Neck to Wrist)	With the arm bent at 90 degrees, measure from the cervicale over the top of the shoulder to the shoulder joint, then along the outside of the arm over the elbow to the prominent wrist bone.	With the arm hanging in the scan position, measure from the center back neck point over the shoulder point along the outside of the arm to the wrist joint.
Bust Point to Bust Point	Measure horizontally from one bust apex to the other.	Same as ASTM.
Neck to Bust Point	Measure from the intersection of shoulder and front neck base to the bust apex.	Measure from the side neck points to the bust apex.

Note: Taken from ([TC]², 2004).

Figure Classification for Males

Somatotyping

The earliest method for classifying the human body was developed by Hippocrates in an attempt to predict which body types were most likely to develop certain diseases. (Simmons, 2002; Wells, 1983). These predictions were concerned with the relationship between an individual's body shape and their health or lack thereof. Today, in addition to health concerns associated with body shape, there is also an interest in classifying body shape to assist in achieving proper fit for the apparel industry.

Research regarding figure classification for males primarily refers to or is based on somatotype categories developed by American psychologist William Sheldon. Determining a person's body structure or build in relation to how fat, muscular, or lean they are can assist in identifying which somatotype category they will fall into (Sheldon, 1954). Sheldon identified a variety of body types that fall within three Somatotype categories: Ectomorph, Endomorph, and Mesomorph (see Figures 2 through 4 and Table 3).

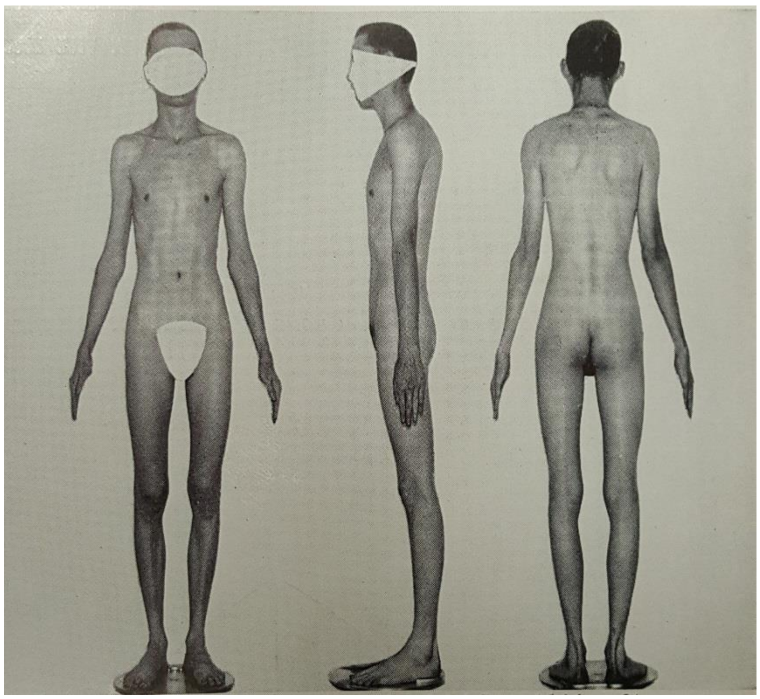


Figure 2: Photograph of a subject with Ectomorph somatotype. (Sheldon, 1954, p. 37)

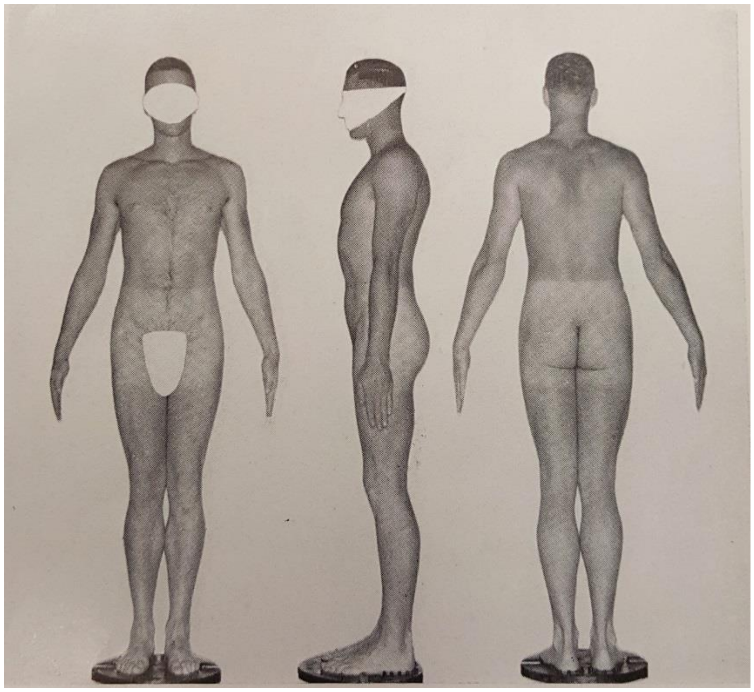


Figure 3: Photograph of a subject with Mesomorph somatotype. (Sheldon, 1954, p. 223)

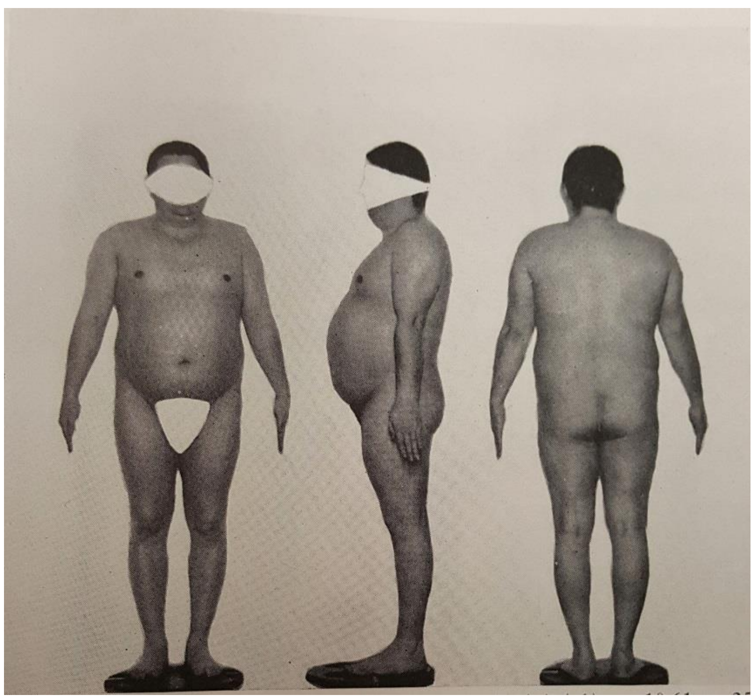


Figure 4: Photograph of a subject with Endomorph somatotype. (Sheldon, 1954, p. 325)

Table 3. Somatotype Category Characteristics

Somatotype Category	**Characteristics**
Ectomorph	• Thin body • Small frail bone structure • Narrow chest • Lean muscle • Fast metabolism • Difficulty gaining weight
Mesomorph	• Athletic body • Well defined muscles • Strong • Gains muscle easily • Gains fat more easily than ectomorphs • Chest is larger than waist • Narrow, low waist
Endomorph	• Round, soft body • Larger in the abdominal region • Stocky; muscles not so well defined • Slow metabolism • Difficulty losing weight

Note: Information obtained from the following: (Nkwocha, 2015; Simmons, 2002; Wells, 1983; Sheldon 1954)

Male Shape Descriptions

Scholarly, academic research regarding male shape descriptions appears to be nonexistent resulting in the use of somatotyping for male figure classification in addition to trend in popular press to classify the male form by comparing body shapes to geometric shapes ranging from the inverted triangle to the rectangle or comparing the body to fruits and vegetables such as beetroots, leeks, and parsnips or objects like snowmen (Chattaraman, Simmons, & Ulrich, 2013; Hawksley, 2014; Hughes Jones, 2013; http://www.style-makeover-hq.com/male-body-shape.html, 2015; Rob-one, 2014). These types of comparisons have long been prevalent in the apparel industry for women but are only recently beginning to be explored for men. Identifying male shape categories could assist the apparel industry in developing clothing options better suited for the body size and shape of their target consumers. Communicating shape information along with size information would aid consumers in identifying apparel options best suited for their particular needs. Table 4 shows a comparison of male figure type terminology with illustrations.

Table 4. Characteristics of Different Figure Type Terminology

• Trapezoid	• Broad shoulders and chest • Medium-narrow waist and hips • Upper torso is bigger than lower torso • Well proportioned	
• Inverted Triangle • Parsnip	• Broad shoulders and chest • Well developed, bulky, shoulders, arms, and chest • Narrow waist and hips • Upper body is significantly larger than lower body	

Note: Information and illustrations obtained from the following: (Hughes Jones, 2013; Hull, 2013; Rob-one, 2014; Style Makeover website, 2015)

Table 5. Characteristics of Different Figure Type Terminology (continued)

• Rectangle • Cucumber • String Bean • Leek	• Chest, waist, and hips are approximately the same size • Torso shape is straight	
• Triangle • Pear • Aubergine	• Sloping shoulder line • Chest is narrower than hips • Lower body is larger than upper body	
• Oval • Tomato • Snowman • Beetroot	• Overall appearance is round • Large stomach	

Note: Information and illustrations obtained from the following: (Hughes Jones, 2013; Hull, 2013; Rob-one, 2014; Style Makeover website, 2015)

Table 6. Characteristics of Different Figure Type Terminology (continued)

• Square • Brick	• Broad all over	

Note: Information and illustrations obtained from the following: (Hughes Jones, 2013; Hull, 2013; Rob-one, 2014; Style Makeover website, 2015)

<u>Big, Tall, and Short</u>

A trend in the apparel industry is to classify the male figure as big, tall, or short. A marketing research firm, NPD Group, providing consumer shopping trends and market research reports that "more than half of U.S. men self-identify as big, tall, or short, and they're more willing to be marketed to as such" (Townsend, 2011, n.d.). A Bloomberg news article reported that one third of US men are obese (Townsend, 2011). These obese men are a key niche market that has been identified as the "Big & Tall" man. A variety of retailers from Walmart to Macy's provide clothing specifically produced for the "Big & Tall" man. King Size and Destination XL are retailers that specialize in clothing for this niche market.

While many retailers provide apparel to the Big & Tall man, literature reveals that less attention is being paid to the short male consumer (Brock, 2013; http://www.petermanningnyc.com/pages/about-us; http://www.originalshortees.com/about/). However, Peter Manning Five Eight New York and Shortees are two retailers catering to male consumers 5'8" and under (http://www.petermanningnyc.com/pages/about-us; http://www. original shortees.com/about/). Shortees focuses on providing t-shirts from small to XXL with lengths of either 25" or 26.5". Peter Manning Five Eight New York has an array of apparel ranging from pants, shirts, and suits to active outerwear and accessories, all catering to the male consumer who is 5'8" and under.

Body Shape Evaluation Software

Literature suggests that there are a variety of software programs capable of evaluating somatotype variables. Aubry and Carter developed a computer program called PROSOMAN. This program calculates somatotypes, descriptive and comparative statistics, and plotting somatocharts (Carter & Heath, 1990). Table 5 shows a summary of the programs contained in PROSOMAN.

Table 7. Summary of Computer Programs in PROSOMAN for Somatotype Analysis

STYPE	• Calculates the anthropometric Heath-Carter somatotype • Provides descriptive statistics for all variables and a listing by subject of the original and derived variables
CATE	• Calculates frequencies in a histogram and a table • Lists subjects by category
SPLOT	• Draws a bi-dimensional somatocharts • Plots frequencies of somatoplots • Provides descriptive statistics for the somatotypes and the somatoplot
SANOV	• Calculates a one-way analysis of variance (ANOVA) using distances between the whole somatotype ratings. • Provides descriptive statistics for the somatotype attitudinal distances (SAD) or the somatotype dispersion distance (SDD) and a distance matrix between means
TPAIR	• Calculates t-ratio for paired somatotypes
MIGDIS	• Calculates the sum of the distances between sequential somatoplots, in two or three dimensions and plots their positions • Results include input somatotypes by subject.
INFREQ	• Calculates and lists the number of subjects from each somatotype sample, which lie inside, outside or in the intersection of circles or spheres

Note: Information obtained from the following: (Carter & Heath, 1990, p. 419)

SOMATYPE is a basic somatotype calculating program compatible with personal computers. This program utilizes anthropometric data to perform somatotype calculations interactively (Simmons, 2002; Devarajan, 2003).

Additionally, SOMAMAN SAS is a program that was created on an IBM mainframe and is used to draw somatocharts and plot somatotype data (Simmons, 2002). This program has three components: One component places the data into SAS and prepares the data for plotting, a second component sets up the plot grid and creates the data set, and a third component plots the somatotype data (Simmons, 2002).

Body Shape, Age, and Fit Preference

Body shapes change with age. The human body is comprised primarily of bones, muscles, fat and water. People often gain weight as they age, which can alter body shape but even if weight is maintained with age, the relative proportion of weight that comes from each of the components that comprise the body can shift over time (Schewe, 1988; Smathers & Horridgem 1978-79; Kolata, 2016). The change in body shape that occurs due to age demonstrates the need for considering body shape in the production of apparel to achieve proper fit for all consumers in all age ranges.

In addition to shifts in body shape, age also affects consumer fit preferences (Johnson, Ulrich, & Connell, 2008; Chattaraman, Simmons, & Ulrich, 2013). Consumers in younger adult age ranges often prefer more fitted clothing options and are more willing to adopt the most current trends while consumers in older adult age ranges tend to prefer looser fitting clothing options and are usually more concerned with comfort (Chattaraman, Simmons, & Ulrich, 2013).

This study focuses on male consumers between the ages on 26 and 35. This age range makes up 14% of the US male population with a median annual income of $57, 000, an approximate 5.6% increase in median income from 2014 to 2015 (http://census.gov/library/publications/2016/demo/p60-256.html). This was the second highest percentage increase compared to the other age ranges. Reports from the Centers for Disease Control (2014) regarding aerobic activity and health status indicate this age range to be in prime health as compared to older age ranges (http://ftp.cdc.gov/pub/Health_Statistics/NCHS/NHIS/SHS/2011-2014_AHB_Table_PA-3.pdf) (http://ftp.cdc.gov/pub/Health_Statistics/NCHS/NHIS/SHS/2014_SHS_Table_A-11.pdf).

Three Dimensional Scanning

History

Three dimensional body scanning as we know it today evolved from scanning technology developed in the 1960s. Early scanners were capable of capturing one side of the body at a time. The capability of scanners to surround the entire body was not realized until Magnant in 1985 (Simmons & Istook, 2003). The initial body scanners obtained data with the use of light, cameras, and projectors and were limited by the amount of labor and time required to operate. Throughout the mid to late eighties, further developments emerged with body scanned data being obtained by the use of white light, lasers, and shadowing.

