ABSTRACT

XIA, SIBEI. Sizing Systems Created Using SizeUSA Data for Three Body Shapes. (Under the direction of Dr. Cynthia Istook).

Literature reviews showed that consumers were not satisfied with the fit of garments sold in stores, primarily due to outdated sizing systems used by companies and the limited number of sizes being produced. Classifying body shapes has been combined with pattern making to improve the fit of apparel and ASTM has updated its standards to cover curvy and straight body shapes. However, the shape definitions used in the studies were fuzzy. Simmons developed a software, Female Figure Identification Technique (FFIT©) for Apparel, that can classify people into nine body shapes with clear criteria. Newcomb (2006) used the FFIT© and developed a sizing standard for the rectangle body shape based on SizeUSA data. It turned out that the rectangle body shape standard was better at serving the rectangle body shape subjects than the ASTM D5585-95 standard (D13 Committee, 1995a). This study was continuous with Newcomb's study and expanded the number of body shapes to three.

The purpose of this study was to create a sizing system included sizes designed for different body shapes based on SizeUSA anthropometric data. A total of 6308 subjects in SizedUSA data were classified into a training set and a validation set. Subjects in both sets went through the same process. The results from the validation set were then compared with the results from the training set to test the repeatability and stability of the sizing system creation method. The sizing system creation process included natural log transformation, principle component analysis (PCA), multivariate linear regression analysis, size range determination and measurements calculation.

A total of 62 key measurements were transformed into their natural log values. Within the 62 transformed variables, 60 variables, along with two variables not transformed went through the PCA and determined two principle components (PCs). Two transformed variables were excluded from PCA for too many missing values. These Principle Components were used as independent variables in the multivariate linear regression to predict all 64 measurements. Multivariate linear regressions were done on the rectangle body shape, the spoon body shape, the bottom hourglass body shape and the whole data set with no shape specification. Sizes were determined by classifying PCs within ranges set by mean value and standard deviation value (SD). PC2 was divided into 3 groups evenly with a range set to [mean-2SD, mean+2SD]. PC1 was divided into 14 groups evenly with a range set to [mean-2.3SD, mean+2SD]. The center PC values for each sizes were applied to formulas created in multivariate linear regression analysis to calculate measurement values. Calculated values were then rounded to the nearest 1/8".The created sizing system was then compared with ASTM D5585-11^{e1} (D13 Committee, 2011a).

Analysis of the results showed that the method used to create the sizing system was reliable and repeatable. The created sizing system provided a better fit for the subjects from the validation set than the ASTM D5585-11^{e1} standard did. Thus, it is necessary to include body shape information in sizing systems. This was an important research effort for apparel manufactures, as it demonstrated the importance of body shape classification, as well as conducted a body sizing system that is flexible and can be altered to fit target consumers.

Sizing Systems Created Using SizeUSA Data for Three Body Shapes

by
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DEDICATION

To my loving parents.

BIOGRAPHY

The author, Sibei Xia, was born in China in 1990. She received her Bachelor of Engineering degree in 2011 from the Fashion, Art and Design Institute, Donghua University, majoring in Fashion Design and Engineering. She enrolled at North Carolina State University in the Fall of 2011 as a graduate student in Textile and Apparel, Technology and Management Department. She had been a teaching assistant for two years. With the help of wonderful faculties and friends in NCSU, she got used to the new culture fast and was able to follow her passion for apparel technology. She is currently completing her graduate requirements for the master degree in Textile Technology and Management and hopes to continue her work in the apparel industry.

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CHAPTER ONE: INTRODUCTION

Sizing systems were originally developed for ready-to-wear (RTW) and mass production. Body sizing systems and garment sizing systems are two subgroups of sizing systems. A garment sizing system begins with a body sizing system and is tested on prototypes for fitting. The study of standard body sizing systems began in the first half of twentieth century and bloomed in the late twentieth century.

A good sizing system benefits both the consumers and the manufacturers (Chen-Yu, Williams, & Kincade, 1999). However, studies have shown that consumers were not satisfied with the fit of apparel (Alexander, Connell, & Presley, 2005; Anderson-Connell, Ulrich, & Brannon, 2002; Goldsberry, Shim, & Reich, 1996; $[TC]^2$, 2004). One reason is the grade rules companies have used are outdated (Ashdown, 1998; Ashdown & Loker, 2010; Shin & Istook, 2007; Workman & Lentz, 2000). Another reason is the number of sizes provided by RTW is limited. An updated and more flexible sizing system is needed.

For the past few years, the clothing industry is turning towards mass customization. This trend is the beginning of the third wave defined by Toffler in his famous book *The Third Wave* (Toffler, Longul, & Forbes, 1981). A goal of mass customization is to give a better fit at a low cost and fast speed (Loker, 2007). Mass customized sizing has been considered a strategy for this. There are three ways of making customized fit patterns: 1) three-dimensional to two-dimensional flattening (Hinds, McCartney, & Woods, 1991; Kwong, 2004; Okabe, Imaoka, Tomiha, & Niwaya, 1992; Yunchu & Weiyuan, 2007); 2) automatic two-dimensional drafting (Kang & Kim, 2000); and 3) altering from tested sizes (Istook, 2002; Song & Ashdown, 2012). A good method of creating sizes based on anthropometric data is critical for the alteration method.

Collecting anthropometric data in the beginning was costly and time consuming. The development of the 3D body scanner in 1990 shortened the measuring time from hours to minutes. Large scale anthropometric surveys have been done in the UK, the USA, Greece and Japan with 3D body scanners. The human body changes as time goes by. People tend to be taller and weigh more compared to 30 years ago, For this reason, ASTM has suggested that body sizing systems need to be updated every 10 years. Keeping track of the growth of population is important for updating body sizing systems. SizeUSA, conducted in 2002 is the most recent large scale anthropometric survey in the United States. Several studies have been done on the SizeUSA data (Kim, Pyun, & Choi, 2010; Lee, Istook, Nam, & Park, 2007). Newcomb (2006) created a sizing standard for the rectangle body shape person with SizeUSA data, using the waist measurement as the only predictor. It would be interesting to see how the standard looks like with multi-predictors and for other body shapes.

Kinect invented in the first decade of 21st century, is trying to break the limitation of scanning place. It is blowing a wind of evolution for the 3D world. The access to 3D body data in the future could be more accessible than today. This will bring opportunities as well as challenges. How can we analyze the data and make full use of it is a question that apparel companies have to face in the near future. Thus, it is important to study the sizing creation method.

Rationale

The study of consumers has revealed that consumers are not satisfied with the fit of apparel. Reasons identified by researchers include the outdated grading rules and the limited number of sizes for production. SizeUSA has the most recent anthropometric data. A sizing system created based on this data would be more accurate and practical. The apparel industry is heading towards mass customization. Altering from standard sizes is a way to approach mass customized fit and this relies strongly on a good sizing system. This addressed the need for creating a sizing method. Many studies have been done on the use of anthropometric data to generate sizes with different methods. It would be interesting to study each of the methods and come up with a method that combines the advantages of other methods.

The result of this study will lead to a better understanding of the value of anthropometric data and how a flexible body sizing system can be created from anthropometric data. With the comparison of different demographic groups, consumers can be served better.

Research Questions

The goal of this study was to demonstrate a way of using anthropometric data and prove the value of it. To guide the research, the following questions were developed:

1. Can the SizeUSA data be used to create a flexible women's body sizing system that will represent a large population?
    a) What are the key measurements for a sizing system?
    b) What are the control variables?

c) What are the key differences between different body shapes that help define a sizing system?

d) How are the intervals between each size created?

e) How does the created sizing system work, compared to ASTM D5585-11^{e1}?

2. What is a sizing strategy that could be used by the industry based on the analysis of SizeUSA and body shapes?

Limitations

This study was limited in the following ways:

The created sizing system was only based on analysis of SizeUSA data. Only 3 out of 9 shapes defined by Simmons (2003) in the Female Figure Identification Technique (FFIT©) for Apparel were studied. Principle Components extracted from the 64 measurements were influenced by too many variables. A reduction in variables may have led to different results.

Definition of Key Terms

Anthropometry: Refers to the measurement of the human individual. It has been used for the purposes of understanding human physical variation, and in various attempts to correlate physical with racial and psychological traits.

Sizing system: "A table of numbers which presents the value of each of the body dimensions used to classify the bodies encountered in the population for each size group in the system" (Petrova, 2007, p. 57).

Rectangle Body Shape: The rectangle body shape represents people whose bust and hip measurement values are fairly equal, and bust-to-waist and hip-to-waist ratios are low (Simmons, Istook, & Devarajan, 2004).

Hourglass Body Shape: The hourglass body shape represents people who have a very small difference in the comparison of the circumferences of their bust and hip, and the ratios of their bust-to-waist and hip-to-waist were about equal and significant (Simmons et al., 2004).

Bottom Hourglass Body Shape: The bottom hourglass body shape represents people who have a larger hip circumference than bust circumference and the ratios of their bust-to-waist and hip-to-waist are significant enough to produce a definite waistline (Simmons et al., 2004).

Spoon Body shape: The Spoon body shape represents people who have large difference between hip and waist, and great high hip-to-waist ratio. The bust-to-waist ratio of this body shape is smaller than that of the Hourglass (Simmons et al., 2004)

American Society of Testing and Materials (ASTM): Formerly known as the American Society for Testing and Materials (ASTM), is a globally recognized leader in the development and delivery of international voluntary consensus standards (ASTM, 2013).

IBM SPSS Statistics: An integrated family of products that addresses the entire analytical process, from planning to data collection to analysis, reporting and deployment (SPSS, 2013).

Linear Regression: An approach to model the relationship between a scalar dependent variable y and one or more explanatory variables denoted as X.

Bespoke: A British English word that means that a clothing item was made to a buyer's specification (personalized or tailored). It was applied to only men's tailored clothing in old times. It now generally includes footwear and other apparel and implies measurement and fitting.

CHAPTER TWO: REVIEW OF LITERATURE

To help understand the importance of a sizing system and the way sizing systems were built, literature was reviewed on sizing and mass customization, methods used to create a body sizing system, female figure shapes, the history of sizing systems and anthropometric surveys and sizing standards in the U.S.

Sizing Seeking Opportunities in Mass Customization

A sizing system is a product of ready-to-wear (RTW). The limited number of sizes that RTW can produce has forced consumers to make a sacrifice in garment fit. Although customization is oriented to an individualized fit, the cost of making customized patterns is relatively high. Mass customization is a combination of RTW and customization and can offer a better fit than RTW with a lower cost than bespoke. Mass customized sizing is the sizing strategy for mass customization. The following is a review of RTW sizing and fitting issues, the trend of mass customization, mass customized sizing studies and some advanced technologies.

Fitting Issues of RTW Sizing System

A sizing system is defined by Petrova (2007, p. 57) as "a table of numbers which presents the value of each of the body dimensions used to classify the bodies encountered in the population for each size group in the system". Sizing systems were originally developed to help ready-to-wear (RTW) manufacturers predict the fit of their potential consumers. They have been studied for decades. Even though much work has been done by companies and researchers to improve sizing systems, studies and reports continue to show that a large percentage of consumers are not satisfied with the fit of RTW.

Evidence of women's dissatisfaction with the fit of ready-to-wear can be found in both academic literature and popular literature (Anderson-Connell et al., 2002). Alexander (2005) noted that 54% of the respondents were somewhat satisfied to mostly dissatisfied with the fit of RTW. This result is consistent with Goldsberry's study and Kurt Salmon Associates' survey. Goldsberry et al. (1996) stated that 70% of females over 55 years of age indicated dissatisfaction with the fit of RTW. Kurt Salmon Associates' survey found that more than 50% of women could not achieve good fit with RTW clothing ($[TC]^2$, 2004).

Fit is related to ease and to body measurements. Ease can be divided into fit ease and style ease. It is linked to a consumer's fit preference and varies from person to person. Ease is relatively subjective (Alexander et al., 2005). Body measurements, on the other hand, are more objective. However, the human body shape has not remained constant over the years (Ashdown & Loker, 2010). The National Health and Nutrition Examination Survey (NHANES) showed that the average body mass index for adults has increased from 22.2 to 26.8 since 1962 (Ogden, Fryar, Carroll, & Flegal, 2004). The formula for calculating BMI is weight (lb) / $[\text{height (in)}]^2$ x 703 and BMI is correlated to body fat ("Healthy Weight," n.d.). Re-evaluating consumers' body measurements is important for ensuring a good fit over time (Ashdown & Loker, 2010).

A common way used in the USA for forming a sizing system for ready-to-wear is to create a size based on the ideal consumer. This size is then transformed it into multiple sizes with incremental grading which has been derived from outdated standards (Ashdown, 1998; Ashdown & Loker, 2010; Shin & Istook, 2007; Workman & Lentz, 2000). Because many companies are using their own sizing systems, consumers are often confused with what size to choose and are forced to try on numerous sizes and brands before they find one that fits them. This is time consuming and causes a significant challenge for e-ecommerce, since bad fit leads to a high return rate (Ashdown & Loker, 2010).

Chen-Yu (1999) found that good fit product increases consumers' loyalty to the company and helps retain customers. It is imperative for companies to solve fit issues if they want to stay competitive. Studying updated body measurement data is a good start. With the development of 3D scanning techniques, it is easier for companies to have access to a large number of 3D anthropometric data. How can a company deal with this data and make use of it all? The study of how to use anthropometric data, thus, is necessary and valuable.

Trend of Mass Customization

Pine (1993) defined mass customization as a strategy that uses information and manufacturing technology to efficiently produce goods with maximum differentiation and low-cost production. Because clothing products are designed to fit consumers' preference and needs, the clothing industry has naturally become an industry in which mass customization is applied (Anderson et al., 1997; Choy & Loker, 2004; Kamali & Loker, 2002; Lee & Chen, 1999; Loker, 2007).

Toffler mentioned in his book that the clothing industry was turning its tend towards mass customization which was the beginning of the third wave. The third wave was oriented at producing "partially or completely customization products", while the first wave was civilization and the second wave was oriented to "the long 'run' of millions of identical, standard products" (Toffler et al., 1981, p181).

A traditional customized company, Tom James, had a $266M sales growth in 2012 (Tom James Company, 2013). A newly founded customized apparel company, Trumaker, received $1.9M in funding from Venrock and others and plans to bring made-to-measure to the masses (Taylor, 2013).

Consumers are more knowledgeable and seek more personal products than before. A shorter product life cycle, increased product varieties, and greater customization are the trend of the apparel industry (Peppers & Rogers, c2011; Simonson, 2005). Mass customization is a strategy that can build a stronger relationship between consumers and companies, reduce waste, improve productivity and increase consumer satisfaction (Ko & Kincade, 1998; Warkentin, Bapna, & Sugumaran, 2000).

Mass Customized Sizing

The clothing industry was one of the earliest adopters of mass customization. But the development of mass customization in the clothing industry seems very slow, compared to the development of mass customization in the electronics industry. An important aspect that the clothing industry has tried to customize is fit. Researchers who work to solve this question can be divided into three groups. They are 1) automatic two-dimensional drafting, 2) three-dimensional to two-dimensional flattening and 3) altering from tested sizes. Customized-sizing emphasizes producing individualized fit with advanced technology at a low cost and fast speed (Loker, 2007). Compared to the first two methods, altering from standard sizing tends to be more reliable and repeatable.

Automatic two-dimensional drafting is approached by linking one-dimensional measurements with two-dimensional patterns by the use of functions, so that the 2D pattern can be altered based on an individual measurements chart. Kang and Kim (2000) developed a pattern drafting and grading system by formulating and coding this drafting principle. Accurate measurements are needed for generating well fitting patterns.

Three-dimensional to two-dimensional flattening is a process that transforms curved surfaces into a plane (Kwong, 2004). Okabe et al. (1992) developed a flattening method by first projecting the 3D surface into 2D, adding darts on the 2D pattern and then meshing on the 2D to simulate the 3D shape. Hinds et al. (1991) created and flattened an offset 3D surface which simulated the ease of the garment. McCartney, Hinds, Seow, & Gong (2000) flattened the 3D surface that contained darts and gussets and this was more realistic. Yunchun & Weiyuan (2007) flattened a 3D prototype by slicing 3D surfaces into stripes, flattening the stripes by keeping the same edge length and then re-pasting them back together into 2D (Figure 1). The 3D to 2D flattening method has high requirements for 3D models.

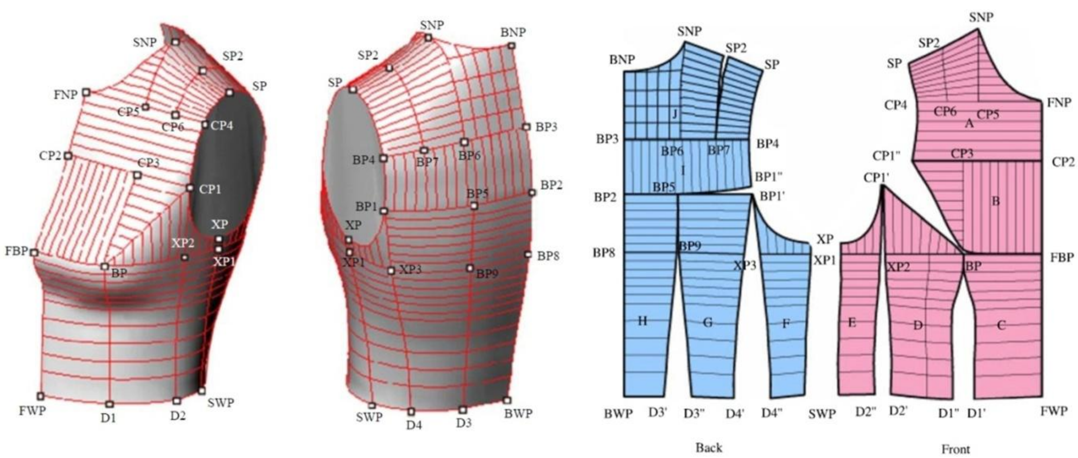


Figure 1. The final wireframe and the final cutting pattern of Yuchun's 3D to 2D flattening method. Source: Yunchu & Weiyuan, 2007, pp. 343, & 345.

Last but not least is the method where alterations are made from tested sizes. Altering patterns was a traditional way to achieve accurate fit for customized apparel, and was time consuming and required experience (Istook, 2002). With the help of computer aided design, pattern alteration requires less effort. Different from drafting methods, alterations are only made on measurements which are of key importance for the fit of a specific garment (Istook, 2002). Song & Ashdown (2012) developed an automated custom-made pants system. These alterations were made to fit individuals on tested pants patterns for three body shapes (Figure 2). It turned out that the altering method which incorporated shape information into block patterns resulted in a better fitting garment. Because the altering method is based on sizes or patterns that have been pre-tested and proved, the study of body dimensions and shape are important.

Technology Possibilities

Three dimensional technology and computer aided design (CAD) are two techniques that are changing the way apparel the industry thinks and works, especially in the production development stage.

Since the invention of the 3D body scanner, researchers have had technology that helps them understand the shape of the human body and that offers them an easy way to collect and store anthropometric data (Chun, 2007). Anthropometric data for the SizeUSA, the SizeUK, the French National Size Survey and Size Korea were all collected by a 3D scanner. Without the 3D scanner, it would be impossible to collect all the data within such a short time period.

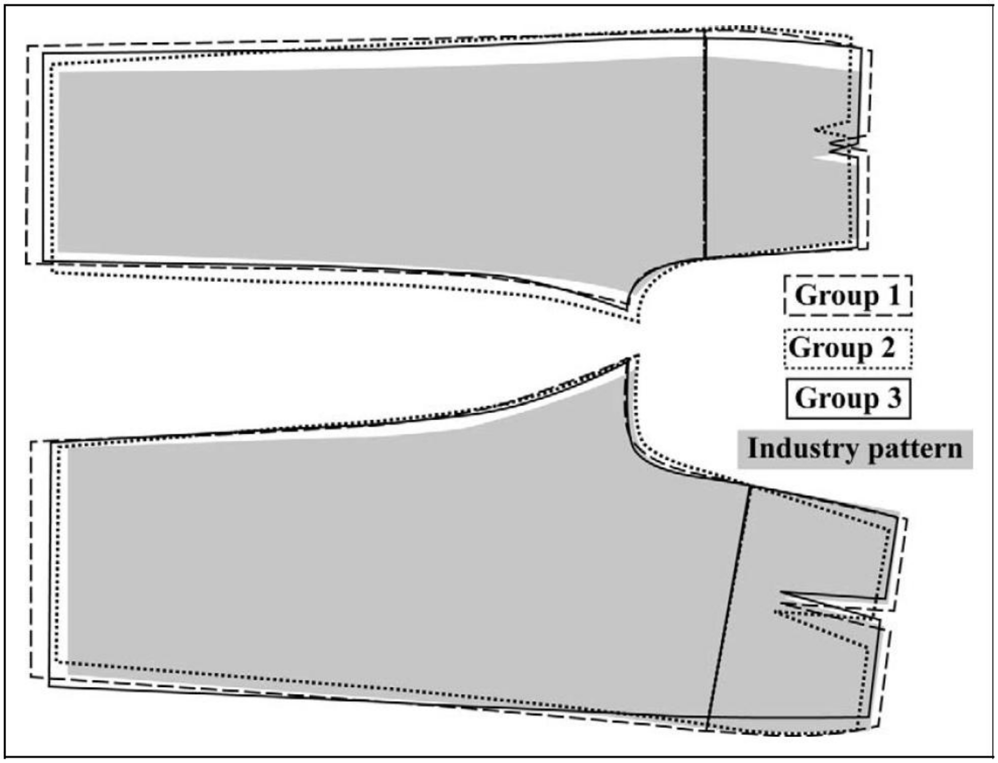


Figure 2. The final block patterns for three body shapes.
Source: Song & Ashdown, 2012, p. 323.