Throughout the nineties and early two thousands there were significant advancements in the development of body scanning systems. As advancements have been developed, the cost of the systems and footprint required for operation have been decreasing, equipping 3D scanning companies with the ability to provide scanning systems to be used for education, design, manufacturing, and retail in addition to being used as a tool in research for sizing studies to develop more accurate size standards in the apparel industry (Deschamps, 2011; Lee, Istook, Nam, & Park, 2007; Shin, & Istook, 2007; http://www.tc2.com/index_3dbodyscan.html).

Current Applications

There are various scanning systems available globally. Four of the most commonly used technologies are laser, white light, millimeter wave, and Kinect or Infrared (Daanen & Ter Haar, 2013; Size Stream, 2015). In the current market, due to technological advances there has been a reduction in costs and scanning technology is being applied in areas never seen before. It is becoming more common to see the use of this technology in the apparel, medical, health/fitness, security, and entertainment industries (Daanen & Ter Haar, 2013; Size Stream, 2013). Some lower cost scanning systems can also be used in hand held devices that are intuitive enough to be used in consumer homes, require no additional extraction software, and output can be used to quickly produce avatars that could be used in virtual fashion applications (Daanen & Ter Haar, 2013; Size Stream, 2013).

Apparel. Marketing strategies of 3D scanning companies targeting the apparel industry consist of information showcasing how 3D scan output can provide designers, manufacturers, and retailers with size and shape information that can be used to produce apparel products that best meet the needs of their particular target customer. Most marketing strategies relay information about the size, shape, speed, and ease of use of equipment, in addition to information regarding the reliability and quality of the output produced and how it can be used to assist in increasing overall efficiency. Figure 5 shows the KX-16 3D body scanner from [TC]² which utilizes Kinect (Infrared) scanning technology. Some of its selling points include its small footprint being similar in size to a normal retail environment dressing room, its safe and private, and can provide hundreds of automatic measurements in seconds. It also boasts that it can be utilized in body shape analysis, sizing surveys, and size predictions, as well as assist in product development, mass customization, and virtual fashion applications (http://www.tc2.com/index_3dbodyscan.html). It is safe to assume this system is capable of all of its claims based on the fact that it utilizes Kinect technology, which research supports is capable of effectively providing accurate size and shape information while producing good resolution images.

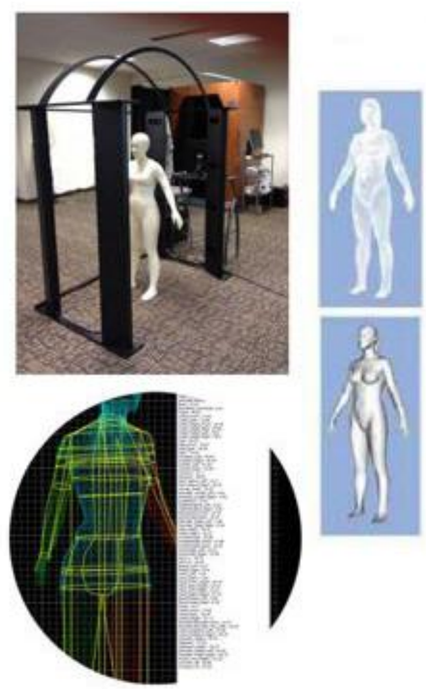


Figure 5:Photograph of a subject with Endomorph somatotype. (Sheldon, 1954, p. 325)

Mass customization. In recent years, some apparel brands have taken on the task of providing mass customization to their customers (Lee, Damhorst, Campbell, Loker, & Parsons, 2011). Levi Strauss, Second Skin Swimwear, and Custom Foot have offered customers mass customization services in addition to ready to wear apparel options (Lee, Kunz, Fiore, & Campbell, 2002). A variety of research has shown that 3D body scanning is becoming a common tool used to obtain consistent and accurate body measurements that can assist in creating mass customized apparel (Ashdown & Choi, 2011; Carrere, Istook, Little, Hong, & Plumlee, 2002; Simmons, & Istook, 2003; Song, & Ashdown, 2010). Mass customization is a term that was first introduced in 1987 by Boston University Research Professor Stanley Davis and later refined and expanded on by Joseph Pine (Christy, 1993; Duray, Ward, Milligan, & Berry, 2000; Welborn, 2007). In Mass customization, businesses seek to produce a good or service that meets a specific customer's need while maintaining the efficiency associated with mass production (Christy, 1993; Duray, Ward, Milligan, & Berry, 2000; Jiao & Tseng, 2001; Pine, B., Davis, & Pine II, B., 1999; Pine II, B., Victor, & Boynton, 1993). Research has indicated that combining 3D body scanning technology with computer aided design (CAD) technologies, industrial cutting machines, and unit production systems can be useful in assisting manufacturers with the ability to achieve automated custom fit (see Figure 6 and Figure 7)(Ashdown &Dunne,2006).

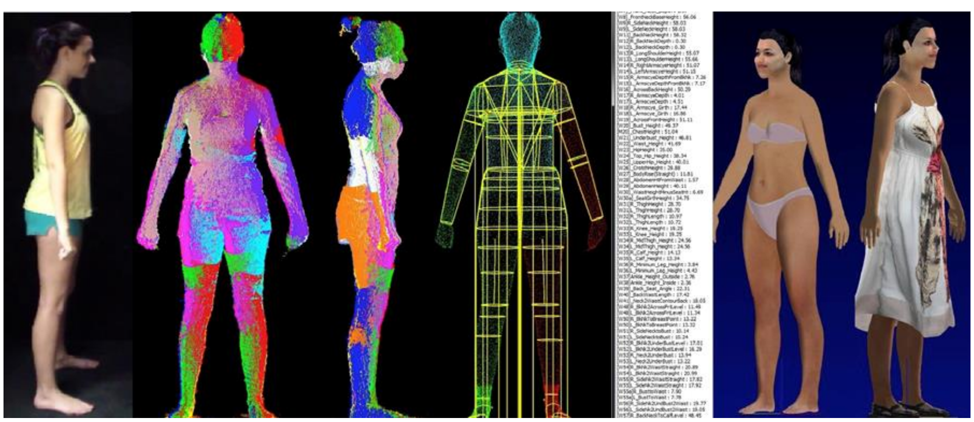


Figure 6: Photograph of a subject with Endomorph somatotype. (Sheldon, 1954, p. 325)

Figure 7: Example of virtual try-on solution. From
http://www.hometrica.ch/en/technology.html#newsletter

Size Management. In the past, consumer clothing was hand crafted by dressmakers and/or tailors. Technological advances have shifted the production of apparel from custom clothing for the individual to the method of mass production and the use of standardized sizing systems (Bye, DeLong, & Labat, 2006). The problem with the current standardized sizing systems used in mass production is they do not accommodate every body size and shape that exists in the entire population (Ashdown, & Dunne, 2006; Chattaraman, Simmons, & Ulrich, 2013; Giovis, 2007). Sizing surveys conducted around the world utilizing 3D scanning technology in addition to manual anthropometric measurements have provided industry professionals with more accurate information regarding the sizes and shapes of consumers in these populations (Deschamps, 2011; Shin, & Istook, 2007; Lee, Istook, Nam, & Park, 2007).

Retail. Retailers are now beginning to use 3D body scanners to give their customers a greater level of customer service and the opportunity to experience virtual fashion (Christian, 2012; Daanen, & Ter Haar, 2013). From body scan output customers can receive information regarding specific brands and styles that are better suited for their particular size and shape. In addition, scan output has the ability to provide customers with an avatar customized to their own specific measurements and body shape that can be used to virtually try on clothing in a matter of seconds. Some software packages allow for avatars to be customized with hair, skin color, and facial features that resemble the customer scanned. Bodymetrics is a company that has introduced the idea of customers having the ability to convert their home TVs into a dressing room. They are exploring opportunities to integrate their PrimeSense 3D sensor solutions into future Smart TVs allowing customers the ability to capture 3D scan output in the comfort of their own homes (Bodymetrics, 2012).

Bloomingdale's is an example of a retailer participating in the 3D body scan revolution by its implementation of a Bodymetrics 3D body scanner in their Stanford, CA location. The Bodymetrics scanner utilized by Bloomingdale's uses Microsoft Kinect technology to produce scan output that gives women the ability to identify the brands of jeans that will work best for their particular size and shape (Christian, 2012).

Speedo is another example of a retailer utilizing 3D scan technology. They are now providing their customers at the Neal Street store in Covent Garden, London with the opportunity to utilize Size Stream body scanners to assist in size prediction (Size Stream, 2015).

Data Analysis Techniques Used in Previous Research

Literature reviewed indicates data analysis techniques used in research regarding body shape primarily has consisted of gathering data via questionnaire and sampling of a sample population. After data was collected it was then sorted and categorized based on measurements, proportions, and shape (http://www.sae.org/technicalcommittees/caesarhome.htm, 2015; Simmons, 2002; [TC]², 2004). These categories have been used to determine the different body shapes or types present in the sample populations that were studied and a name was given to each body shape or type. Multivariate analysis has been used to assist in categorizing and validating results (Devarajan, 2003). Additional data analysis techniques used in previous research consists of the following:

- Cluster Analysis to analyze shape sorting technique (Deverajan, 2003)
- Factor Analysis to determine the important variables for grouping (Shin, Istook, & Lee, 2011)
- Discriminant Analysis to determine if body measurement ratios accurately predict shapes better than random chance (Deverajan, 2003)
- Multivariate Analysis to determine if there is a significant difference between defined shapes (Deverajan, 2003)
- Principle Component Analysis to determine measurement variables important to identifying shapes and sizes (Xia, 2013)
- Multivariate Regression to predict measurements based on Principle Component (Xia, 2013)

Summary

A comprehensive literature review has demonstrated there are issues regarding fit in the apparel industry. Outdated sizing standards based on young Caucasians in the 1940s do not take into account the varying body shapes that exist within the varying age ranges in the population in addition to other demographics factors that have occurred since the 1940s.

In an attempt to gain more current anthropometric data, there have been a variety of sizing surveys conducted utilizing 3D scanning technology and manual anthropometric measurements. This information has been used in a wealth of information and research surrounding body size and shape classifications for women, however, research in these areas for men is lacking.

The research regarding body shape classifications for males primarily refers to or is based on three somatotype categories developed by American psychologist William Sheldon in the 1950s. In addition to the use of somatotyping, there is a trend in popular press to classify the male form by comparing body shapes to geometric shapes or comparing the body to fruits and vegetables.

Therefore, male shape categories are needed to assist the apparel industry in providing apparel that accommodates the varying body shapes of males that might help identify size categories. In addition, shape categories will assist male consumers in choosing clothing styles and silhouettes that are best suited for their particular body shape.

CHAPTER 3: METHODOLOGY

The objective of this research was to determine male body shape classifications for men ages 26 to 35 utilizing 3D scan data. While there is research regarding female body shape classifications, research regarding men's body shape classifications has been lacking. This research will assist in establishing a baseline for further studies in this area.

Specific research questions include:

1. Can SizeUSA data collected for men be used to identify the predominant shapes of male bodies in the US for men ages 26 to 35?
2. Based on literature review and the visual properties of the bodies within each shape, can a descriptive label be identified that would aid in an understanding of the shape differentiators?
3. Does the ASTM D6240 sizing system developed for males meet the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey?

SizeUSA Data Collection

Data from the SizeUSA National Sizing Survey was used in the research for this study. The SizeUSA National Sizing Survey was organized and conducted by [TC]^2 from 2002 to 2003 utilizing white light 3D scanning technology and was partially funded by the U.S. Department of Commerce and additionally supported by apparel industry companies, the Army, Navy, and academic universities. A sample was selected of over 10,000 adults of which 35% were men and 65% were women from 13 U.S. cities. The sample contained four ethnic categories (51% Non-Hispanic White, 18% Non-Hispanic Black, 8% Hispanic, and 8% Other) and covered 6 age categories (25% = 18 to 25, 22% = 26 to 35, 22% = 36 to 45, 18% = 46 to 55, 9% = 56 to 65, and 4% = 66+). The sampling strategy used modelled approximate height and weight distribution of a previously valid study by the National Health and Nutrition Examination Survey III. Prior to being scanned, subjects completed a questionnaire that identified their age, sex, ethnicity, zip code, annual household income, marital status, body structure, lifestyle, education, employment, preferred clothing sizes, preferred stores, and types of clothing worn ([TC]², 2004; Zernike, 2004). The reliability of the body scan data was validated by a comparison of scan measurements to manual measurements ([TC]², 2004).

Data Description

A total of 788 male subjects between the ages of 26 and 35 were used as a basis for the research in this paper. Figure 8 through Figure 16 illustrate a portion of the demographic information found in the SizeUSA data for males in the specified age range. Thirty-five percent were Non-Hispanic White with 20% Non-Hispanic Black (See Figure 10). Thirty-one percent of male subjects in this age range identified themselves as wearing a large size while half of the male subjects in this age range identifying themselves as wearing either Medium or XL (see Figure 15).

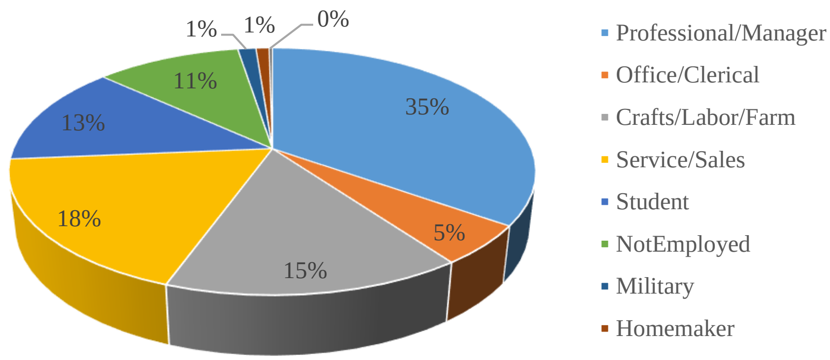


Figure 8: SizeUSA Demographics for male subjects ages 26 to 35– Current Employment. From [TC]². (2004).

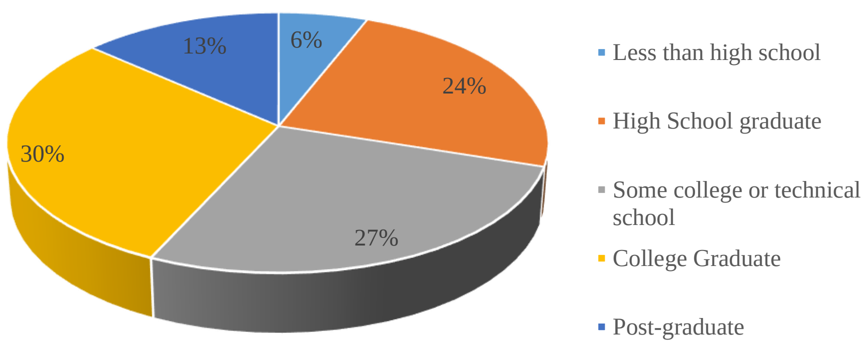


Figure 9: SizeUSA Demographics for male subjects ages 26 to 35 – Education Level. From: [TC]². (2004).