Now the 3D scanner is moving towards a less costly and more portable model. The invention of Kinect by Microsoft made 3D scanning available at home (Figure 3), even though the technique is not yet perfect. Anthropometric data will be more accessible in the future.

CAD is a technique that has been talked about and used for decades. Some popular apparel CAD software packages include Kaledo, Adobe Illustrator, Photoshop, Modaris, Accumark and Optitex. Design stages like style design, pattern making, grading, marking and cutting can all be done with CAD. A good CAD system makes communication easy and real-

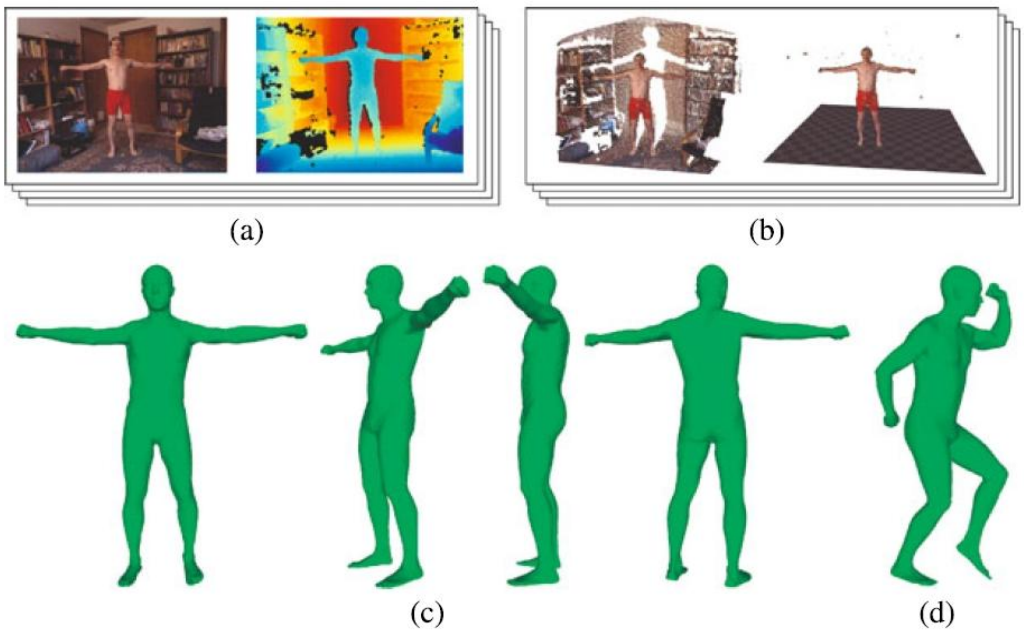


Figure 3. Overview of Kinect body scanning: (a) capture image (b) segment 3D body point cloud (c) recovered pose and shapes from 3D body point cloud (d) recovered body shapes using the SCAPE model presented in the literature.
Source: Weiss, Hirshberg, & Black, 2013, p. 101.

time. Creating 3D avatar is one of the most advanced CAD techniques. It is based on a 3D body model that has been built in a 3D capable software and then generally used in pattern making software to check the fit of patterns. For example, the pattern making software Modaris by Lectra can "sew" 2D patterns and fit it on a 3D model (Figure 4). A 2D avatar is already available on some companies' websites to help consumers make decisions about design and styles. It would be interesting to see a 3D avatar online which can both demonstrate design and fit.

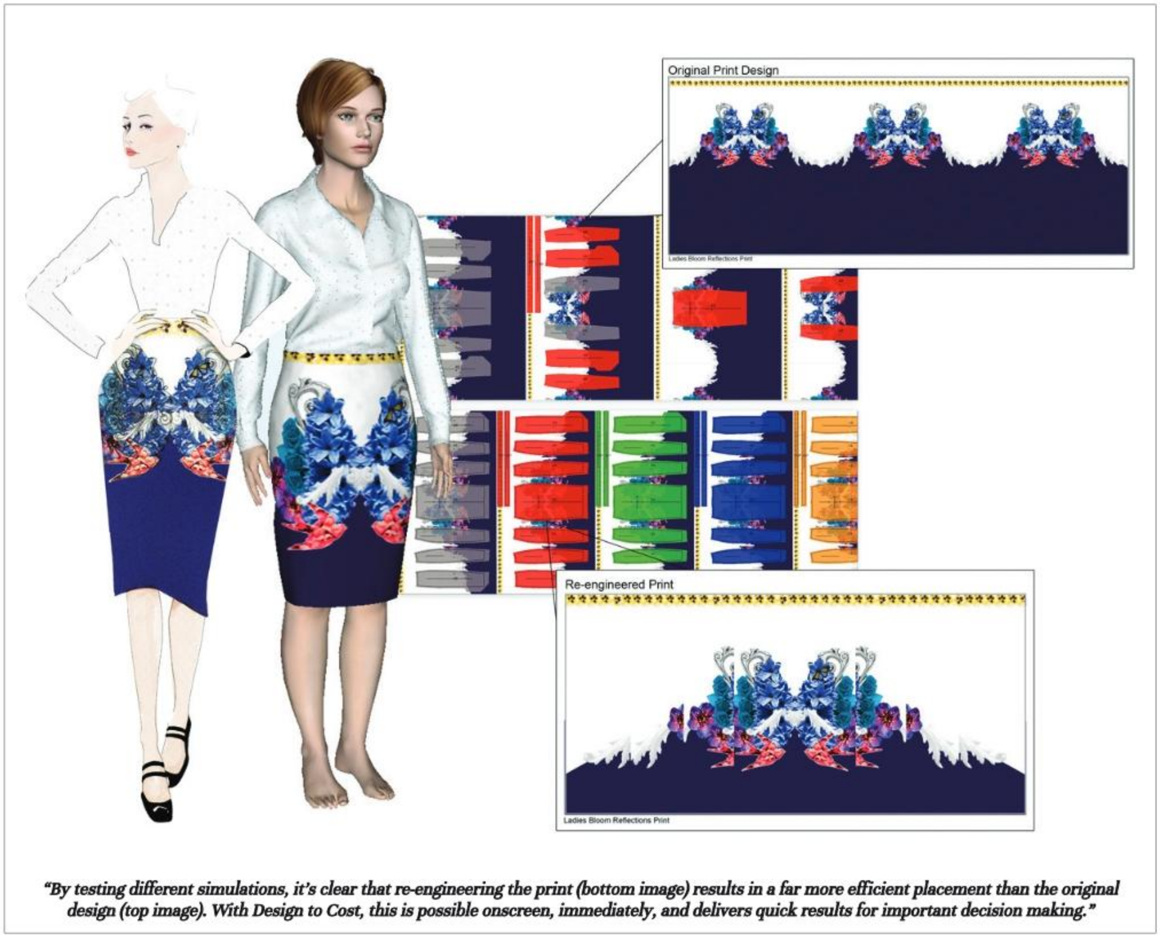


Figure 4. Computer aided Design. Source: Lectra, 2013, p. 6.

Methods Used to Create Body Sizing Systems

The purpose of creating a sizing system is to help manufactures produce ready-to-wear clothes that will fit the potential consumer as well as possible and at the same time, allow manufacturers to make a profit (Petrova, 2007; Winks, 1997). A good sizing system benefits both the company and the consumers.

Sizing systems can be classified as either a garment sizing system or a body sizing system. A garment sizing system is the estimation of the garment dimensions, while a body sizing system is the estimation of the body dimensions. The garment sizing system includes both body information and design ease. Because ease is largely influenced by the garment style and the consumer's personal preference, recently published sizing systems are body sizing systems.

To create a body sizing system, a couple of aspects need to be considered. 1) the proportion of the population to be covered; 2) the number of sizes to be designed; 3) the size interval; 4) the control variables to classify size groups; 5) the secondary dimensions to help construct garments; and 6) labeling to avoid miscommunication (Petrova, 2007). Creating a body sizing system often follows the process of collecting and preparing anthropometric data, picking control variables, deciding a size range for each control dimension (deleting outliers), developing a subgroup population based on intervals and size numbers, calculating secondary dimensions and, finally, labeling the sizing system. The following discusses some common methods used in each stage of creating a body sizing system.

Preparing Data

In order to collect body data, an anthropometric survey is designed and conducted. The number of big scale anthropometric surveys in history around the world is countable because "the cost of conducting a statistically significant manual sizing study is astronomical" ([TC]^2, 2004). Even though we now have the body scanner to help us save time on measuring, it is still costly. Body scanners can cost up to a hundred thousand dollars.

A good survey should be able to get a representative sample of the target population which requires thousands of subjects to meet the criteria of statistical validity ([TC]^2, 2004). It should also contain both body measurements and demographic information. The demographic data is a valuable resource for comparison and advanced analysis, because the human body differs between ethnic groups, age groups, countries, etc. The most commonly used body dimensions are height, front waist length, back waist length, cervical height, waist height, hip height, shoulder width, out-seam, arm length, neck girth, bust girth, waist girth, hip girth, thigh girth, knee girth, ankle girth, upper arm girth and wrist girth (O'brien & Shelton, 1941; [TC]^2, 2004).

Because anthropometric surveys have many steps and requires the effort of many people over a long period, there are always some missing values and sometimes a few errors within the data. One way of dealing with missing values is deletion. For example, one method is list wise deletion. In the list wise deletion method, only cases with available data on each variable are analyzed (Humphries, 2013). The advantage of this method is that it is simple, but because anthropometric surveys always contain a lot of variables, the proportion of deletion can be large, which reduces the statistical significance. Hsu & Wang (2005) used the list wise deletion method and the number of subjects was reduced from 610 to 590. The other way of dealing with missing values is by replacing the missing value with its estimation, for example, using the series mean method. In the series mean method, the missing value is replaced with the mean for the entire series. Esfandarani & Shahrabi (2012) used the series mean algorithm to replace the missing values when they were preparing data for a suit sizing system.

Control variables

Control variables are the body measurements which are used to classify size groups (Petrova, 2007). There are some characteristics necessary for control variables. First, control variables should be the measurements that best describe the body size for each individual. Because the body shape variation in the population is large and the number of control variables is limited, the selected dimension should be representative and predictive of other non-control variables. Secondly, they should also be easy to measure, because consumers need to be able to use their own measurements to find the right sizes. Thirdly, if more than one measurement is chosen as the control dimension, there should not be too much correlation between the control variables. This is because when control variables are controlling sizes, the whole population is first divided into groups based on the distribution of the primary control dimension. Then, within each group, subgroups are classified based on the distribution of the second control dimension. If the two control variables are correlated to each other, some subgroups will be empty, which is against the efficient goal of sizing. Last but not least, control variables may change when a sizing system is designed for different styles.

A statistical method that is usually used to find control variables is called the Principle-Component Analysis (PCA). It is a method of Factor Analysis and the purpose of it is to remove redundant variables from the data, replacing the entire data with a smaller number of uncorrelated variables (SPSS Statistics, 2011). The following is cited from SPSS about how PCA works.

> The principal components method of extraction begins by finding a linear combination of variables (a component) that accounts for as much variation in the original variables as possible. It then finds another component that accounts for as much of the remaining variation as possible and is uncorrelated with the previous component, continuing in this way until there are as many components as original variables. Usually, a few components will account for most of the variation, and

> these components can be used to replace the original variables. (SPSS Statistics, 2011, online help)

Guan (2012) used PCA to reduce 12 dimensions into three principle components (PCs) in a truck driver anthropometric study. Because sometimes principal components with small eigenvalue may be as important as those with a large variance (Jolliffe, 1982) , Esfandarani & Shahrabi (2012) did a test on the suit sizing chart with a different numbers of PCs. Loss of fit for each cluster was calculated and it was found that two components were the best choice in that situation.

The PCs extracted from the PCA can sometimes be represented by measurements, which can be classified as principle measurements. When selecting representatives for the PCs, practical situations must be considered. For example, O'Brien and Shelton (1941) found weight to be a principle measurement, but stores and homes often do not have scales available. This has limited the expansibility of their theory. With the consideration of predicting both the top part and bottom part of the body, Newcomb (2006) used waist measurement to represent her PC1. This was the only PC she extracted, while creating a sizing system for the rectangle body shape which was more practical and applicable. Another example is when Hsu & Wang (2005) used waist girth to represent the girth factor, even though hip girth was more closely related to the girth factor. Waist girth was actually the most important factor for pants design.

Proportion

When designing for the majority of the population, a sizing system is usually set to cover a certain range of people, which is called the size range. The proportion of the population that is covered by the sizing system is called the accommodation rate of the sizing system (Petrova, 2007). Even within the sizing system, not all sizes will be produced. Only those garments with sizes which represent majority of the target consumers will be manufactured. The actual production accommodation rate is between 65% and 85% (Petrova, 2007). This means no matter how accurate the sizing system is, at least 15% to 35% of the population will not be able to find the right size, and this gives manufacturers an opportunity for garment customization.

When the sample size is large, percentiles of the control variables or the PCs can set the size range. The 90th percentile of body mass index (BMI) was used in Song & Ashdown's research on body shape categorization (2011). However, percentile values are not additive. A subject with a 95-percentile height does not necessary have a 95-percentile waist girth. Guan et al used a 95% accommodation level with a 5% exclusion for the ellipsoid created by the three orthogonal PCs (2012).

Intervals and Size number

The control variables are divided into small scales and are ranges for each size. The increments are called the size intervals. The interval can be either a constant or a variable. The size number is determined by the size range and the intervals. For a garment sizing system, the value of the interval depends on the absolute value of the control variables, the fabric properties, and the tolerance level of consumers for the control variables (Ashdown & DeLong, 1995; Petrova, 2007). As mentioned before, the number of designed sizes is not necessarily the same as the number of sizes used for production. Only garments with sizes that contain a large number of people or sizes that fit within the fixed accommodation rate will be manufactured (Petrova, 2007).

There are two types of methods for determining intervals. One method is to set intervals according to convenience, common practices and fit consideration (Petrova, 2007). Mpama, Azariadis, & Sapidis (2010) classified the population into seven body types by setting the intervals of the drop value between chest girth and waist girth manually to a constant value of 4cm. Gupta & Gangadhar (2004) classified sizes by using the standard deviation as the interval for height. The other method is to use a using statistical procedure. For example, the K-means cluster analysis, can be used to set and optimize the intervals automatically (Petrova, 2007).

SPSS defines the K-means analysis as a tool designed to assign cases to a fixed number of clusters whose characteristics are not yet known but are based on a set of specified variables (SPSS Statistics, 2011). The K-means cluster is most useful for classifying a large number of cases. In K-means cluster analysis, 1) the initial cluster centers are chosen by the computer or you design your own initial cluster center; 2) each subject is examined and assigned to the closest cluster center depending on the distance; 3) the centroid position is then recalculated and the subjects are re-assigned; 4) the centroid position continues to recalculate until no changes are necessary and the final cluster center is achieved ("k-Means clustering Algorithm," 2013). The K-means cluster center is very sensitive to the initial cluster centers (Bradley & Fayyad, 1998). The number of sizes has to be pre-defined. Sometimes you have to rerun the analysis a couple of times with different initial centers and size numbers until a satisfactory result is exported.

Song & Ashdown (2012) applied K-means cluster analysis with three PCs and two z-scores as variables of 2,488 female subjects with the number of clusters fixed on two, three and four. Finally, the three clusters result was picked as the best one. To help identify each new subject's body shape, discriminant analysis (DA) was performed. DA attempts to find discriminants among variables that provide maximum separation between clusters (Taylor, 1998).

Secondary Dimensions

Patterns cannot be drawn only with control variables. Secondary dimensions are necessary to describe the detail of a body (Petrova, 2007). Secondary dimensions usually have a strong relationship with the control variables and can be calculated by them.

The statistical method often used to calculate secondary dimension functions is called linear regression. (SPSS Statistics, 2011) described linear regression is used to model the value of a dependent scale variable based on its linear relationship to one or more predictors. Predictors here refer to the control variables. A secondary measurement y is calculated by control variables $x_{i1}...x_{ip}$ using formula $y = b_0 + b_1 x_{i1} + \cdots + b_p x_{ip} + e_i$. The variable p is the number of control variables. The linear regression model assumes that the error term has a normal distribution with a mean of 0, the variance of the error term is constant across cases and independent of the variables in the model and the value of the error term for a given case is independent of the values of the variables in the model and of the values of the error term for other cases (SPSS Statistics, 2011). Newcomb (2006) used linear regression to predict bust, high hip, hip, upper arm and thigh max with waist as the predictor. Koblyakova (1980) found that quadratic regression did a better job in approximating secondary dimensions than linear regression. The formula used in quadratic regression is $y = b_0 + b_1 x_{i1} + c_1 x_{i1}^2 + \cdots + b_p x_{ip} + c_p x_{ip}^2 + e_i$.

Labeling

The sizing system is not complete until it is coded and labeled. Most ASTM standards labels sizes with a number from 00 to 20. Some companies use bust measurements to label the sizes. Knit wear is often labeled as small, median, and large. Top wear and bottom wear have different labeling systems. Outwear and underwear have different labeling systems. Consumers often get confused with all these labeling systems or methods. Faust & Carrier designed a labeling system with a graph illustrating the silhouette (Figure 5) which would "not only convey better information but also be highly predictive of the garment (pants in this case) that women would find fitting"(2010, p. 122).

Female Figure Shapes

The early body shape studies, or "Somatotyping" defined by Sheldon (1970), were mostly focused on exploring the relationship between the morphology and the psychology of various people (Devarajan, 2004; Simmons, 2003). Douty was the first to combine shape and apparel fit together. She developed a method that she called "visual somatometry" which classified body types by the body silhouette (Douty, 1968). Later on, pattern making and grading researchers started to combine sizes with shapes. Words like junior/misses/women, petite/regular/tall, pear/cone/ruler/apple and V frame/H frame/X frame/O frame were used to categorize shapes (Armstrong, c2010; Duffy, 1987; Simmons, 2003.

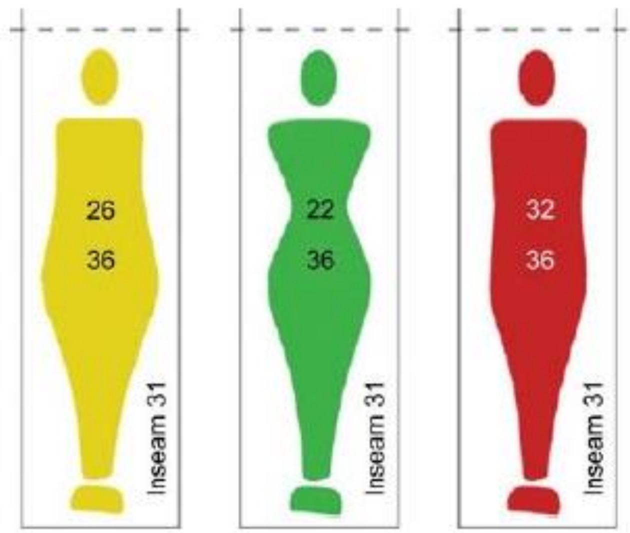


Figure 5. Faust's potential size labeling with facing silhouette and measurements.
Source: Faust & Carrier, 2010, p. 122.

Research done by Simmons et al. categorized body shapes in a 3D view by calculating and grouping the drop value of bust to waist, hips to waist and bust to hip, along with ratio of high hip to waist (2003, 2004). Nine body shapes were extracted and they were rectangle, spoon, hourglass, top hourglass, bottom hourglass, triangle, inverted triangle, oval and diamond (Figure 6). A software called Female Figure Identification Technique (FFIT©) for Apparel was coded to determine the shape of individuals. The FFIT© was then verified by Devarajan (2004) with the method of multivariate statistical methods of discriminant analysis and Multivariate Analysis of Variance (MANOVA). This study found that there was a significant difference between each body shape. Later, the FFIT© was used to define the rectangle shape with SizeUSA data in Newcomb's thesis (2006).