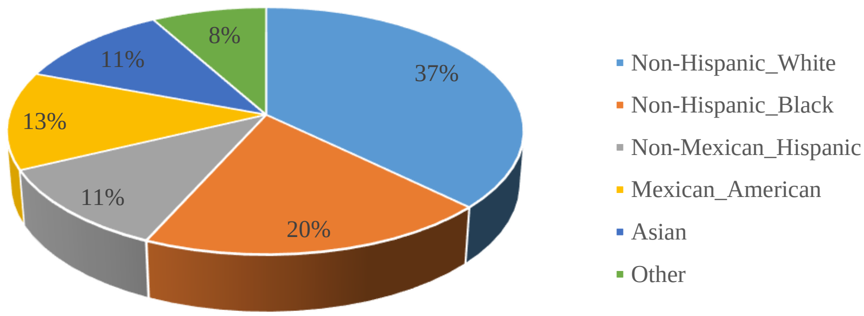


Figure 10: SizeUSA Demographics for male subjects ages 26 to 35 – Ethnicity. From: [TC]². (2004).

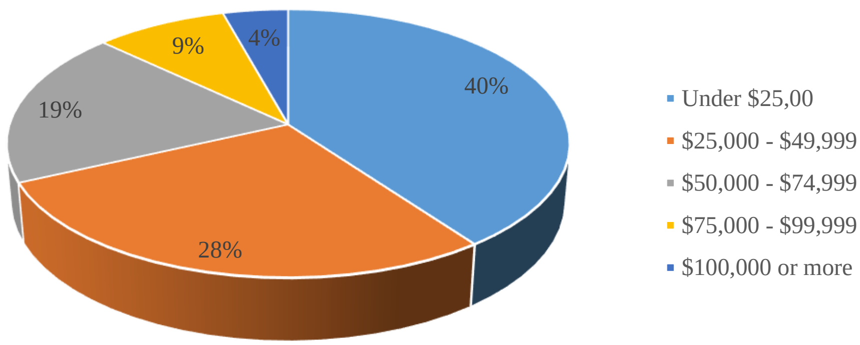
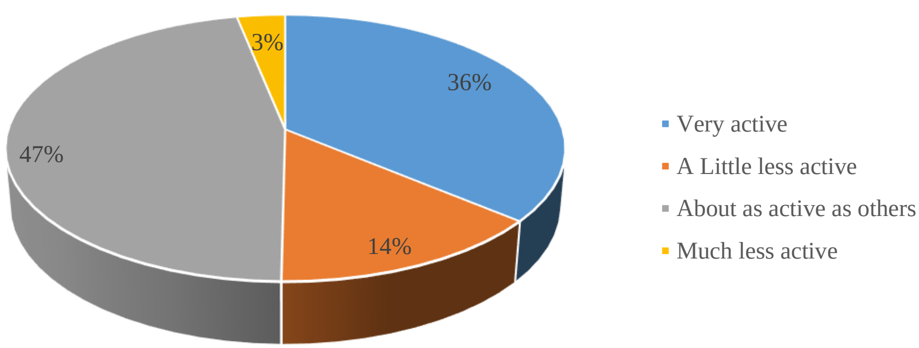


Figure 11: SizeUSA Demographics for male subjects ages 26 to 35 – Income. From: [TC]².



(2004).

Figure 12: SizeUSA Demogarphics for male subjects ages 26 to 35 – Lifestyle. From: [TC]². (2004).

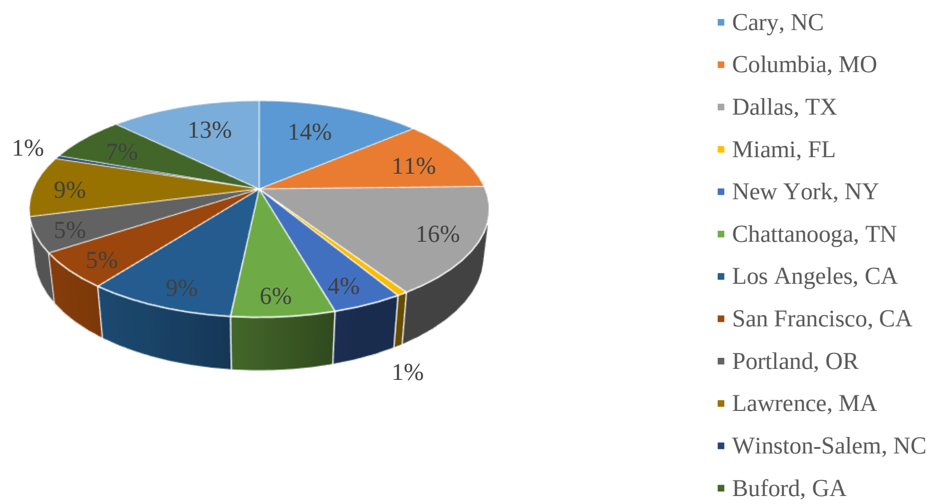


Figure 13: SizeUSA Demographics for male subjects ages 26 to 35 – Scan Location. From: [TC]². (2004).

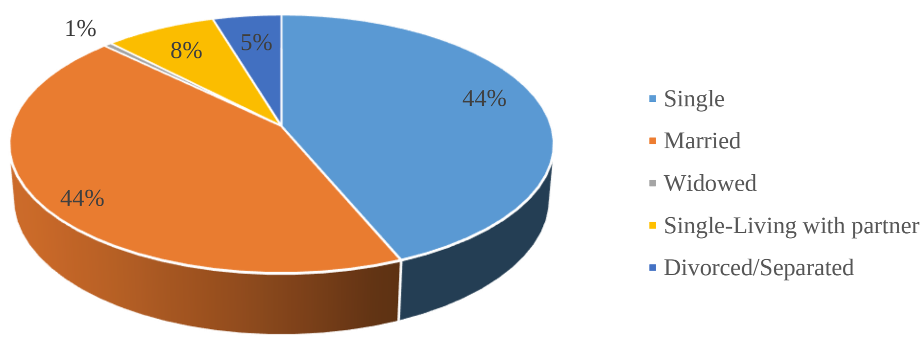


Figure 14: SizeUSA Demographics for male subjects ages 26 to 35 – Marital Status. From: [TC]². (2004).

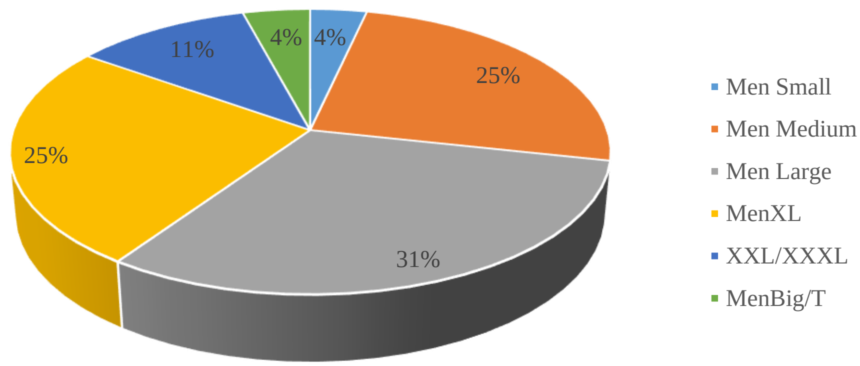


Figure 15: SizeUSA Demographics for male subjects ages 26 to 35 – Size Perception. From: [TC]². (2004).

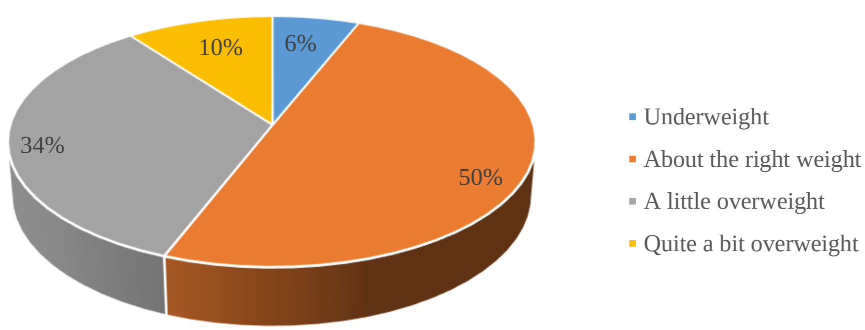


Figure 16: SizeUSA Demographics for male subjects ages 26 to 35 – Weight Perception. From: [TC]². (2004).

Data Analysis

For the purposes of this research, scan data obtained from SizeUSA for male subjects between the ages of 26 and 35 and the statistical and graphical functions of Microsoft Excel and JPM statistical analysis software were used to answer three research questions. The following details the methodology used to approach each question:

Research Question 1

Can SizeUSA data collected for men be used to identify the predominant shapes of male bodies in the US for men ages 26 to 35?

To address this research question, male body shapes categories were identified based on SizeUSA scan data and using cluster analysis. SizeUSA measurement data collected from 788 male subjects age 26 to 35 was extracted from the total population of 3691 male subjects and was randomly divided into two groups each containing 394 subjects using Microsoft Excel. Group 1 was used as the training set and group 2 was used as the validation set.

A principle component analysis was ran on the whole data set of 788 males to identify the important variables used in determining body shape. This analysis identified the chest (bust), waist, hip, and high hip measurements as the principle components that determine body shape (See Appendix A through Appendix D). Because of the lack of research regarding male body shape classifications, additional guidance for determining the measurements necessary to identify body shapes was taken from previous female studies. The Female Figure Identification Technique© (FFIT) for Apparel used six circumference measurements from 3D scan data to identify nine female body shape categories. The six measurements used were bust, waist, hip, high hip, abdomen, and stomach (Simmons, 2002). The use of these measurements was also supported in research conducted by Xia (2013) for the creation of sizing systems for three different body types in addition to being used in research conducted by Lee, Istook, Nam, and Park (2007) for comparing body shape between women in the US and women in Korea. However, SizeUSA data for men did not include stomach or abdomen measurements, therefore, for the purposes of this study, the chest (bust), waist, hip, and high hip measurements were used.

Step one. Using the training set, five drop values were calculated from the chest, waist, hip, and high hip measurements (see Table 6 and Figure 17). A drop value is the difference between two circumference measurements. Drop values are better indicators of body shape than are circumference values alone and are commonly used in the sizing for men's tailored suits (Shin, Istook, Lee, 2011). These drop values were used to perform a cluster analysis to categorize male body shapes. The output from the cluster analysis was evaluated to determine if clusters were different. The training set was then divided by cluster. Point cloud images were randomly selected from each cluster. These point cloud images were visually evaluated to determine if the clusters identified were significantly different from each other and that the subjects in each cluster were similar. Input was given from individuals possessing knowledge of body shape, proportions, and the apparel industry.

Table 8. Drop Values

Variable Name	**Calculation**
Drop 1	Chest – High Hip
Drop 2	Hip – High Hip
Drop 3	Waist – High Hip
Drop 4	Chest – Waist
Drop 5	Hip - Waist

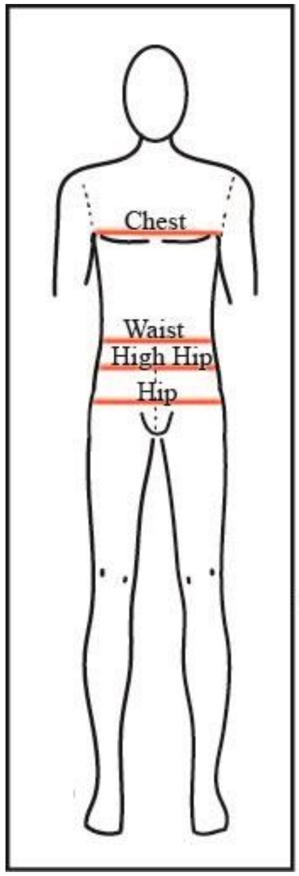


Figure 17: Body measurement locations.

Step two. To validate findings, the five drop values calculated using the training set were calculated again using the validation set. These drop values were used to perform a second cluster analysis to categorize male body shapes for the validation set. The cluster means from this cluster analysis were compared to the cluster means derived from the training set. The validation set was then divided by cluster. Point cloud images were randomly selected from each of the validation clusters to allow visual evaluation of the male body shapes and comparison to the point cloud images from the training set.

Step three. Drop values and ratios calculated from the primary circumferential measurements (chest, waist, high hip and hip) were used in Microsoft Excel to develop formulas that were applied to the entire sample set of SizeUSA measurement data for males ages 26 to 35 to further delineate the shapes that were identified by the cluster analysis. The use of this method for identifying shape clusters has been named, MSIT (Male Shape Identification Technique) for Apparel. The Point cloud images were randomly selected from each cluster generated by MSIT. These point cloud images were visually evaluated and compared to the images grouped together by the cluster analysis.

Research Question 2

Based on literature review and the visual properties of the bodies within each shape, can a descriptive label be identified that would aid in an understanding of the shape differentiators?

To address this question, a comprehensive look at literature revealed that in most cases, labels assigned to male body shape categories were the result of visual comparisons to geometric shapes, fruits and vegetables, and objects (Hawksley, 2014; Hughes Jones, 2013; http://www.style-makeover-hq.com/male-body-shape.html; Rob-one, 2014). This information provided direction in identifying a descriptive label for the male body shapes represented in each cluster resulting from the analysis in research question 1.

For the purposes of this study, geometric shapes were used as the labels for the male shape clusters. Point cloud images from each cluster identified in the cluster analysis performed in research question 1 were compared to commonly known geometric shapes and were assigned a descriptive label that corresponds with the geometric shape they were most like.

In addition, point cloud images from each cluster identified by MSIT for Apparel performed in research question 1 were compared to commonly known geometric shapes and were assigned a descriptive label that corresponds with the geometric shape they were most like.

Research Question 3

Does the ASTM D6240 sizing system developed for males meet the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey?

To address this question, the same five drop values calculated using the training and validation sets in research question 1 were calculated using ASTM D6240 measurement data. The minimum and maximum values in each ASTM drop were used to create a range for each drop. These ranges were used in a formula to determine whether or not any of the ASTM drops satisfy the measurement needs of all the male subjects age 26 to 35 in the SizeUSA data in each of the shape categories (See Appendix E). It is important to note that the current ASTM D6240 measurement data available is for males ages 35 and older. There are no ASTM standards currently available for adult males under the age of 35 (https://www.astm.org/Standards/D6240.htm).

CHAPTER 4: RESULTS

The primary objective of this research was to determine male body shape classifications for men ages 26 to 35 utilizing 3D scan data. This research will assist in establishing a baseline for further studies in this area. The following presents the analysis of the data used to address the research questions for this study.

Subject Information

For the purposes of this research, SizeUSA data for male subjects between the ages of 26 and 35 were used as a basis for the research in this paper. The number of subjects totaled 788.

The subjects in this sample were predominantly Non-Hispanic White, with the next largest group being Non-Hispanic Black (see Figure 18). The average weight was 186.5 pounds with a range of 68.5 pounds to 383 pounds (see Figure 19). The average height of subjects was approximately 5’9” tall with a range of 4’11½” to 7’tall (see Figure 20).

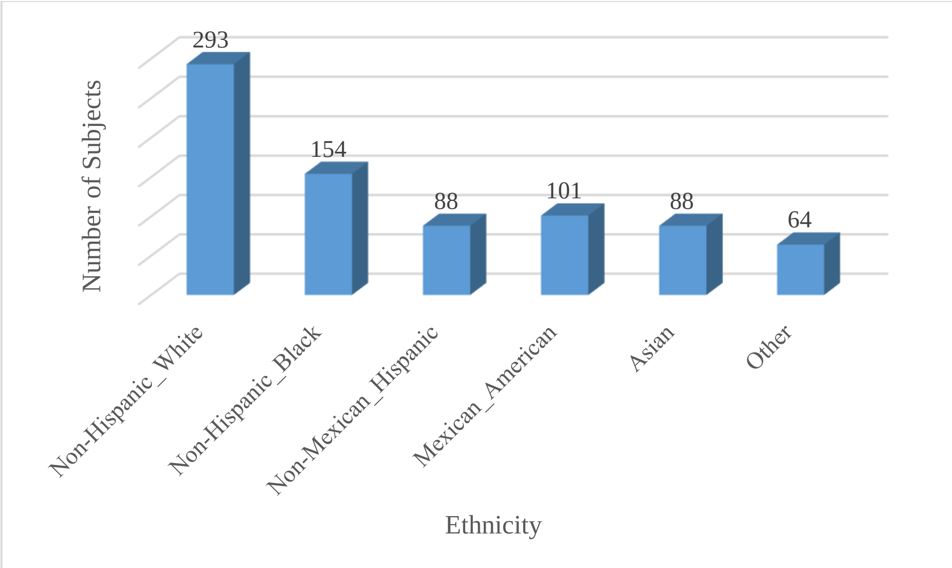


Figure 18: Ethnicity frequencies for the 788 male subjects ages 26 to 35.

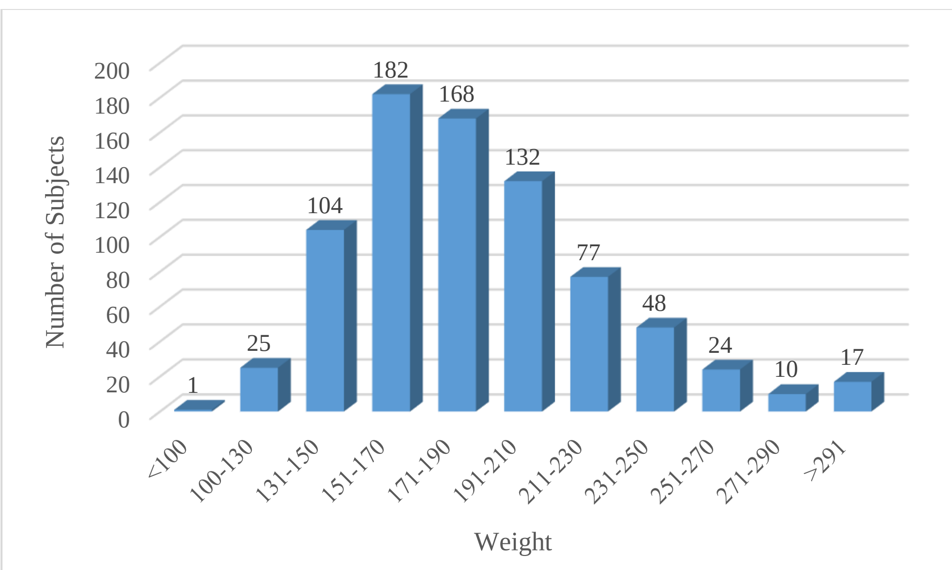


Figure 19: Weight frequencies for the 788 male subjects ages 26 to 35.

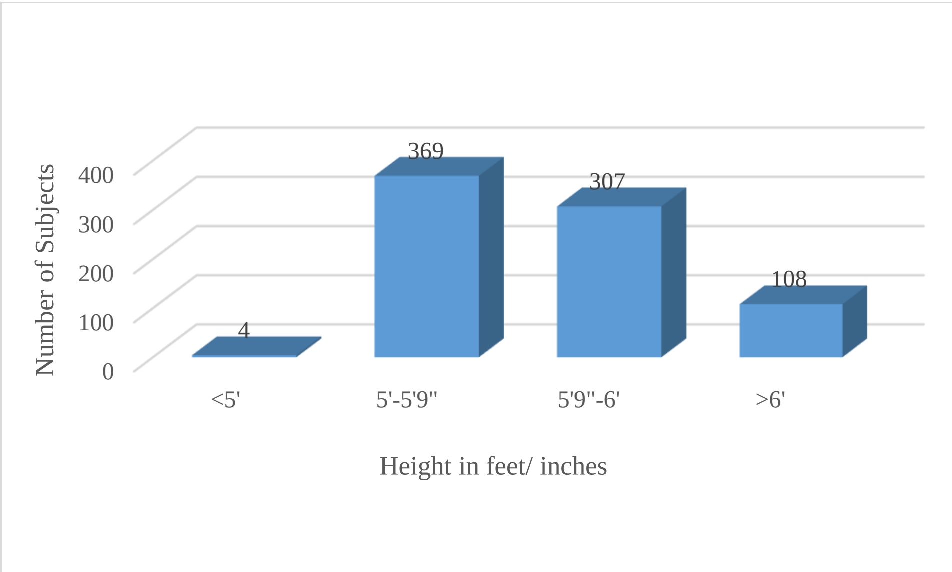


Figure 20: Height frequencies for the 788 male subjects ages 26 to 35.

Identifying Male Body Shape Categories

Cluster Analysis

Training set. The first objective of this research was to use SizeUSA data to identify the predominant shapes of male bodies in the US for males age 26 to 35. SizeUSA data for 788 male subjects between the ages of 26 and 35 was randomly divided into two groups each containing 394 subjects using Microsoft Excel. Group 1 was used as the training set and group 2 was used as the validation set. Using the training set, the chest, waist, hip, and high hip measurements were used to calculate five drop values. These drop values were used as the variables in a cluster analysis. Based on the cluster analysis that was performed, it was determined that there were three distinct clusters of body shapes for males in this age range. Table 7 identifies the descriptive measurement data for the subjects that fell within each cluster in the training set. These numbers demonstrate the collective difference between the subjects separated within each cluster. The Dendrogram in Figure 21 shows the grouping structure of the 3 clusters.

Table 9. Cluster Means (in inches) - Training Set

		Drop 1	**Drop 2**	**Drop 3**	**Drop 4**	**Drop 5**
Cluster	**Count**	**C-HH drop**	**H-HH drop**	**W-HH**	**C-W**	**H-W**
1	221	3.099	1.501	-2.187	5.286	3.688
2	96	1.218	2.379	-4.193	5.411	6.573
3	77	5.207	3.295	-3.381	8.588	6.676

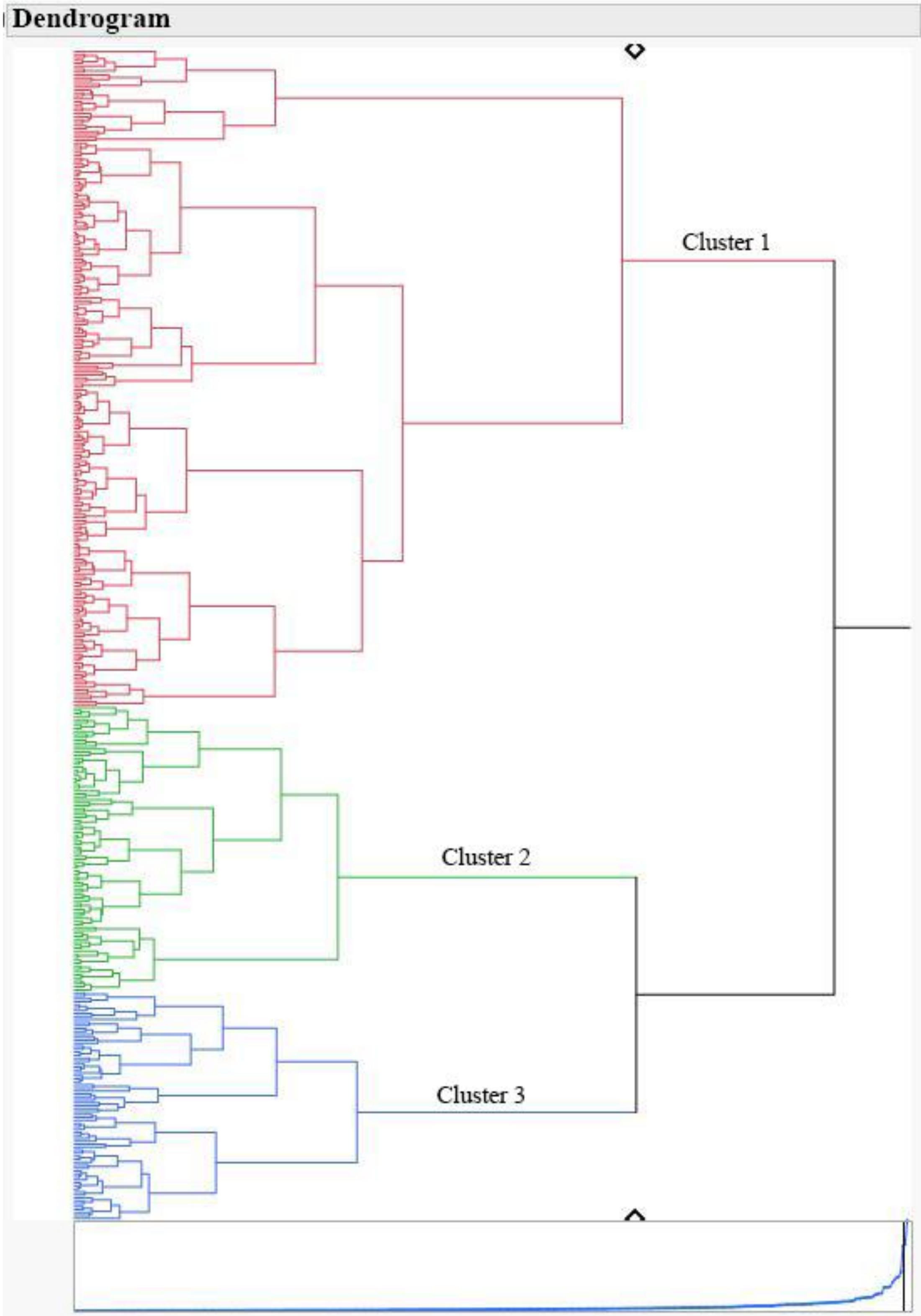


Figure 21: Grouping structure of clusters identified with the Training Set.

Data for the training set was then run through a separate cluster analysis process. Point cloud images of specific subjects were randomly selected from each cluster and assembled together separately on three posters labelled Cluster 1, Cluster 2, and Cluster 3 (see Figure 22 through Figure 24). Each poster was approximately 35 inches in height and 60 inches in width. The three posters were hung side by side on a wall to be visually evaluated by a small team of individuals with expertise in the apparel industry, body shape, and body proportions. The small team consisted of two academics both possessing extensive apparel industry experience and the third a recent apparel design and merchandising college graduate possessing retail and showroom

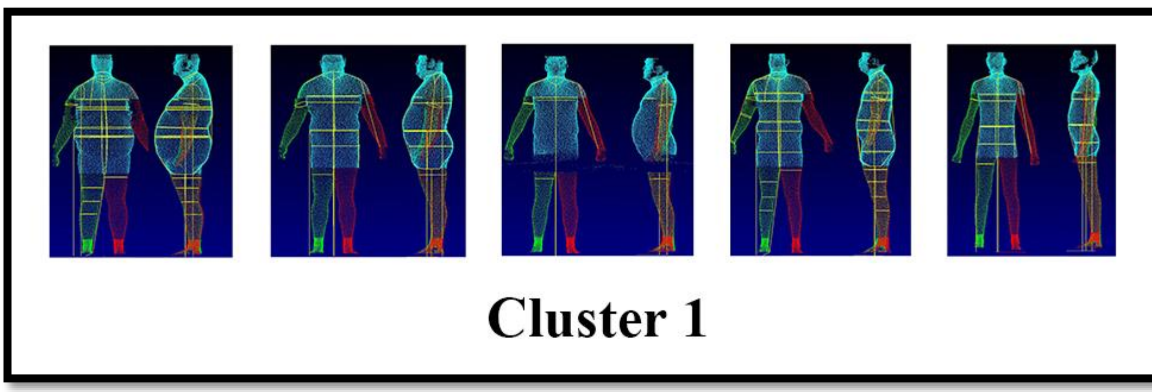


Figure 22: Point Cloud Images - Cluster 1

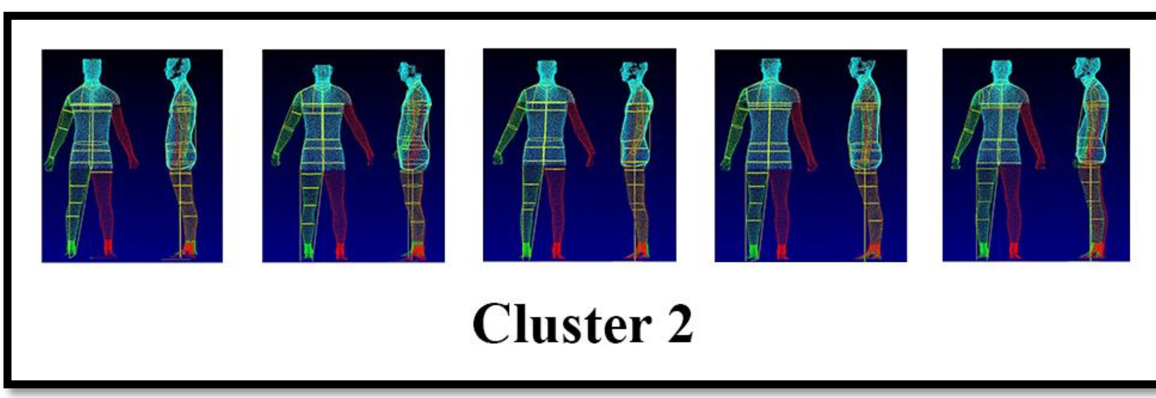


Figure 23: Point Cloud Images - Cluster 2

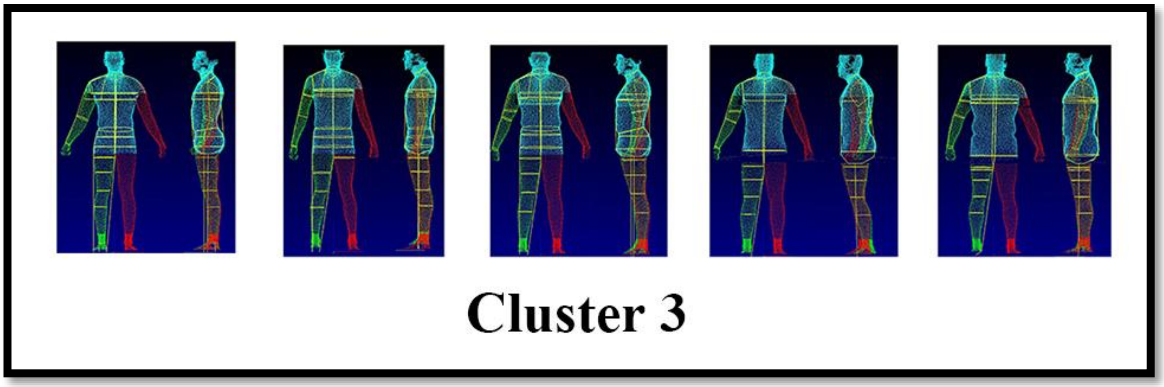


Figure 24: Point Cloud Images - Cluster 3

experience. The small team was asked to enter the room where the three posters were hung and to visually evaluate each poster and determine if the subjects identified within each cluster were similar. The small team was also asked to visually evaluate the posters and determine if the three clusters were significantly different.