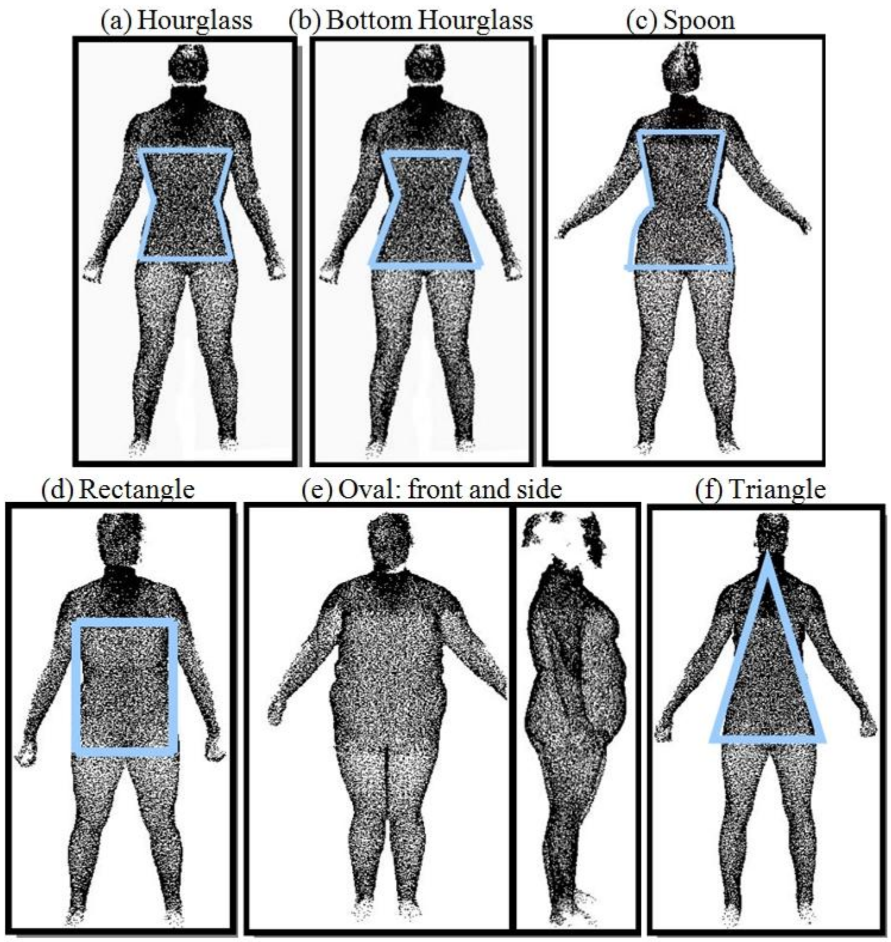


Figure 6. Body shapes divided by FFIT©.
Source: Simmons, 2003. pp. 107, 113, 116, 121, & 124.

History of Sizing Systems

Godley (1997) believed that it was not the invention of the sewing machine, but the development of standard sizes that prompted the development of ready-to-wear.

1800-1850: The Begin of Sizing

Before the nineteenth century, most garments were bespoke garments (custom-made clothing) provided by tailors (Aldrich, 2007; Yu, 2004). Sizes started to appear in the pattern books for simple garments by the end of the eighteenth century (The Society of Adepts in the Profession, 1796). The earliest sizes were proportionally scaled from the smallest ones to the largest ones. The East India Company began the production of the first large-scale ready-made goods in England in the late 17th century (Lemire, 1984). However, it was not until the second half of the nineteenth century that simple ready-made garments started to be manufactured by shop-keepers (Wray, 1957).

The Napoleonic Wars from 1803 to 1815 brought demand for ready-to-wear army clothing. This increased the need for sizing systems and grading (Aldrich, 2007). The simple grading method could not fulfill the growing needs. Therefore, lots of tailors' drafts were published during the first half of the nineteenth century (Aldrich, 2000). Some drafts contained sizing charts and grading methods. These charts and methods were very important for the later more sophisticated pattern making and grading methods (Aldrich, 2007).

Aldrich categorized all cutting methods into three groups: the divisional system, the direct system and the combination system (Aldrich, 2007). The divisional system is a system that uses one or two major measurements to calculate the other measurements proportionally. The direct system uses measurements with direct reference to the body and the garment measurements. The combination system is a system that combines the two former systems.

In 1815, Benjamin Read, who used the divisional system method, published The Proportionate and Universal Table (Figure 7). It was one of the earliest size tables (Aldrich, 2007). The table had ten sizes with bust measurements ranging from 36" to 41". The other measurements in the table that were calculated arithmetically were half-back, back neck, side seam hollow, armhole, half-front or top of the outside thigh, fork width, armhole for pelisses, front edge to shoulder point and diameter for a cloak (Aldrich, 2007; Read, 1815). All measurements were taken from clothing. Read's sizing table was based only on the proportion of the bust measurement and was illogical to some other tailors (Hadfield, 1826).

1	2	3	4	5	6	7	8	9	10
36	5	2	4	19	10 1/2	4 1/2	17	4	16
36 1/2	00	00	00	00	10 31/48	00	17 17/72	00	00
37	5 5/36	2 1/18	4 1/9	19 19/36	10 19/24	00	17 17/36	4 1/9	16 4/9
37 1/2	00	00	00	00	10 15/16	00	17 17/24	00	00
38	5 5/18	2 1/9	4 2/9	20 1/18	11 1/12	00	17 17/18	4 2/9	16 8/9
38 1/2	00	00	00	00	11 11/48	00	18 13/72	00	00
39	5 5/12	2 1/6	4 1/3	20 7/12	11 3/8	00	18 5/12	4 1/3	17 1/3
39 1/2	00	00	00	00	11 25/48	00	18 47/72	00	00
40	5 5/9	2 2/9	4 4/9	21 1/9	11 2/3	00	18 8/9	4 4/9	17 7/9
40 1/2	00	00	00	00	11 13/16	00	19 1/8	00	00
41	5 25/36	2 5/18	4 5/9	21 23/36	11 23/24	00	19 13/36	4 5/9	18 2/9

Figure 7. One of the earliest size tables.
Source: Read, 1815 (as cited in Aldrich, 2007, pp. 8-9).

In 1826, Cook and Golding published a combination system in *The Tailor's Assistant or Unerring Instructor* where direct measurements were used to build one size (Cook, 1826). Other sizes were then graded proportionally. For a pair of breeches, four length and five width measurements were needed. Figure 8 contains some pattern pieces for bottom wear from *The Tailor's Assistant or Unerring Instructor*. There are 3 sizes of breeches within this picture. The "Figs. 2", "Figs. 4" and "Figs. 5" in Figure 8 are designed for persons who have the same height measurement but a different waist measurement. The "Figs. 2" in figure 2.8 is for a 34" waist (36" bust) whereas the "Figs. 4" in Figure 8 is for a 44" waist (40" bust) and the "Figs. 5" in Figure 8 is for a 50"waist (44" bust) (Cook, 1826).

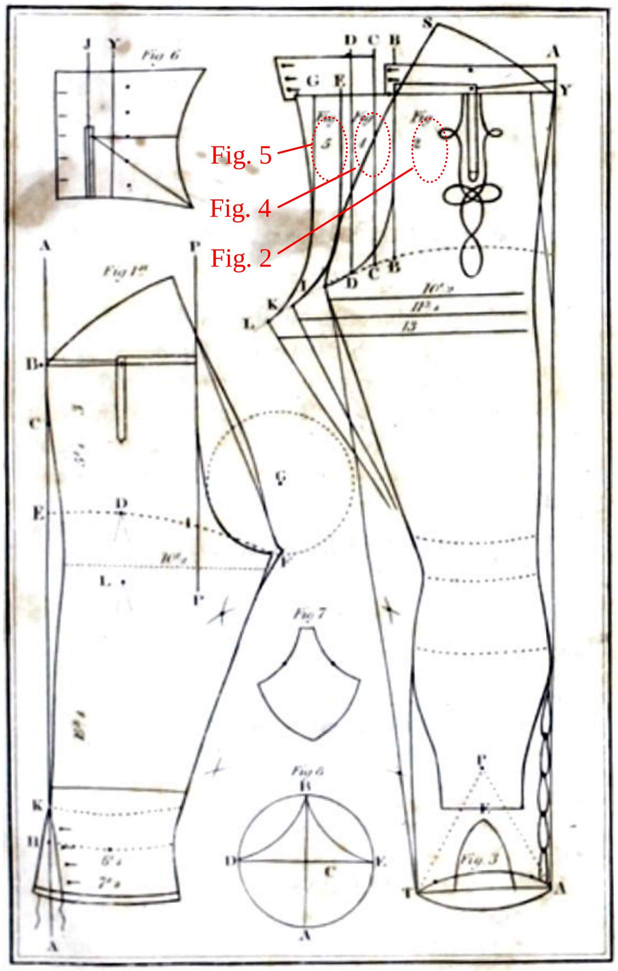


Figure 8. Graded men's bottom wear Source: Cook, 1826, pp. 24-25.

By 1820, tailors who had access to these sizing systems were able to make ready-to-wear clothing (Aldrich, 2007). For tailors and clothiers who were not skilled enough to draft, full-size patterns and templates were available in the market. In 1822, Wyatt published a sizing method that could extend patterns through certain lines and angles. In 1825, Byfield published a grading system which was based on enlarging a 'square' that related to the patterns (Figure 9).

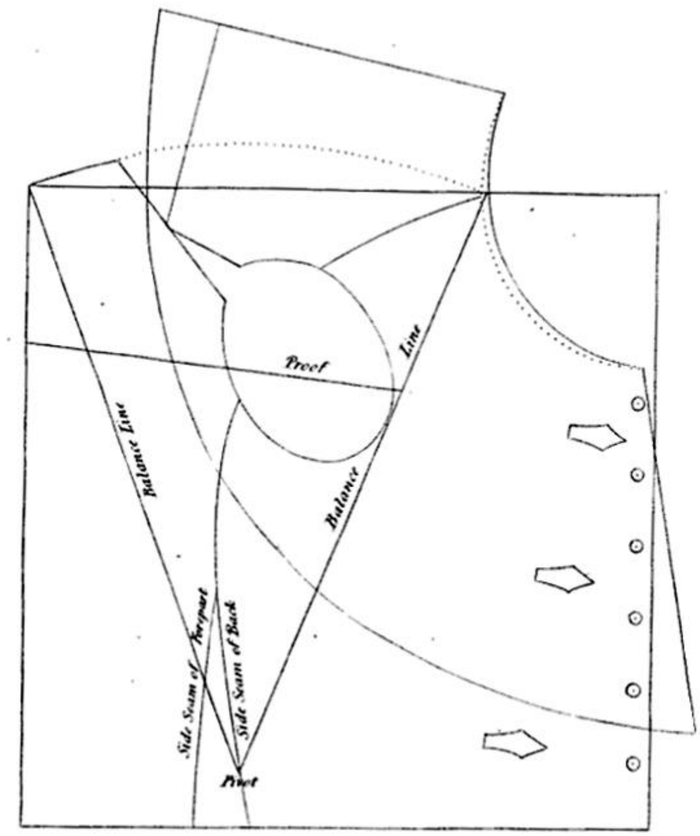


Figure 9. A grading system based on a square. Source: Byfield, 1825, plate II.