The small team determined that there were a group of similar shaped subjects within each cluster, however there were some that seemed to be identified incorrectly, but also did not necessarily fit within the shapes identified by the other clusters. Figures 25 through 27 show subjects circled in red that were determined by the small team to be identified incorrectly.

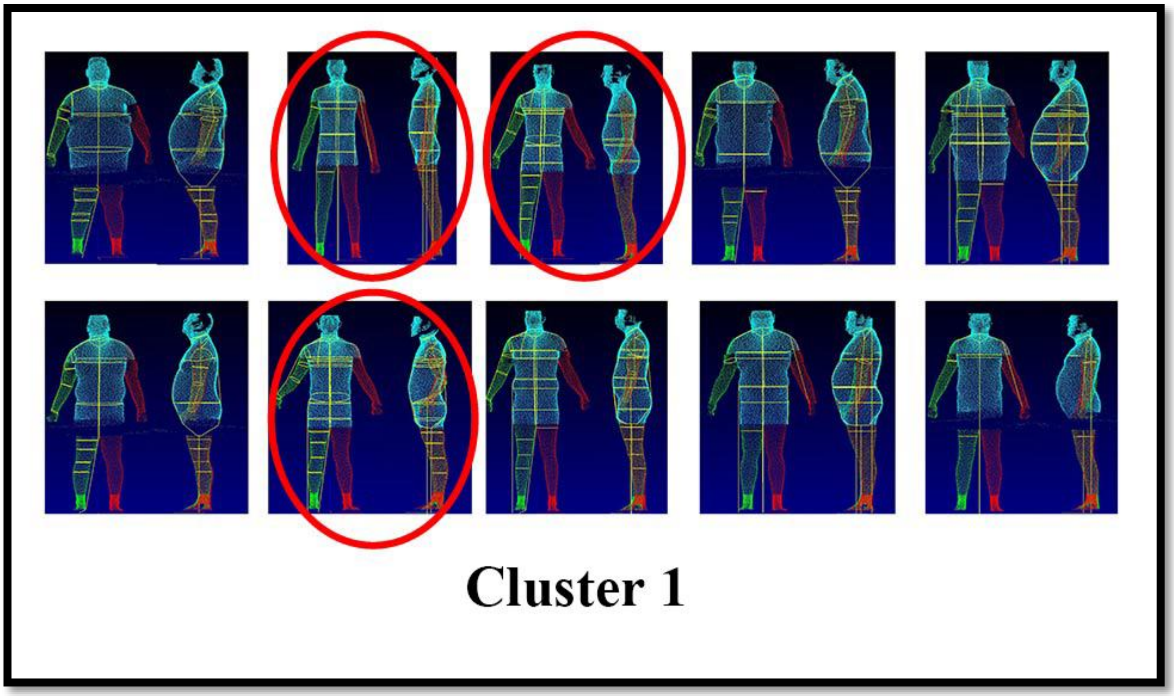


Figure 25: Subjects Incorrectly Identified as Cluster 1

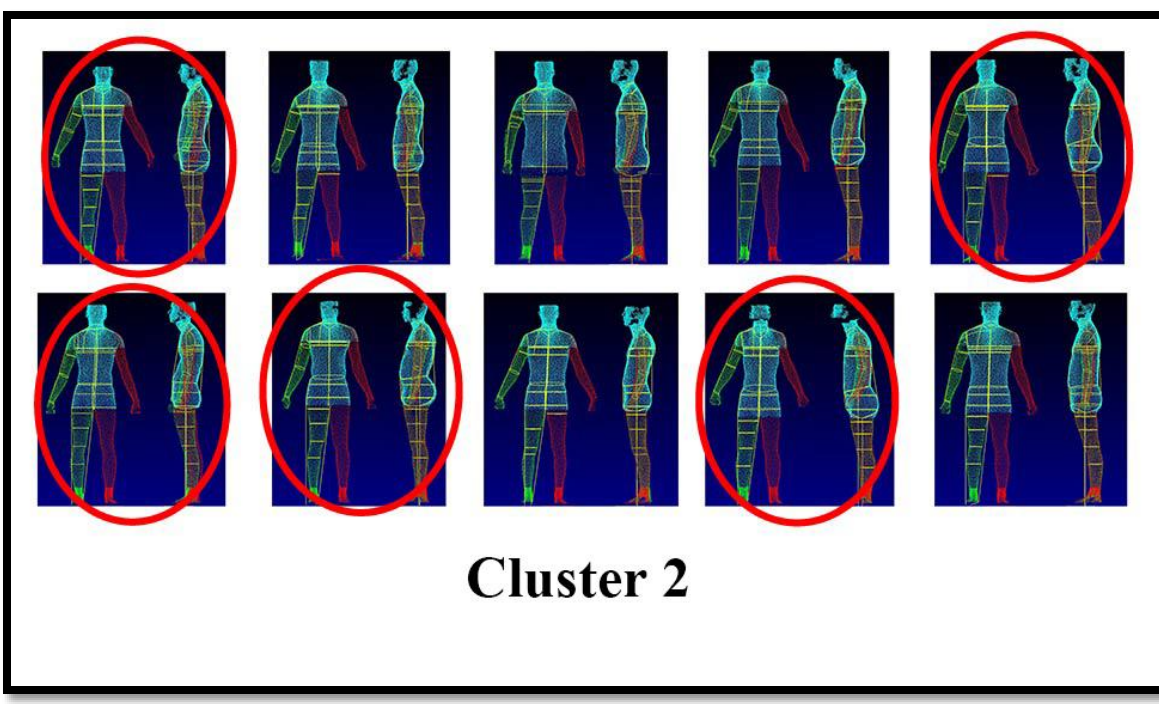


Figure 26: Subjects Incorrectly Identified as Cluster 2

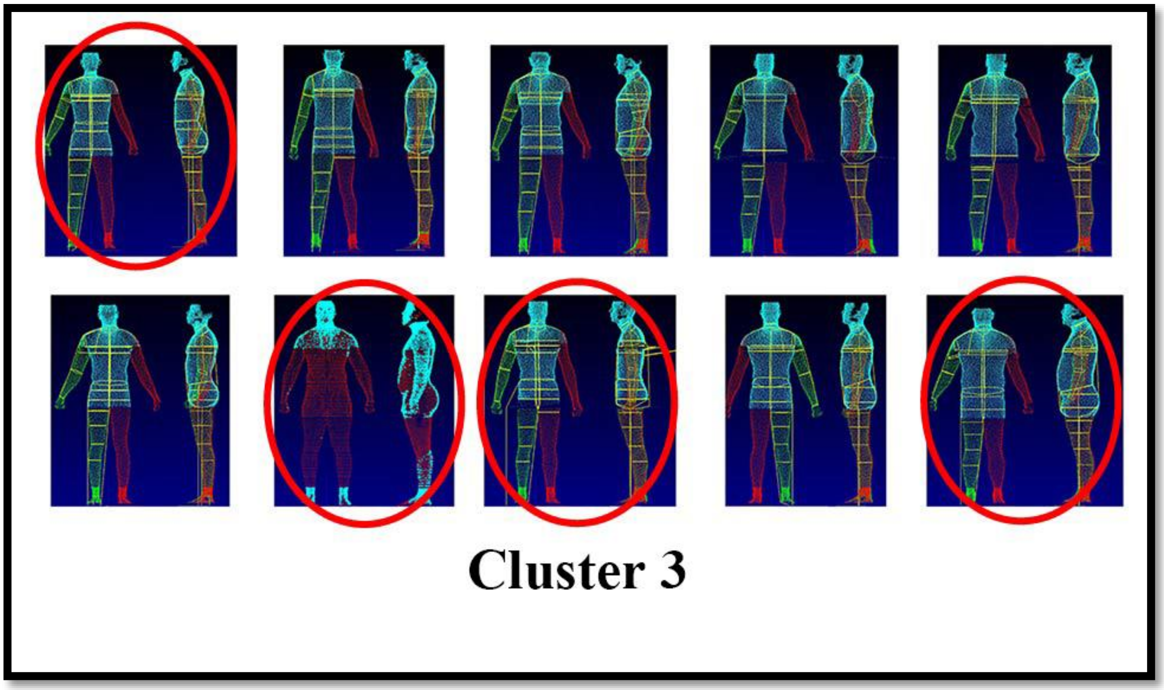


Figure 27: Subjects Incorrectly Identified as Cluster 3

To validate findings, the five drop values calculated using the training set were calculated again using the validation set and were used to perform a cluster analysis to categorize male body shapes for the validation set. Like the training set, the cluster analysis identified three distinct clusters or categories of body shapes for males in this age range (see Figure 28). The cluster means of the validation set were compared to the cluster means of the training set.

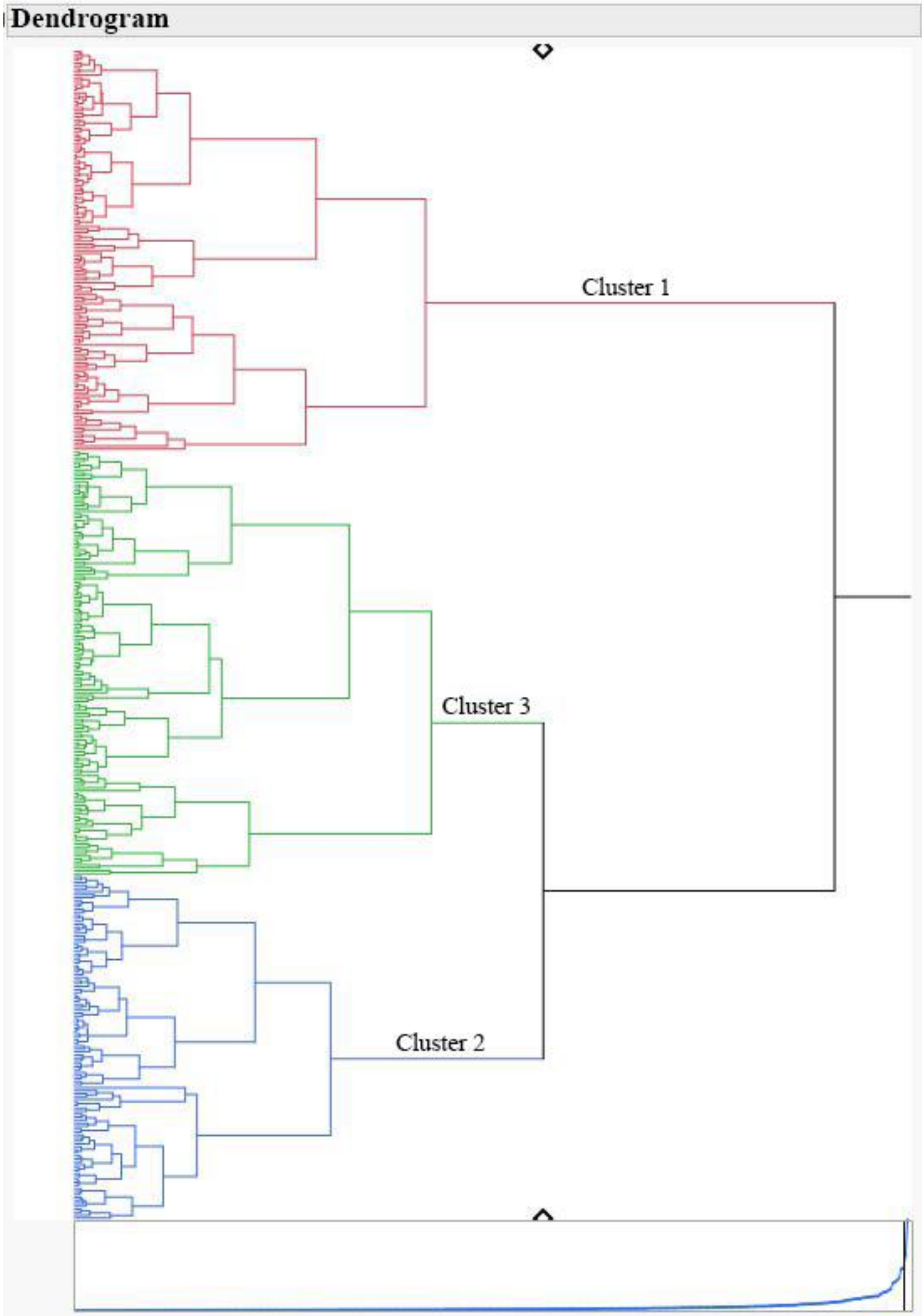


Figure 28: Grouping structure of clusters identified with the Validation Set.

This comparison showed that within each cluster, the validation set was very similar to the training set (see Table 8 through Table 10). The validated shape clusters were used as the shape categories to identify the predominant shapes of male bodies in the US within the specified age range.

Table 10. Cluster Means Comparison (in inches) – Cluster 1

		Drop 1	Drop 2	Drop 3	Drop 4	Drop 5
Set	**Count**	**C-HH drop**	**H-HH drop**	**W-HH**	**C-W**	**H-W**
Training	221	3.099	1.501	-2.187	5.286	3.688
Validation	135	2.411	0.992	-1.849	4.260	2.841

Table 11. Cluster Means Comparison (in inches) – Cluster 2

		Drop 1	Drop 2	Drop 3	Drop 4	Drop 5
Set	**Count**	**C-HH drop**	**H-HH drop**	**W-HH**	**C-W**	**H-W**
Training	96	1.218	2.379	-4.193	5.411	6.573
Validation	116	1.877	2.100	-3.996	5.873	6.096

Table 12. Cluster Means Comparison (in inches) – Cluster 3

		Drop 1	Drop 2	Drop 3	Drop 4	Drop 5
Set	**Count**	**C-HH drop**	**H-HH drop**	**W-HH**	**C-W**	**H-W**
Training	77	5.207	3.295	-3.381	8.588	6.676
Validation	143	5.013	2.827	-3.071	8.084	5.898

Drop values and ratios calculated from the primary circumferential measurements (chest, waist, high hip and hip) were used Microsoft Excel to develop formulas that were applied to the entire sample set of SizeUSA measurement data for males ages 26 to 35 to further delineate the shapes that were identified by the cluster analysis. The use of this method for identifying shape clusters has been named, MSIT (Male Shape Identification Technique) for Apparel. This process required significant effort to determine the body variables that were vital when describing the different shapes that represented the 26-35 aged subjects within the SizeUSA dataset. An outcome of this process was the identification of an additional shape category that had not been identified by the cluster analysis processes (see Figure 29).

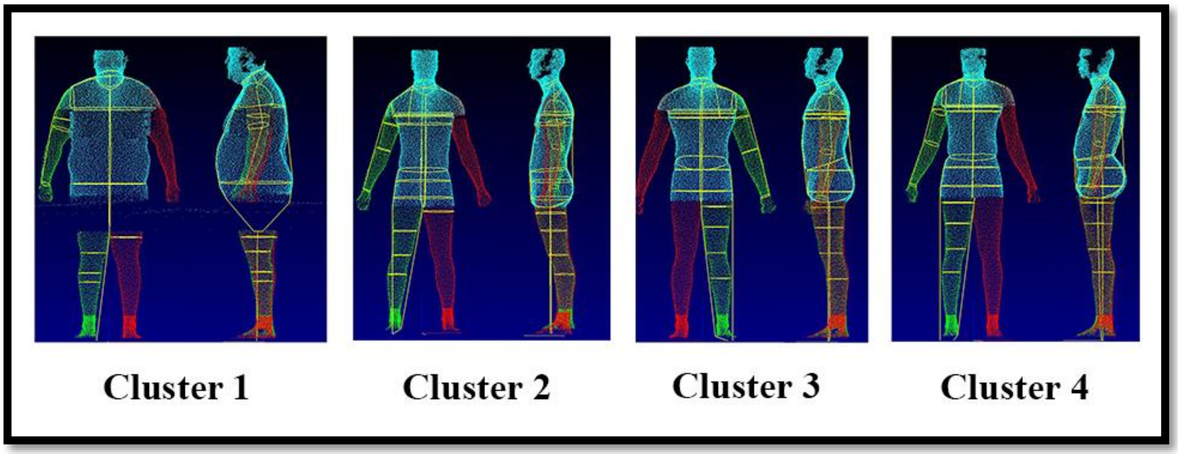


Figure 29: Point Cloud Images of Clusters Identified by MSIT for Apparel

Shape Descriptions

The second objective of this research was to identify a descriptive label for each shape category that would aid in an understanding of the shape differentiators. Literature reviewed provided direction in identifying a descriptive label for the male body shapes represented in each cluster or shape category for this research. For the purposes of this study, the male shape categories were assigned names based on geometric shapes (see Figure 30 and Figure 31).

Subjects in Cluster 1 exhibited an overall round appearance, were larger in the abdominal region, and muscles were not well defined. These subjects had chest and hip measurements that were generally smaller than the waist measurements. This cluster was assigned the Oval category because they most similarly resembled the oval shape. This shape category was identified by the cluster analysis and by using MSIT for Apparel.

Subjects in Cluster 2 exhibited a straighter torso. The chest and hip measurements were generally the same and the waist was not larger than the chest or hips. Overall, the subjects in this cluster appeared to be leaner than the subjects in the other clusters. This cluster was assigned the Rectangle category because they most similarly resembled the rectangle shape. This shape category was identified by the cluster analysis and by using MSIT for Apparel.

Subjects in Cluster 3 exhibited a defined broad chest, broad shoulders with waist measurements that were smaller than chest measurements. Waist measurements were also smaller than or similar in size to hip measurements. These subjects appeared to have more muscle definition than the subjects in the other clusters. This cluster was assigned the Trapezoid category because they most similarly resembled the trapezoid shape. This shape category was identified by the cluster analysis and by using MSIT for Apparel.

Subjects in Cluster 4 exhibited normal to sloping shoulders, and hip measurements were larger than chest measurements. These subjects appeared to have more weight in the lower part of the body. This cluster was assigned the Inverted Trapezoid category because they most similarly resembled the inverted trapezoid shape. This shape category was identified by using MSIT for Apparel and was not identified by the cluster analysis.

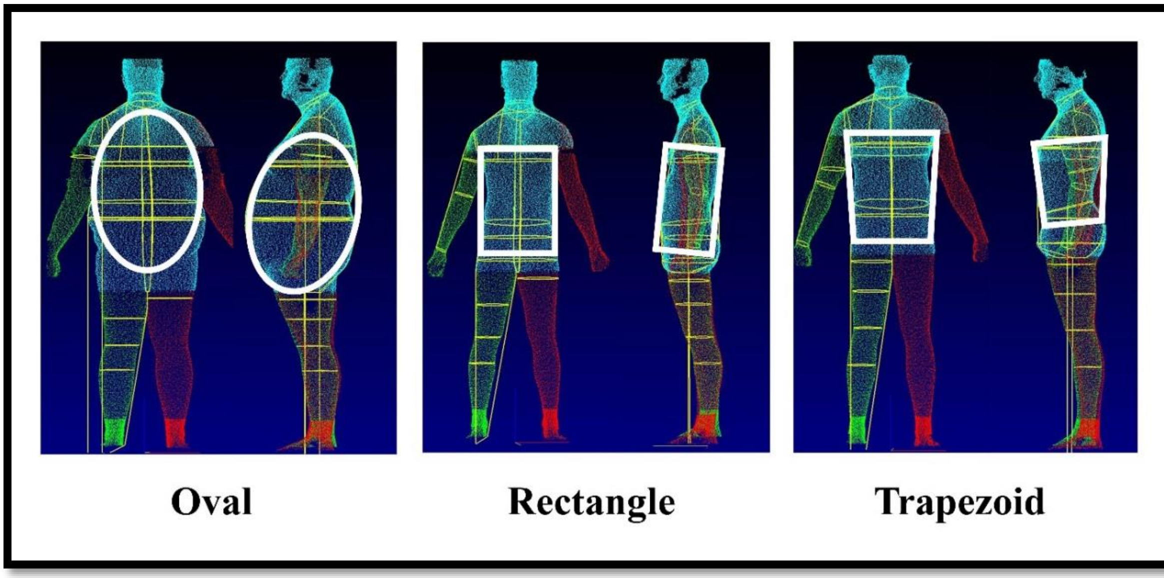


Figure 30: Body Shape Categories generated from Cluster Analysis.

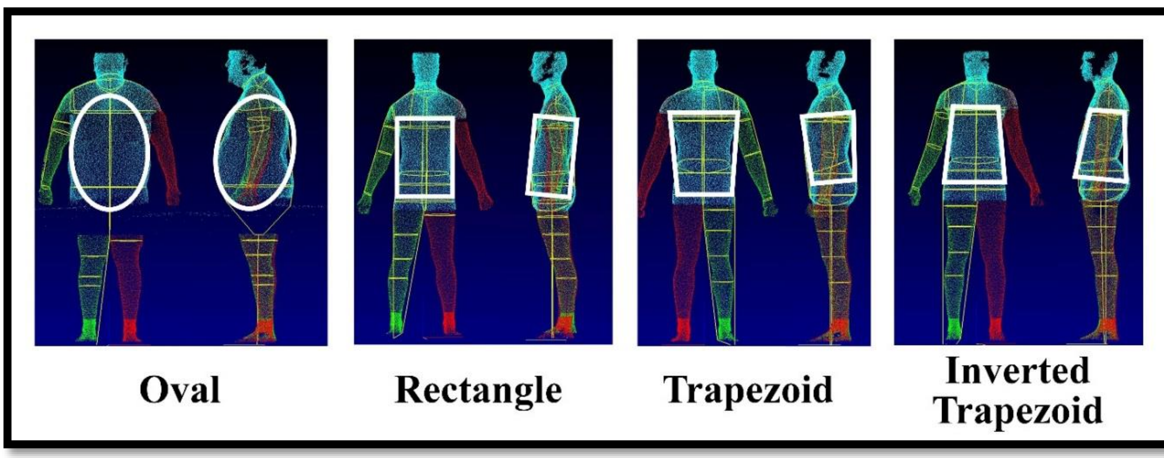


Figure 31: Body Shape Categories generated from MSIT for Apparel.

The Rectangle shape had the largest number of subjects in the four shape categories with the Inverted Triangle shape having the least. However, not all subjects were easily defined by the four shape categories. There was a minimal amount of subjects that could not be defined by any of the shape categories and a number of subjects that fell into more than one shape category (see Figure 32).

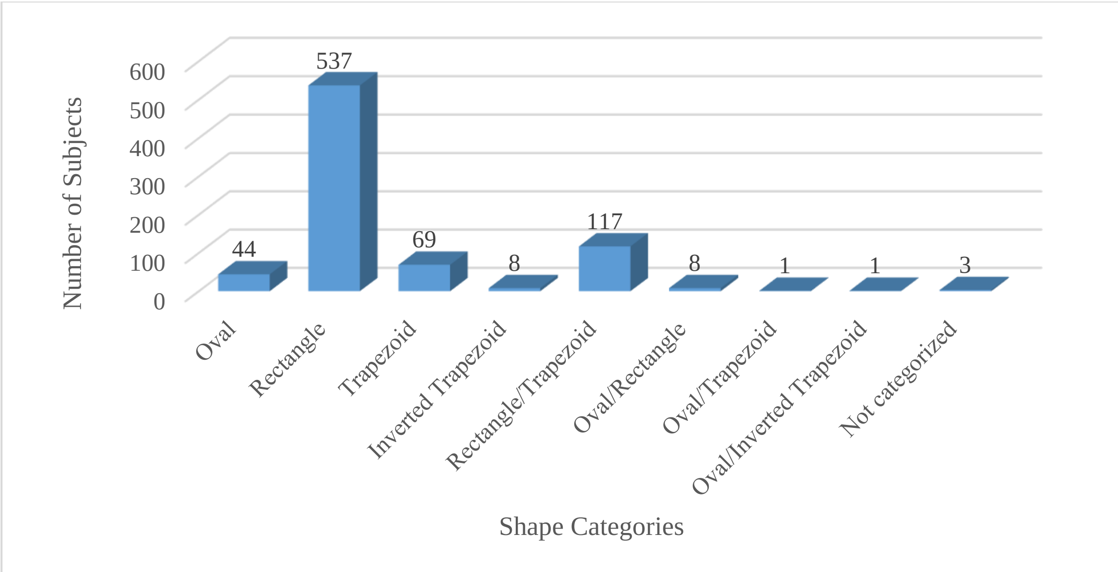


Figure 32: Shape category frequencies for the 788 male subjects ages 26 to 35.

ASTM Sizing Standard Comparison

The third objective of this research was to determine if the ASTM D6240 sizing system developed for males meets the measurement needs of the male subjects within the 26 to 35 age range of the SizeUSA sizing survey. Five drop values were calculated using ASTM D6240 measurement data (see Table 11). The minimum and maximum values in each ASTM drop were used to create a range for each drop. These ranges were used in a formula to determine whether or not any of the ASTM sizing standards for males satisfied the measurement needs of the male subjects ages 26 to 35 in the SizeUSA data in each of the shape categories. The formula was applied to all of the male subject's drop values from the SizeUSA data for the specified age range (See Appendix E). If a subject's drop value from the SizeUSA data fell within the range specified in the formula, a "1" was entered into the corresponding ASTM drop value column, otherwise a "0" was entered. This formula was applied to the five drop values generated for every male subject age 26 to 35 from the

SizeUSA data. The number of drops met for each subject in each cluster was calculated. This analysis showed that there were no subjects that had all five drops satisfied by the current ASTM D6240 sizing standard for males. In other words, none of the subjects would be able to find one size that fit their whole body, as defined by the ASTM sizing standard.

Table 13. ASTM Drop Values (in inches)

				Drop 1	Drop2	Drop 3	Drop 4	Drop 5		
Size		Chest	Waist	C-HH drop	H-HH drop	W-HH	C-W	H-W	High_Hip	Hips
34		34	28.5	3.25	2.75	-2.25	5.5	5	30.75	33.5
35	S	35	29.5	3.25	2.75	-2.25	5.5	5	31.75	34.5
36		36	30.5	3.25	2.75	-2.25	5.5	5	32.75	35.5
37		37	31.5	3.25	2.75	-2.25	5.5	5	33.75	36.5
38		38	32.5	3.25	2.75	-2.25	5.5	5	34.75	37.5
39	M	39	33.5	3.25	2.75	-2.25	5.5	5	35.75	38.5
40		40	34.5	3.25	2.75	-2.25	5.5	5	36.75	39.5
41		41	35.5	3.25	2.75	-2.25	5.5	5	37.75	40.5
42		42	36.5	3.25	2.75	-2.25	5.5	5	38.75	41.5
43	L	43	37.5	3.375	2.625	-2.125	5.5	4.75	39.625	42.25
44		44	38.5	3.5	2.5	-2	5.5	4.5	40.5	43
45		45	39.75	3.5	2.25	-1.75	5.25	4	41.5	43.75
46	XL	46	41	3.5	2	-1.5	5	3.5	42.5	44.5
48		48	43.5	3.5	1.5	-1	4.5	2.5	44.5	46
50	2XL	50	46	3.5	1	-0.5	4	1.5	46.5	47.5
52		52	48.5	3.5	0.5	0	3.5	0.5	48.5	49

In Cluster 1 (Oval) for all males in the specified age range, the ASTM D6240 standard met under half of the subjects' measurement needs for Hip to Waist drop (34%). Its second highest proficiency was in the Hip to High Hip drop (29%). Both of these drops are related to waist, high hip, and hip measurements which indicates that the ASTM standard may be proficient in fitting less than half of the male subjects in this shape category for garments that require some level of fit from the waist to hip area of the body (see Figure 33).