Before 1820, nearly all measurements mentioned in sizing systems and drafting methods were either measured out of clothing, or the measurements of clothing. The thickness of the fabric, to a certain extent, influenced the accuracy of the measurements

(Lindsay, 1828). One of the earliest records of measurements measured using the body can be found in Michel Bailly's patented system in 1826. This system illustrated the measurements on the naked body and demonstrated the connection between body measurements and drafted patterns (Aldrich, 2007).

Measuring under the coat became an established practice by mid-eighteenth century. Anatomy was applied to pattern drafting which contributed to standard sizing (Aldrich, 2007)). Figure information started to be combined with the tailor's experience for proportional calculation. Henry Wampen, a Germen professor of Mathematics, published a series of books on the human figure and garment construction between 1837 and 1864 (Aldrich, 2007).

The adoption of principles in publications on size charts and drafting methods in the middle of nineteenth century enabled tailors and clothiers to expand their business to the ready-made garment trade and the mass-customization garment trade (Aldrich, 2007). Ready-to-wear began to show in the market.

1851-1900: Sizing Grew with Ready-to-Wear

The Crimean War, from 1853 to 1856, and the American Civil War, from 1861 to 1865, accelerated the mass production of uniforms. There was a demand for uniformity of design and speed of production (Scranton, 1994). There were also growing demands for men's suits. The second half of the nineteenth century saw the fast growth of ready-to-wear and the application of sizing systems. Elias Moses, a clothing entrepreneur, mentioned in 1860 that 80% of the population purchased ready-made clothing. More and more tailors were following his pace of selling ready-made clothing (1860).

America and Britain were trying different paths of expansion in the ready-to-wear business. In 1856, the first clothing factory in Leeds was opened (Honeyman, 2000). The adoption of sewing machine made wholesale bespoke tailoring become affordable and popular and this inhibited mass production in Britain (Aldrich, 2007), while in America, standard sizes were built based on body measurements of recruits. Manufacturers moved quickly to install sewing machines and subdivided the labor process in order to fulfill the contracts rapidly (Scranton, 1994).

Although the sizing for menswear began in the early nineteenth century, it was not until the late nineteenth century that sizes started to show up in women's wear draft books. Aldrich believes that it was the change of fashion from 1830 to 1910 that accelerated the development of women's ready-to-wear (2007). The fashion before the mid-nineteenth century defined the difference in the body shapes of women and men more sharply. Women's wear was extremely close fitted, and most women's wear was custom made. In contract, men's wear included some ease for movement (Aldrich, 2007). With the technological advancements during the mid-nineteenth century, men's ready-to-wear clothing became more industrialized and affordable and this led to brought up women's demand for women's ready-to-wear.

In Britain, dressmakers began to write pattern-drafting books in 1860, and the number of dress-drafting books reached to a peak from 1880 to 1900 (Aldrich, 2003). By the end of nineteenth century, tables of proportionate measurements for women started to show up in British. Figure 10 is a size table adapted from Stone. However in America, women's ready-to-wear began in 1880s and sales reached to $68 million in 1890. In 1900, sales were almost

$160 million (Scranton, 1994). Mass-produced women's clothing began to outstrip clothing produced by dressmakers (Aldrich, 2007; Scranton, 1994).

PROPORTIONATE SCALE OF AVERAGE MEASUREMENTS.

HEIGHT	CIRCUMFERENCE					Natural	Inside Length of Arm to Elbow	Full Sleeve Length	Side Length	Depth of Scye	Blade
Feet - Inches	Breast	Bust	Waist	Neck	Scye	Waist Length					
4- 0	24	24	20	11	11	12	6¼	12½	6½	5½	7⅔
4- 2	25	25	20¼	11¼	11½	12½	6½	13	6¾	5¾	8
4- 4	26	26	20½	11½	12	13	6¾	13½	7	6	8⅓
4- 6	27	27	20¾	11¾	12½	13½	7	14	7¼	6¼	8⅔
4- 8	28	28¼	21	12½	13	14	7¼	14½	7½	6½	9
4-10	29	29½	21¼	12¾	13½	14½	7½	15	7¾	6¾	9⅓
5- 0	30	30¾	21½	13⅛	14	15	7¾	15½	8	7	9⅔
5- 1	31	32	22	13½	14½	15¼	7⅞	15¾	8 1/16	7 3/16	10
5- 2	32	33¼	22½	13⅞	15	15½	8	16	8⅛	7⅜	10⅓
5- 3	33	34½	23¼	14¼	15½	15¾	8⅛	16¼	8 3/16	7 9/16	10⅔
5- 4	34	35¾	24	14⅝	16	16	8¼	16½	8¼	7¾	11
5- 4½	35	37	24¾	15	16½	16⅛	8 5/16	16⅝	8¼	7⅞	11⅓
5- 5	36	38	25½	15⅜	17	16¼	8⅜	16¾	8 1/16	8 3/16	11⅔
5- 5½	37	39	26¼	15¾	17½	16⅜	8 7/16	16⅞	8 1/16	8 5/16	12
5- 6	38	40	27	16⅛	18	16½	8½	17	8 1/16	8 7/16	12⅓
5- 6½	39	41	27¾	16½	18½	16⅝	8 9/16	17⅛	8 1/16	8 7/16	12⅔
5- 7	40	42	28½	16⅞	19	16¾	8⅝	17¼	8	8¾	13
5- 7¼	41	42¾	29¼	17¼	19¼	16 13/16	8 11/16	17⅜	7 15/16	8⅞	13¼
5- 7½	42	43½	30	17⅝	19½	16⅞	8¾	17½	7⅞	9	13½
5- 7¾	43	44½	30¾	18	19¾	16 15/16	8 13/16	17⅝	7 13/16	9⅛	14
5- 8	44	45½	31¼	18⅜	20	17	8⅞	17¾	7¾	9¼	14¼

Figure 10. Stone's proportional sizing table. Source: Stone, 1897, p. VIIII.

1901-2000: Sizing Bloomed with Mass Production

Although the mass-production of ready-to-wear kept growing in America during the first half of twentieth century, the clothing produced in Britain was still developing using the methods of the wholesale trade (Aldrich, 2007). The fashion changes during 1908 through 1913 allowed the acceptance and development of women's ready-to-wear (Aldrich, 2003). American size charts were adopted by many British manufactures, because most of the British size charts were based on tailors' experiences. Some of these measurements were neither accurate nor standardized (Aldrich, 2007).

During World War I (1914-1918), a large number of men's body measurements were collected. Some standard sizes were created based on the analysis of this data (Yu, 2004). However, because only some basic measurements were taken, the application of this anthropometric data was limited. Another large-scale anthropometric survey was conducted by O'Brien and Shelton in 1939 and 1940.

Sizes for the second half of the twentieth century started to be based on body measurements, instead of the confusing clothing measurements. Standardized anthropometric equipment began to be used in the measuring process. Statistical methods were used for developing sizes (Aldrich, 2007). Standard sizes were published within different countries. Further details about anthropometric surveys and sizing standards will be explained in the Anthropometric Surveys and Sizing Standard in the U.S. part.

In summary, the manufacturing of clothing grew rapidly during the first half of the twentieth century, beginning in America and spreading to Europe. This led to the requirement of sizing standards, especially for women's wear. Many sizing standards were developed for fitting people from different countries during the second half on twentieth century.

2001-2013: Sizing Combined with Mass Customization

Sizing studies in the 21st century have been conducted to fit the needs of mass customization or to fit the needs of niche markets. Guan et al. (2012) did an anthropometric study on cab design, Song & Ashdown (2012) developed a sizing study on customized pants creation, and Mpampa et al. (2010) developed a sizing system in which the degree of mass customization can be controlled. Sizing systems are not only serving RTW production, but are also forming part of mass customization.

Anthropometric Surveys and Sizing Standard in the U.S.

Standard Sizing is a classification method for body shapes, and it can provide guidance for garment production (LaBat, 2007). An anthropometric survey helps prepare data for sizing analysis and generation. A good understanding of the sizing standard and the anthropometric study history is necessary for developing a good sizing system. A list of American sizing standards and anthropometric surveys followed by a timeline can be found in Figure 12.

Anthropometric Surveys

The first large-scale anthropometric survey for children was taken from 1937 to 1941. It was designed by **O'Brien and Shelton** and was sponsored by the US Department of Agriculture. A total of 147,000 boys and girls was measured (O'Brien, Girshick, & Hunt, 1941). From 1939 to 1940, a further study of 150,000 American women was conducted by the same team. Weight and 58 measurements were taken with identical calibrated measuring instruments by trained employees. Figure 11 shows the location of 34 measurements and the average value of the measurements based on the survey results. The purpose of the anthropometric survey was to improve the fit of women's garments by increasing the accuracy of standard sizes. No such size scientific study of this size using body measurements had been done before for the purpose of designing women's clothing sizes (O'Brien, 1930; O'brien & Shelton, 1941). With the application of statistical analysis, O'Brien and Shelton found that stature was the best predictor for length measurements and weight was the best predictors for girth measurements (O'brien & Shelton, 1941; Petrova, 2007). However, the data did not represent the whole population, because the women measured in this survey were volunteers with an age range of 18 to 30 (O'brien & Shelton, 1941; Petrova, 2007). Sizing selection suggestions were included but no sizing standard was published based on this data set until the CS 215-58. This sizing standard was published in 1958 by the National Bureau of Standards.

The Anthropometric Survey of the U.S. Army (ANSUR) was conducted from 1987 through 1988 at 11 army bases. The 25,811 subjects were measured for height and weight, and they also filled out biographical questionnaires. The subjects included 2,208 females and 1,774 males. They were measured in detail using 132 traditional measurements, in addition to head detail measurements, and they were also given the biographical questionnaire (Gordon, Churchill, Clauser, Bradtmiller, & McConville, 1989; Yu, 2004).

The Civilian American and European Surface Anthropometric Research (**CAESAR**) project was a large scale anthropometric survey conducted in three countries using the 3D scanner technique as part of the measuring process (Newcomb, 2006; Robinette,

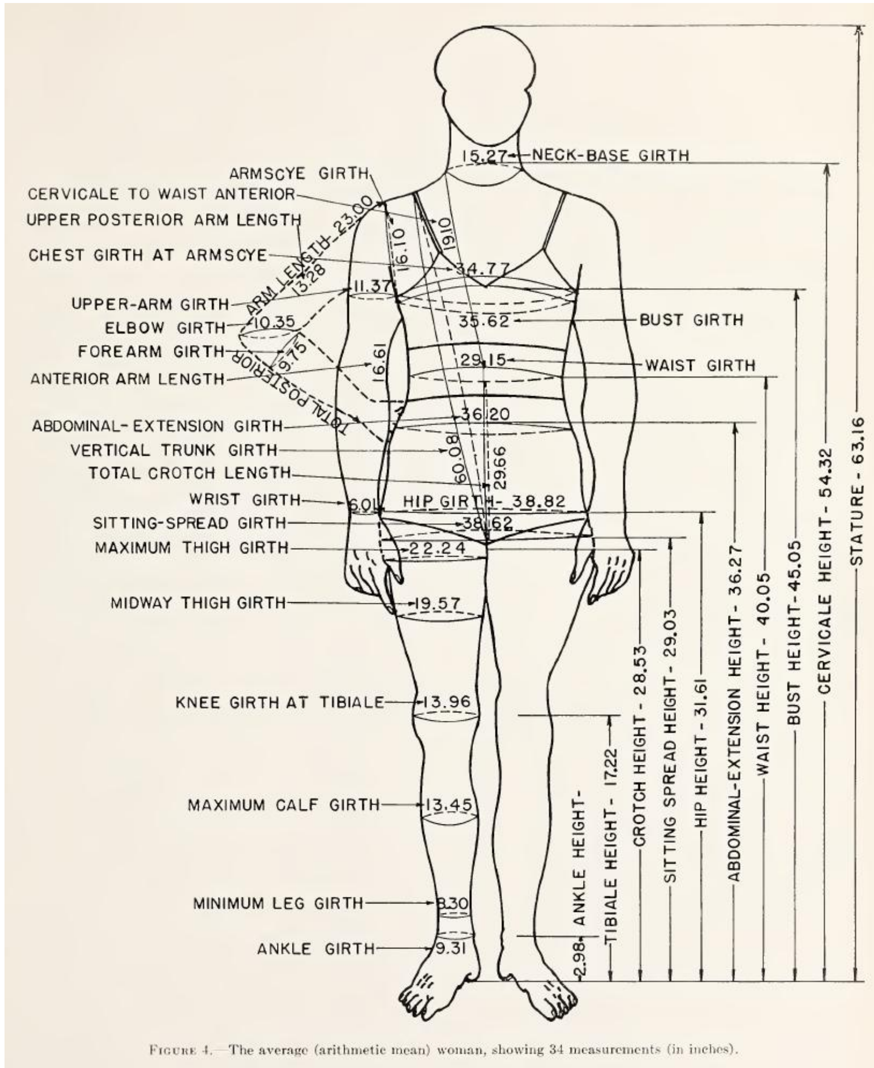


FIGURE 4.—The average (arithmetic mean) woman, showing 34 measurements (in inches).

Figure 11. The average women in O'Brien and Shelton's anthropometric survey.
Source: O'brien & Shelton, 1941, p. 29.

Blackwell, Daanen, Boehmer, & Fleming, 2002). The estimated cost for CAESAR was $6 million ([TC][2], 2004). A total of 4,500 subjects were measured and 99 measurements were collected. Some of the companies that sponsored the CAESAR study were Gap Inc., Jantzen Inc., Lee Co., Levi Strauss and Company, Sara Lee Knit Products, Sears Manufacturing

Company, and Vanity Fair. No sizing system was developed by the Civilian American and European Surface Anthropometry Resource group companies, although they had access to the data and were responsible for determining how to apply the data (Labat, 2007). The survey in the U.S. was taken from 1998 to 2002.

SizeUSA, conducted by [TC]^2, the U.S. Department of Commerce and many industry participants between 2002 and 2003, is the most recent large-scale anthropometric survey in the United State. It was apparent that the apparel industry was losing business opportunities because of the lack of size and size distribution data. Therefore, the purpose of SizeUSA was to measure the body dimensions of a representative sample of the U.S. population. With the adoption and use of the 3D body scanner from Textile/Clothing Technology Corp ([TC]^2) , the survey became more financially feasible. About 11,000 people from 13 cities were body scanned and measured in just over four months. No sizing system was developed, but a lot of research was done with the SizeUSA data. Newcomb (2006) applied a software called Female Figure Identification Technique (FFIT©) For Apparel on the SizeUSA data and generated a sizing table for the rectangle shape. Lee et al. (2007) compared the shapes between Americans and Koreans with SizeUSA and SizeKorea data. Kim et al. (2010) selected seat design subjects based on the statistical results of SizeUSA. Song & Ashdown (2011) used part of the SizeUSA data to categorize lower body shapes for females between 18-35 years old.

One big anthropometric surveys around the world was SizeUK. It was conducted on a total of 10,000 females and males from 1999 through 2002 by the UK Government using a [TC]^2 3D body scanner. The Japanese Size Survey was another large survey and was conducted on 19,000 males and 15,000 males aged 7 to 90 by the Research Institute of Human Engineering for Quality Life (HQL) between 1992 and 1994. It used the Voxelan laser 3D body scanner. Another large survey was the Chinese national size survey which was carried out on 14,000 women, men and children during 1987 in 10 provinces (Yu, 2004).

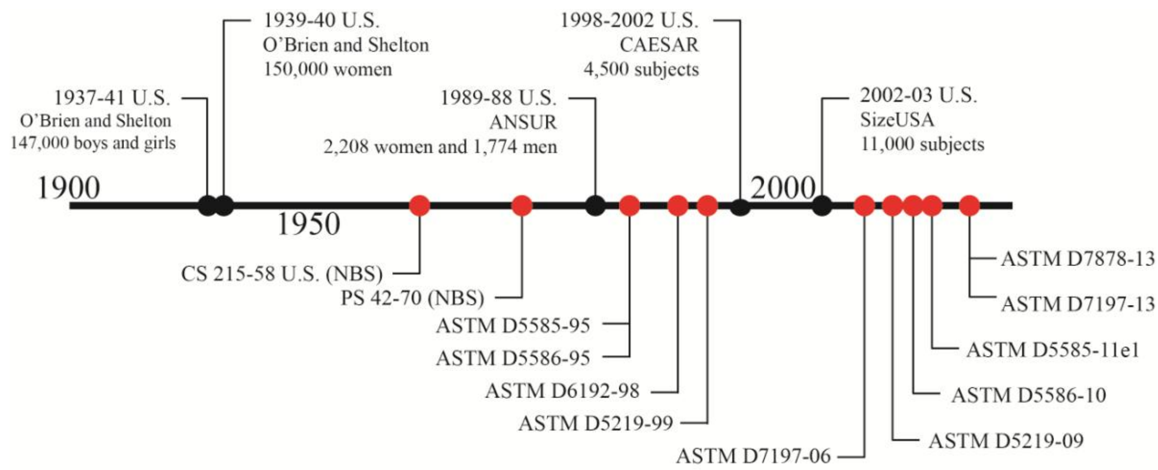


Figure 12. Anthropometric surveys and sizing standards in the U.S.

Sizing Standards

Before standard sizing systems were published, manufacturers developed their own sizing charts by trial and error. The result was a lot of variations and sometimes consumers were confused and dissatisfied (LaBat, 2007). Sizing standards were first published in the United State, followed by Britain, Germany, France, China and then other countries. The publication of sizing standards reached a peak during the second half of the twentieth century. Aiming at better international guidance and rules in size standards, the International Organization for Standardization (ISO) set up a technical committee named the "sizing systems and designations for clothes". Seventeen countries had representatives who presented at the first meeting in 1970 (Winks, 1997; Yu, 2004). By studying sizing standards published in America, a better understanding on how sizes are formed can be gained, and it is beneficial to carry out this research.

In CS 215-58, titled "body measurements for the sizing of women's patterns and apparel", a voluntary standard was encouraged by the Mail Order Association of America (MOAA) and was published in 1958 by the National Bureau of Standard (NBS) (LaBat, 2007; U.S. Department of Commerce, 1958). This standard was based on the analysis of the O'Brien and Shelton's anthropometric survey data and was expected to be able to improve the fit of RTW. The females' body sizes were divided into Misses, Women, Junior and Halfsize based on age, divided into Average Hip, Slender hip and Full hip based on the drop value between hip and waist, and divided into Tall, Short and Regular based on height measurement (Simmons, 2003). Bust was the control measurement between sizes. However, because the anthropometric data was old and was not representative of the population at the time the standard was published, MOAA requested a revision of the standard ((LaBat, 2007).

The revision of CS 215-58 was **PS 42-70**, titled "Body Measurements for the Sizing of Women's Patterns and Apparel". Similar sizing standards included PS 36-70 for boys, PS 45-71 for young men and PS 54-72 for girls. Because no large-scale anthropometric survey was conducted between CS 215-58 and PS 42-70, the edition was based on the data from the Health Survey conducted between 1960 and 1962. Bust was still the control dimension between sizes but it was increased by one grade interval per size code for all figure types based on the result of the Health surveys. The results indicated that women in the 1960s were slightly taller and heavier than women in the 1940s (LaBat, 2007; Stoudt, Damon, McFarland, & Roberts, 1965).The revised version contained size tables of Junior Petite, Junior, Misses Petite, Misses, Misses Talls, Women's and Half-Sizes (U.S. Department of Commerce, 1970). Table 1 lists the bust measurement, waist measurement, hips measurement and height measurements from PS 42-70.

Table 1. Comparison of PS 42-70 Misses-petite, PS 42-70 Misses and PS 42-70 Misses-tall sizing standards.