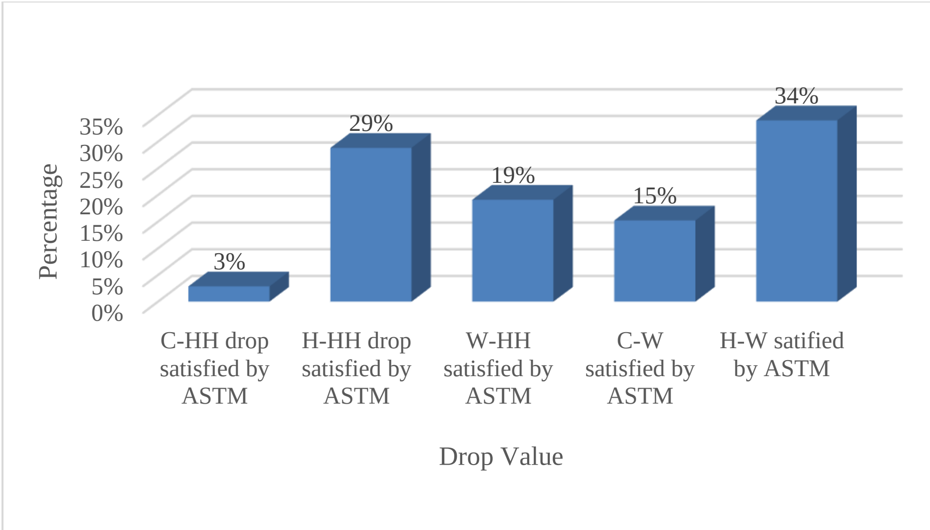


Figure 33: ASTM D6240 Proficiency – Cluster 1 (Oval).

For Cluster 2 (Rectangle) the standard met just over half of the subjects' measurement needs in the Hip to High Hip drop (55%). Its second highest proficiency was in the Chest to Waist drop (31%). Both of these drops are related to upper portion of the body indicating that the ASTM standard may be proficient in fitting half of the male subjects in this category for garments that require some level of fit in the chest, waist, and high hip areas of the body (see Figure 34).

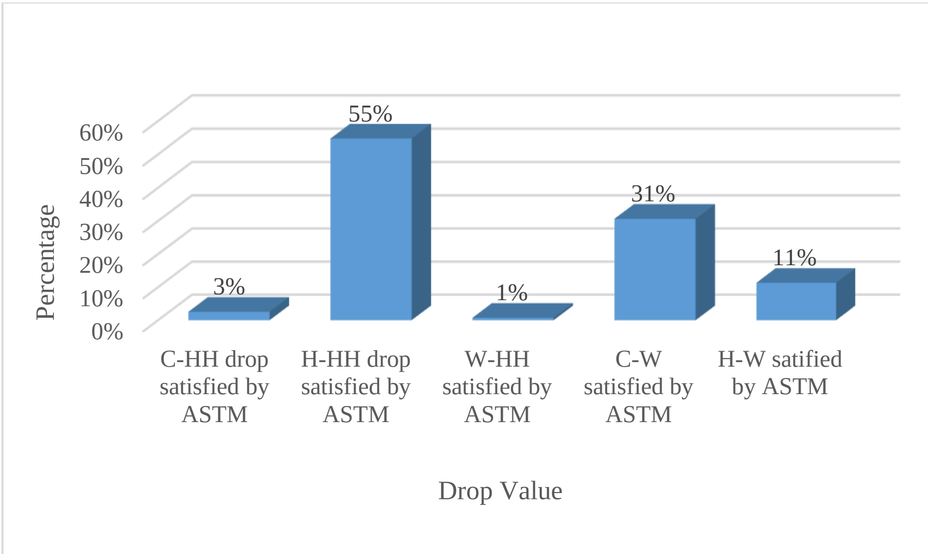


Figure 34: ASTM D6240 Proficiency – Cluster 2 (Rectangle).

For Cluster 3 (Trapezoid) the ASTM standard met just under half of the measurement needs for the Hip to High Hip drop (47%). Its second highest proficiency being in the Hip to Waist drop (22%). Both of these drops are related to waist, high hip, and hip measurements which indicates that the ASTM standard may be proficient in fitting less than half of the male subjects in this shape category for garments that require some level of fit from the waist to hip area of the body (see Figure 35).

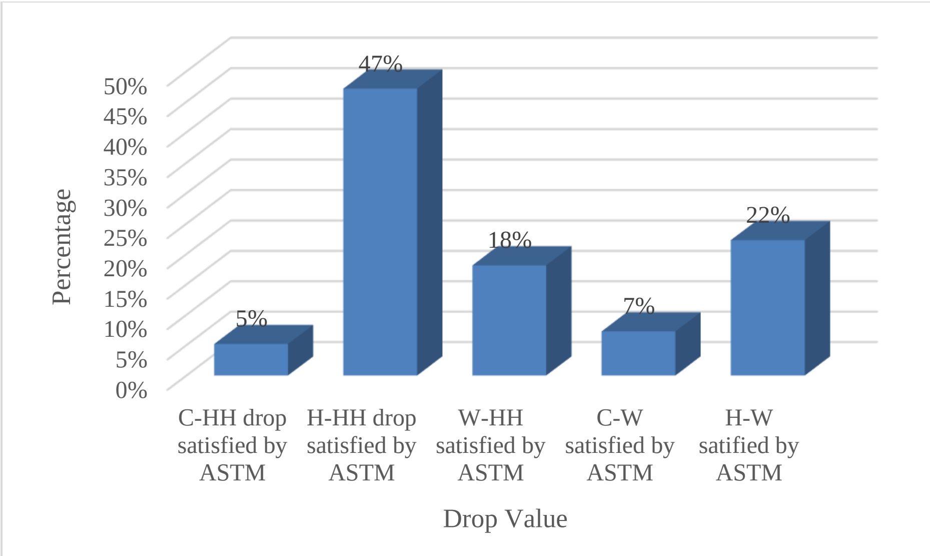


Figure 35: ASTM D6240 Proficiency – Cluster 3 (Trapezoid).

For Cluster 4 (Inverted Trapezoid) the ASTM standard met half of the measurement needs for the Hip to Waist drop (50%). It was minimally successful in meeting the needs in any of the other drop values. The Hip to Waist drop is related to waist and hip measurements which indicates that the ASTM standard may be proficient in fitting half of the male subjects in this shape category for garments that require some level of fit from the waist to hip area of the body (see Figure 36).

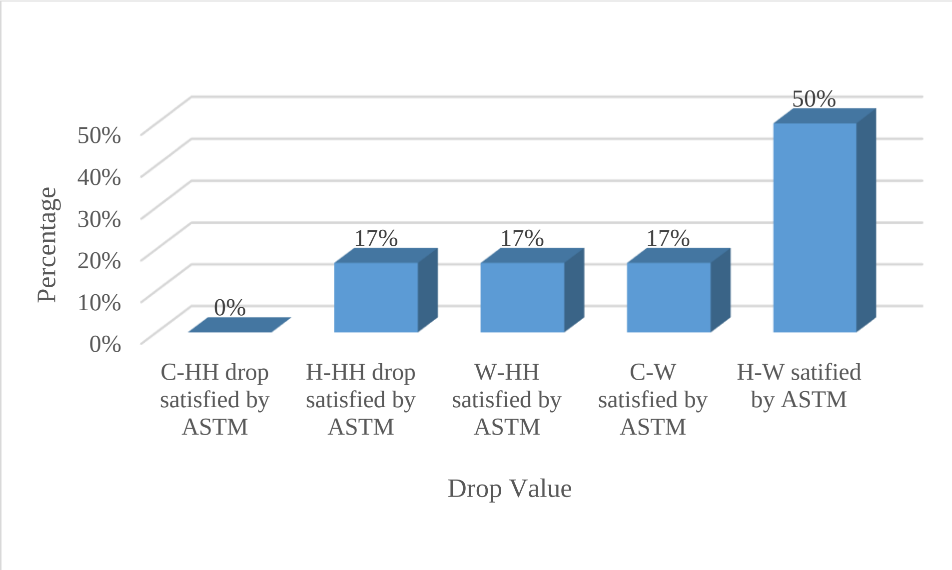


Figure 36: ASTM D6240 Proficiency – Cluster 4 (Inverted Trapezoid).

Summary of Results

To solve research question one SizeUSA data for 788 US males ages 26 to 35 was randomly separated into two evenly divided groups (training set and validation set). From the training set, five drop values were calculated and used as the variables in a cluster analysis. The cluster analysis identified three distinct body shapes for males in this age range. Point cloud images of specified subjects from each cluster were assembled for visual evaluation to determine if the subjects identified in each cluster were similar to each other and if they were also significantly different from the subjects that represented the other clusters. It was determined that there were a group of the subjects within each cluster that were similar but there were some that seemed to be identified incorrectly and also some subjects that did not necessarily fit within the shapes identified by the other clusters.

To validate findings, the five drop values calculated using the training set were calculated again using the validation set and were used as the variables in a second cluster analysis. Like the training set, the cluster analysis identified three distinct body shapes for males in this age range. A comparison was made between the cluster means from the training set and the cluster means from the validation set. The comparison determined that within each cluster, the validation set was very similar to the training set. The validated shape clusters were used as the shape categories to identify the predominant shapes of male bodies in the US ages 26 to 35.

Drop values and ratios were calculated from the primary circumferential measurements (chest, waist, high hip and hip) and used in Microsoft Excel software to develop the MSIT for Apparel which was applied to the entire sample set of SizeUSA measurement data for males ages 26 to 35 to further describe the shapes that were identified by the cluster analysis. This analysis identified an additional shape category that had not been identified by the cluster analysis.

To solve research question two literature reviewed provided direction in identifying a descriptive label based on a geometric shape for the male body shapes represented in each cluster or shape category for this research. The descriptive labels assigned to each cluster were: Oval, Rectangle, Trapezoid, and Inverted Trapezoid. The Rectangle category had the largest number of subjects in the four categories with the Inverted Trapezoid category having the least amount of subjects in the four categories. A minimal amount of subjects could not be categorized and a number of subjects fell into more than one category.

To solve research question three the same five drop values calculated to solve research question one were calculated using ASTM D6240 measurement data. A range for each drop was created from the minimum and maximum values in each ASTM drop. These ranges were used in a formula to assess the ASTM sizing standards' ability to satisfy the measurement needs of the male subjects ages 26 to 35 in the SizeUSA data in each of the shape categories. This analysis showed that there were no subjects that had all five drops satisfied by the current ASTM D6240 sizing standard for males. This means that no subject in this study would be able to find one size that fit their whole body, as defined by the ASTM 6240.

CHAPTER 5: DISCUSSION, CONCLUSIONS AND FUTURE RESEARCH

Research has shown that consumers are frustrated with the lack of consistency of fit across apparel brands. More than half of male consumers have difficulty finding good fit in apparel (DesMarteau, 2000). In addition to the lack of consistency across brands, there is a currently outdated standardized sizing system in place that is used as the basis for developing fit for men. The current sizing systems are based on averages and percentages that don't fully capture every size and shape in the population, nor do they take into consideration that two consumers that are the same height and weight can have very different body shapes due to factors such as age, ethnicity, heredity, or level of physical fitness.

Current sizing standards do not take into consideration the varying body shapes that exist within the varying age ranges in the population not to mention the other demographics factors that have occurred over time. The current standardized sizing system for males is based on measurements obtained primarily from young Caucasian male soldiers from the 1800s resulting in body size, shape, and proportion information that did not represent the entirety of the population of its time nor does it represent the differences present in body size, shape, and proportion in the current population due to the demographic changes that have occurred since the 1800s (http://museum.nist.gov/exhibits/apparel/history.htm; [TC]^2, 2004; Zernike, 2004). The ASTM sizing table currently available is for mature men 35 years of age and older. There is no ASTM standard currently available for young men under 35 years of age (https://www.astm.org/Standards/D6240.htm) which indicates the need for a standard that addresses the size and shape needs of this segment of the male population.

In an attempt to gain more current anthropometric data there have been a variety of sizing surveys conducted in the United Kingdom, the United States, Mexico, Korea, and

Thailand utilizing 3D scanning technology in addition to manual anthropometric measurements (Deschamps, 2011; Lee, Istook, Nam, & Park, 2007; Shin, & Istook, 2007). Three dimensional body scanning as we know it today evolved from scanning technology developed in the 1960s. This technology has the capability of providing accurate and reliable anthropometric information regarding the size, shape, and proportion of the human body. Because shape and proportion is just as important as size in regards to apparel fit, 3D scanning technology is becoming more commonly used in the apparel industry. This information has been used in a wealth of information and research surrounding body size and shape classifications for women, however, research in these areas for men is lacking.

The research regarding body shape categories for males primarily refers to or is based on three somatotype categories developed by American psychologist William Sheldon in the 1950s. In addition to the use of somatotyping, there is a trend in popular press to classify the male form by comparing body shapes to geometric shapes or comparing the body to fruits and vegetables (Hawksley, 2014; Hughes Jones, 2013; http://www.style-makeover-hq.com/male-body-shape.html, 2015; Rob-one, 2014).

Therefore, male shape categories are needed to assist the apparel industry in providing apparel that accommodates the varying body shapes of males that occur within a size category. In addition, shape categories will assist male consumers in choosing clothing styles and silhouettes that are best suited for their particular body shape.

The purpose of this research was to identify male body shape classifications for men ages 26 to 35 utilizing 3D scan data. This research will assist in establishing a baseline for further studies in this area. This research study focused on three objectives:

1. Can SizeUSA data collected for men be used to identify the predominant shapes of male bodies in the US for men ages 26 to 35?
2. Based on literature review and the visual properties of the bodies within each shape, can a descriptive label be identified that would aid in an understanding of the shape differentiators?
3. Does the ASTM D6240 sizing system developed for males meet the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey?

Discussion of Results

Identification of Body Shape for Males 26 - 35

Male subjects between the ages of 26 and 35 from the SizeUSA National Sizing Survey were used as a basis for the research in this paper. Thirty-five percent were Non-Hispanic White, 20% Non-Hispanic Black, 11% Non-Mexican Hispanic, 13% Mexican American, 11% Asian, and 8% Other. A total of 788 male subjects were randomly divided into two groups (Training set and a Test set) each containing 394 subjects. The training set was used to calculate five drop values that were then used in a cluster analysis to determine shape clusters. It is important to note that due to the lack of research regarding male body shape classifications, prior to the cluster analysis, a principle component analysis was ran on the whole data set for this sample to identify the important variables used in determining body shape. The chest (bust), waist, hip, and high hip measurements were identified as the principle components defining body shape. Because of the lack of research regarding male body shape classifications, additional guidance for determining the measurements necessary to identify body shapes was taken from previous female studies. Previous female body size and shape studies conducted by Simmons (2002), Xia (2013), and Lee et al. (2007) in addition to the results of the principle component analysis all supported the tacit knowledge obtained through years of solving garment fit issues and resulted in the use of chest (bust), waist, hip, and high hip measurements for this study.

The cluster analysis produced three distinct clusters. The training set was divided by cluster. A visual evaluation of point cloud images from each cluster was conducted and determined that while each cluster was significantly different, there were subjects in each cluster that seemed to be identified incorrectly. A comparison of the measurement data of the incorrectly identified subjects revealed that measurements that had been labelled as waist measurements were actually taken in a position that was either above or below the actual waist. This was also true of hip and high hip measurements and there were instances where some subjects' hip measurements were recorded but there was no way to determine the actual position on the subject's body where the measurement was taken. This could explain why some subjects were clustered incorrectly.

The three shape clusters identified from the training set were validated by repeating the previous analyses on the validation set. A comparison of the analyses of the validation set with the analyses of the training set confirmed that the clusters were very similar. The three clusters identified through cluster analysis were used for the basis for identification of the body shape categories of US males age 26 to 35. However, further analysis was conducted on the basis that each of the three clusters contained subjects that did not seem to belong.

Drop values and ratios calculated from significant measurements (chest, waist, hip, and high hip) were used in Microsoft Excel to develop formulas that were applied to the entire sample set of SizeUSA measurement data for males ages 26 to 35 to further differentiate the shapes identified through cluster analysis. The use of this method for identifying shape clusters has been named, MSIT (Male Shape Identification Technique) for Apparel.

Subject images within each shape category were evaluated to determine if the formulas that had been developed in MSIT for Apparel provided a more reasonable explanation of shape differences than could be explained through the cluster analysis process. This iterative process (evaluation of 3D images and formula refinement) aided in the creation of the formulas used in MSIT for Apparel and helped identify shape categories that would actually impact clothing fit. While the cluster analysis process was helpful by providing initial groupings, the statistical analysis could not be directly applied to the creation of differentiated products that might better meet the needs of the 26 to 35 year old male. MSIT for Apparel identified four different shape clusters: Oval, Rectangle, Trapezoid, and Inverted Trapezoid. These shapes have very different body measurement combinations that might be used to develop differentiated blocks that could be graded to meet the needs of the ranges of sizes (from small to large) of subjects who fall within a specific shape category.

Discussion of Shape Labels

Two sets of body shape categories were determined. One set was based on the shape clusters identified by the cluster analysis and the other was based on the shape clusters identified by MSIT (Male Shape Identification Technique) for Apparel. Previous literature reviewed provided direction in identifying a descriptive label for the male body shapes represented in each cluster or shape category. The male shape categories were assigned names based on geometric shapes. For the shape clusters identified by the cluster analysis the shape categories were as follows:

- Cluster 1 became the Oval category
    - Exhibited an overall round appearance, were larger in the abdominal region, and muscles were not well defined.
    - These subjects had chest and hip measurements that were smaller than the waist measurements
- Cluster 2 became the Rectangle category
    - Exhibited a straighter torso.
    - There was very little variation in the chest, waist, and hip measurements for these subjects.
    - Overall, the subjects in this cluster appeared to be leaner than the subjects in the other clusters.
- Cluster 3 became the Trapezoid category
    - Exhibited a defined broad chest, broad shoulders with waist measurements that were smaller than chest measurements.
    - Waist measurements were also smaller than or similar in size to hip measurements.
    - These subjects appeared to have more muscle definition than the subjects in the other clusters.

A fourth shape category was developed, based on the shape clusters identified using MSIT for Apparel:

- Shape 4 became the Inverted Trapezoid category

- Exhibited normal to sloping shoulders, and hip measurements were larger than chest measurements.
- These subjects appeared to have more weight in the lower part of the body.
- This cluster was assigned the Inverted Trapezoid category because they most similarly resembled the Inverted Trapezoid shape.

It is important to note that not all of the subjects were easily identified by these four shapes. There were at least three subjects whose body measurements did not fit within the broad shape categories. Because we did not have access to every 3D image for every subject in our study, it is impossible to determine exactly why this might occur, however there are several reasonable explanations. First, we do know from evaluation of the 3D images we did have access to that there were cases where the measurements extracted for the individual subject were not from the correct locations on the body. This is a significant area of potential error, especially with body scanning, where the software does not have the tacit knowledge of an expert, nor does it have the ability to see or feel important body landmarks. This issue might be alleviated to some degree, if each scan were evaluated by an expert who had the opportunity to adjust measurement locations, at least on a visual basis. This becomes an insurmountable task when there are huge numbers of subjects within a study. This being said, measurement error is a potential problem regardless of how it is done, through manual processes or by 3D scanning, and regardless of the standardization process developed (as mentioned with the Caesar project). Studies have shown that there is a greater chance of error in measurements taken by humans than those extracted through the scanning process (Yoon & Radwin, 1994; Beazley & Bond, 2003; Hwang, 2004; Ashdown & Dunne, 2006).

A second explanation for why some of the subjects did not fit into any shape category is that their shapes are very different from those described, but they are not a large enough group to warrant their own shape category. These subjects, and perhaps many more, would be great candidates for mass customization efforts.

In addition to the group of subjects who fell outside the four shape categories, there were a number of subjects who fell within more than one shape category. This is also an important finding because it demonstrates that four shapes are not enough to clearly meet the needs of everyone in this age range (or likely others). When we consider the application of these shapes to the development of differentiated sizing standards that would better meet the needs of the male population, we would also have to factor in height ratios that have not been included in the development of the shapes. It is logical that there could be a short, average, and tall Rectangular man (as well as many in outlier heights), as well as varied height in Ovals, Trapezoids, and Inverted Trapezoids. This has increased the number of sizing systems from 4 to 12, just to meet the basic needs of the males ages 26 to 35. It is highly unlikely that the industry would choose to unilaterally adopt 12 new size ranges with the significant increase in skus that this would represent. What might be a more likely scenario is the development of garments that are styled to more precisely meet the needs of the population within specific applications. For example, pants designed to fit the Oval shaped person would need to be very different from those designed to fit a Rectangle, Trapezoid or Inverted Trapezoid shaped person. These shape accommodations should be defined more deliberately so that consumers could more accurately determine a garment that might fit their needs. While Levis already has a variety of styles with different "fits", the style descriptions more closely relate to design issues (such as design ease, waist slope, leg shape, etc.) than descriptions that might identify measurement ratios (such as hip to waist or high hip) that a consumer would need to more easily find the correct "fit" for their specific body shape. The same situation is true for shirt styles, such as European cut, athletic cut, etc. While the styling of many products might accommodate a fairly large percentage of the male population within a top or bottom category, there is a lack in the industry of communicating the shapes that the products might fit (accommodate the measurement ratios in this case), nor does it communicate how the product was designed to fit (the correct design ease for a specific body shape) to aid consumers in easily locating the products that ideally work best for them.

Comparison to ASTM D6240 Sizing Standard

The final objective in this study was to determine if the ASTM D6240 sizing system developed for males meets the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey. Minimum and maximum values were identified for ASTM drop values that corresponded with the drop values generated from the SizeUSA measurement data for males age 26 to 35. The minimum and maximum values in each ASTM drop were used to create a range for each drop. These ranges were used in a formula to determine whether or not any of the ASTM sizing standards for males satisfied the measurement needs of the male subjects ages 26 to 35 in the SizeUSA data in each of the shape categories. This analysis showed that there were no subjects that had all five drops satisfied by the current ASTM D6240 sizing standard for males.

The analysis showed that the current ASTM D6240 sizing standard for males is not sufficient in fully meeting the measurement needs across all drop values for any of the subjects for the shape categories found in this study. However, there were some drop values that were met by the ASTM sizing standard. The ASTM standard seemed to meet the hip-to-waist drop measurement needs for almost half of the subjects in the Oval category, met slightly more than half of the hip-to-high hip drop measurements for the Rectangle category, met slightly less than half of the hip-to-high hip drop measurement needs for the subjects in the Trapezoid category, and met half of the hip-to-waist drop measurement needs for the subjects in the Inverted Trapezoid category.

This indicates that shirts and jackets based on this standard would provide poor fit for the majority of the males in this age range but might be proficient for use in pants or garments for the lower half of the body for approximately half of the male subjects ages 26 to 35. This comparison demonstrated the need for an ASTM that considers the needs of males ages 26 to 35.

Response to research questions:

1. *Can SizeUSA data collected for men be used to identify the predominant shapes of male bodies in the US for men ages 26 to 35?*

Yes. SizeUSA data was used in two different methods to identify two sets of body shape clusters for males ages 26 to 35. One method using cluster analysis and one method using drop values and ratios of drop values in the development of MSIT for Apparel to identify shape groups. The cluster analysis identified three different body shapes and MSIT for apparel identified four body shapes. Grouping the shapes using MSIT for apparel proved to be better at identifying the various body shapes that existed than the statistical cluster analysis method.

2. *Based on literature review and the visual properties of the bodies within each shape, can a descriptive name be identified that would aid in an understanding of the shape differentiators?*

Yes. Two sets of shape categories were determined based on the two methods used in identifying the different shape clusters. Each cluster from each set was assigned a descriptive name based on the characteristics exhibited by the subjects within each cluster. Cluster analysis set:

- Cluster 1 = Oval category
- Cluster 2 = Rectangle category
- Cluster 3 = Trapezoid category

Set identified by MSIT for Apparel:

- Cluster 1 = Oval category
- Cluster 2 = Rectangle category
- Cluster 3 = Trapezoid category
- Cluster 4 = Inverted Trapezoid category

3. *Does the ASTM D6240 sizing system developed for males meet the measurement needs of the male subjects age 26 to 35 from the SizeUSA sizing survey?*

No. There were some drop values that were met by the ASTM sizing standard but the analysis showed that the current ASTM D6240 sizing standard for males is not sufficient in fully meeting the measurement needs across all drop values for any of the subjects in any of the shape categories found in this study. However, the standard may be suitable for use in pants or garments worn on the lower half of the body for approximately half of the male subjects in all shape categories.

Conclusions

In conclusion, this study used two different methods to identify the predominant shapes of male bodies in the US for males age 26 to 35 utilizing SizeUSA. One set was based on the shape clusters identified by the cluster analysis and the other was based on the shape groupings identified using MSIT for Apparel. Each of the identified shape clusters was assigned a descriptive category label. The categories identified by cluster analysis were labeled: Oval, Rectangle, and Trapezoid. The categories identified by using MSIT for Apparel were labeled: Oval, Rectangle, Trapezoid, and Inverted Trapezoid. Drop values from the ASTM D6240 sizing standard were proven to be insufficient to fully meet the measurement needs of the male subjects within the specific age range from the SizeUSA sizing survey.

This research is of value to the apparel industry and will assist in establishing a baseline for further studies in the area of body shape categories for males. The findings in this research study can aid apparel industry professionals in achieving and communicating better fitting apparel for US males in the 26 to 35 age range and has the potential to help with other age ranges.

Future Research

The research regarding male body shape classifications is lacking. This research study will assist in establishing a baseline for further studies in this area. Future research should include:

1. SizeUSA data should be used to analyze the new ASTM standards for younger adult males, when they are released.
2. The methodology of this research should be incorporated in a full scale study to determine if the shapes identified would appropriately describe the body shape categories for all males in the US population. Things to consider with a full scale study:
    a. a much larger sample not restricted by age, and
    b. the need for access to all 3D image data.
3. The data obtained in the SizeUSA study is more powerful than just the extracted measurements that were created. Individual evaluations of measurement extractions for individual bodies might demonstrate the development of a more accurate data set. This research effort might also lead to clues on how to "train or teach" the computer program to make more intelligent decisions when extracting measurements.
4. Further studies should be conducted to identify the predominant body shapes that exist for US males in different ethnicities.
5. Further studies should be conducted to identify the predominant body shapes that exist for US males in different age ranges.
6. Further studies should be conducted to compare the predominant body shapes of US males to the predominant shapes of males in other countries.
7. The shapes identified from these studies could be used as the basis for the development of more appropriate sizing systems that would help the male consumer find products that meet their needs.

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APPENDICES

Appendix A: Principal Component Analysis on Correlations

	Chest	Waist	High_Hip	Hips	Cross_Back_Width	Cross_Chest_Width
Chest	1.0000	0.9032	0.8959	0.8814	0.7428	0.7727
Waist	0.9032	1.0000	0.9711	0.9320	0.6511	0.6853
High_Hip	0.8959	0.9711	1.0000	0.9675	0.6502	0.6659
Hips	0.8814	0.9320	0.9675	1.0000	0.6390	0.6527
Cross_Back_Width	0.7428	0.6511	0.6502	0.6390	1.0000	0.2848
Cross_Chest_Width	0.7727	0.6853	0.6659	0.6527	0.2848	1.0000

Appendix B: Principle Component Analysis Eigenvalues

Eigenvalues

Number	Eigenvalue	Percent	Cum Percent
1	4.8277	80.461	80.461
2	0.7157	11.929	92.390
3	0.3295	5.492	97.882
4	0.0664	1.107	98.989
5	0.0429	0.715	99.704
6	0.0177	0.296	100.000

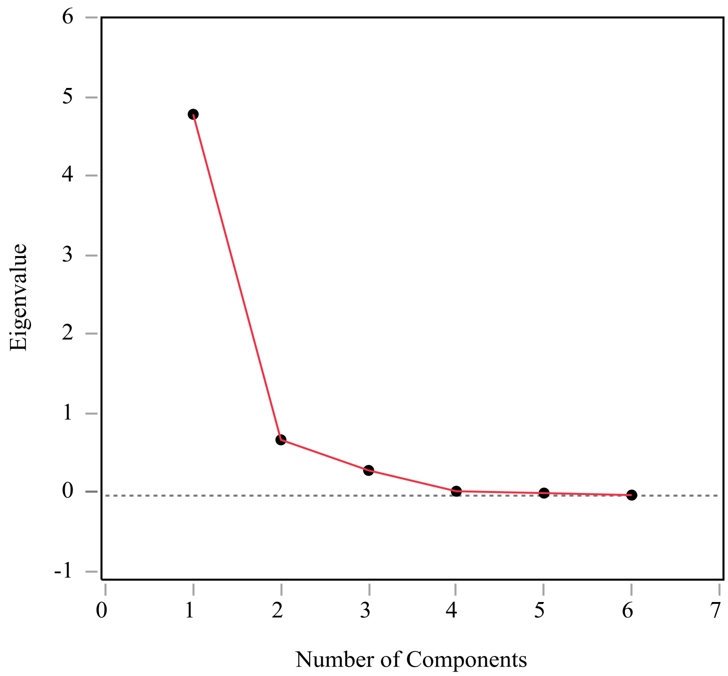
Appendix C: Principal Component Analysis Eigenvectors

Eigenvectors

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6
Chest	0.44101	-0.00636	0.30425	-0.01660	-0.84304	-0.04368
Waist	0.43985	-0.01703	-0.29577	-0.70053	0.11323	0.46389
High_Hip	0.44094	0.00168	-0.38576	-0.06610	0.13401	-0.79651
Hips	0.43430	0.00399	-0.40332	0.70570	0.04774	0.38523
Cross_Back_Width	0.33334	0.72864	0.48766	0.04396	0.34380	0.00409
Cross_Chest_Width	0.34334	-0.68464	0.52024	0.06832	0.37152	-0.00650

Appendix D: Principal Component Analysis Scree Plot

Scree Plot



Appendix E: Formula to determine ASTM6240 ability to meet measurement needs of male subjects age 26 to 35

Microsoft Excel If, Then statement:
=If(AND(variable 1 >= min ASTM value,variable 1<= max ASTM value),”1”,“0”)