				PS 42-70: Misses-petite					
Measurements		8P	10P	12P	14P	16P	18P		
Bust		**32.5**	**33.5**	**35**	**36.5**	**38**	**40**		
Waist		23.5	24.5	26	27.5	29	31		
Hips		34.5	35.5	37	38.5	40	42		
Stature		59.5	60	60.5	61	61.5	62		
				PS 42-70: Misses					
Measurements	6	8	10	12	14	16	18	20	22
Bust	**31.5**	**32.5**	**33.5**	**35**	**36.5**	**38**	**40**	**42**	**44**
Waist	22.5	23.5	24.5	26	27.5	29	31	33	35
Hips	33.5	34.5	35.5	37	38.5	40	42	44	46
Stature	62.5	63	63.5	64	64.5	65	65.5	66	66.5
				PS 42-70: Misses-tall					
Measurements			10T	12T	14T	16T	18T	20T	22T
Bust			**33.5**	**35**	**36.5**	**38**	**40**	**42**	**44**
Waist			24.5	26	27.5	29	31	33	35
Hips			35.5	37	38.5	40	42	44	46
Stature			67.5	68	68.5	69	69.5	70	70.5

Note: All measurements are in inches. Source: U.S. Department of Commerce, 1970, pp. 9-11.

The program of Voluntary Product Standards (VPS) which developed CS 215-58 and PS 42-70 standards was withdrawn in 1953 by the U.S. Department of Commerce (DoC). The American Society for Testing and Materials (ASTM) has been developing sizing systems for Americans since then. In 1982, ASTM established Subcommittee D13.55 to take over the work of defining body measurements and apparel sizes. A series of standards for infants, children, teenagers, and adults have been published.

The sizing system, **ASTM D5585**, titled Standard Tables of Body Measurements for Adult Female Misses Figure Type, Size Range 00–20, was first published in 1995, updated in 2011 and re-edited. The newest version is ASTM D5585-11^{e1} (D13 Committee, 2011a). ASTM D5585-11^{e1} was developed based on PS 54-72 by the U.S. Department of Commerce, the CAESAR study, the SizeUSA study, industry studies and documentation from Alvanon Inc. Table 2 lists the bust, waist, hips and height measurements of these three sizing standards. The ASTM D5585-11^{e1} standard is divided in the table into curvy and straight, two body types with different waist, hip and other girth measurements. In ASTM D5585-95, the intervals for bust, waist and hips were the same between sizes, while they were different in ASTM D5585-11^{e1}. Stature in ASTM D5585-95 increased from a smaller size to a bigger size. In ASTM D5585-11^{e1} stature was a fixed number. However, no description about how these sizes were developed were included in the explanation of the standard.

The sizing standard, **ASTM D5586**, titled Standard Tables of Body Measurements for Women 55 and Older (All Figure Types), was first published in 1995 based on the Reich and Goldsberry's anthropometric study conducted in 1993 (D13 Committee, 1995b). A total of 6786 subjects American women who were over 55 years old participated in the study and 58 body measurements were recorded (Reich & Goldsberry, 1993). ASTM D5586 was updated in 2001 and 2010. Sizes were divided into seven categories similar to PS 42-70. Because the standards were formed with raw results, it was hard to interpret and apply the measurements' values.

Table 2. Comparison between ASTM D5585-11^{e1} and ASTM D5585-95.

					ASTM D5585-11^{e1}							
			ASTM D 5585-11(listed measurements are the same as ASTM D5585-11^{e1})									
Measurements	00	0	2	4	6	8	10	12	14	16	18	20
Bust	**31.125**	**31.75**	**33**	**34.125**	**35.25**	**36.25**	**37.25**	**38.75**	**40.375**	**42.125**	**44**	**46**
Waist-Curvy	23.875	24.625	25.375	26.125	27	28	29	30.75	32.5	34.5	36.75	39
Waist-Straight	25.375	26.125	26.875	27.625	28.5	29.5	30.5	32.25	34	36	38.25	40.5
Hips-Curvy	34	34.625	35.875	37.125	38.25	39.25	40.25	41.75	43.25	45	46.75	48.75
Hips-Straight	33.25	33.875	35.125	36.375	37.5	38.5	39.5	41	42.5	44.25	46	48
Stature	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5
					ASTM D5585-95							
Measurements			2	4	6	8	10	12	14	16	18	20
Bust			**32**	**33**	**34**	**35**	**36**	**37.5**	**39**	**40.5**	**42.5**	**44.5**
Waist			24	25	26	27	28	29.5	31	32.5	34.5	36.5
Hips			34.5	35.5	36.5	37.5	38.5	40	41.5	43	45	47
Stature			63.5	64	64.5	65	65.5	66	66.5	67	67.5	68

Note: All measurements are in inches. Source: D13 Committee, 1995a p. 4; D13 Committee, 2011a, p. 3.

The sizing standard, **ASTM D7878**, titled Standard Tables for Body Measurements for Adult Female Misses Petite Figure Type, Size Range 00P – 20P, was published in 2013. It defined 5 ft 2 1/2 inches tall as a petite figure, compared to the ASTM D5585-11^{e1} labeled a regular figure as 5 ft 5 1/2 inches high (D13 Committee, 2011a; D13 Committee, 2013a). Curvy and Straight shapes were applied to the waist, high hip, hip/seat, thigh and mid-thigh girth measurements. The 3D avatar was used for visual reference (Figure 13), as was used in ASTM D5585-11^{e1}.

Other standards include 1) **ASTM D5219**, tiltled Standard Terminology Relating to Body Dimensions for Apparel Sizing first published in 1999 and updated in 2002, 2007 and 2009 (D13 Committee, 2009); 2) **ASTM D7197**, titled Standard Table of Body Measurements for Misses Maternity Sizes Two to Twenty-Two (2-22), first published in 2006 and updated in 2013 (D13 Committee, 2013b); 3) **ASTM D6192**, titled D6192 Standard Tables of Body Measurements for Girls, Sizes 7 to 16 first published in 1998 and divided girls body shape into regular, slim and plus in 2007 (D13 Committee, 2011b); 4)

ASTM D6829, titled Standard Tables of Body Measurements for Juniors, Sizes 0 to 19, first published in 2002 and targeted for Junior Females (D13 Committee, 2008); 5) **ASTM D6458** designed for boys and 7) **ASTM D6240** designed for men (D13 Committee, 2012a; D13 Committee, 2012b).

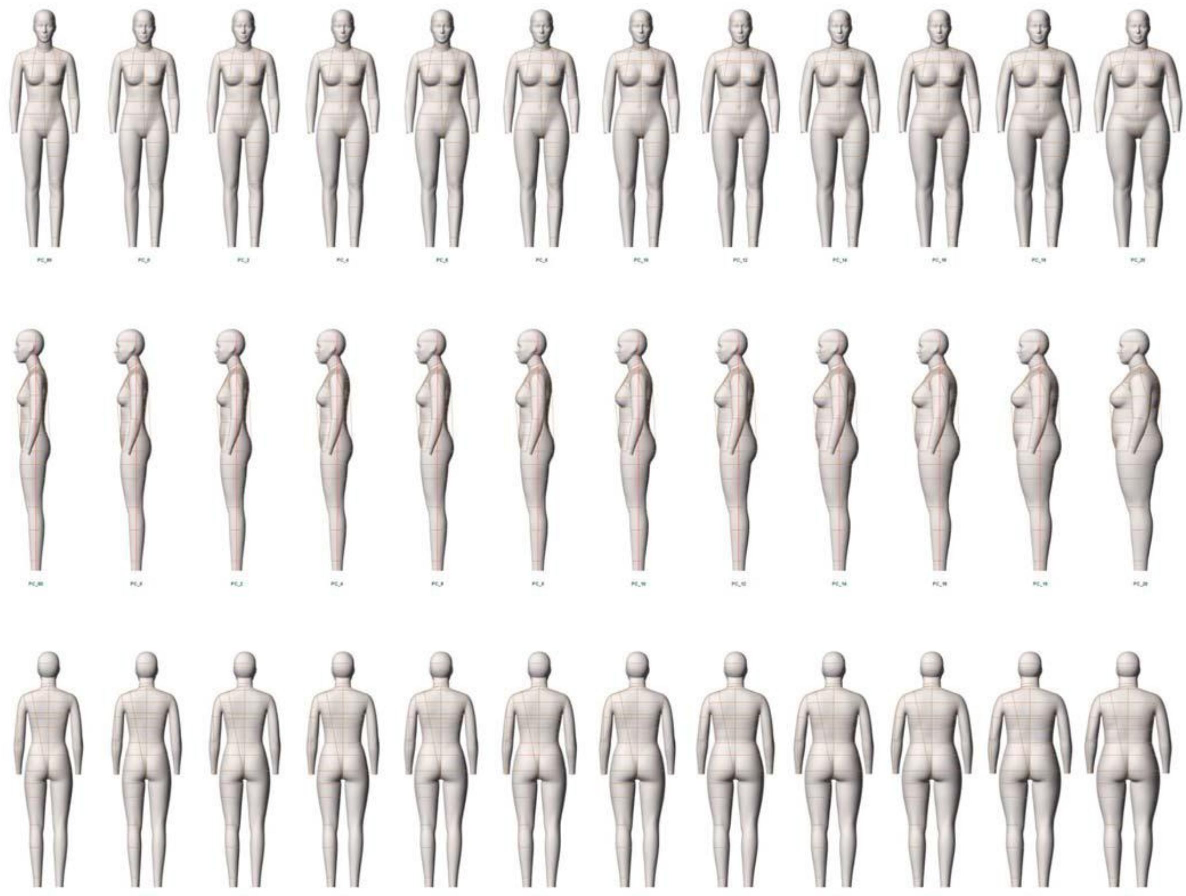


Figure 13. Missy Petite Avatar Curvy in ASTM D7878. Source: D13 Committee, 2013a, p. 5.

CHAPTER THREE: METHODOLOGY

Research Purpose

The major objective of the research was to design a method to create a sizing system based on anthropometric data and to test SizeUSA data and include shape information in the standard. The SizeUSA data was divided into two groups randomly to create a training set and a validation set. Overall, the study resulted in a more complete understanding of size creation and resulted in the application of shape into the sizing standard to improve the consumer's satisfaction with the fit of apparel.

A natural log transformation was done on height, girth and width measurements, because when the measurement value was large, the interval increased too. Intervals can then be distributed evenly on the transformed data, and it results in increasing intervals for the transformed back data. Clustering was done on two Principle Component sores and the standard deviation was used to set the range and intervals. Multivariate regression was used to predict the secondary dimensions. All of these methods have been used in literature reviews separately, but a combination of them is relatively novel. Body shapes defined by FFIT© for Apparel were applied in this study. Different regressions were done for the top three popular body shapes. This has not been done before. The standard sizing system created in this study was flexible and can be re-shaped to fit different target groups.

Research Questions

Framing this research were two main research questions, and the first question was divided into 5 sub-questions. The approach to answering each of these questions will be covered in detail in the data analysis section of this chapter.

1. Can the SizeUSA data be used to create a flexible women's body sizing system that will represent a large population?
    a) What are the key measurements for a sizing system?
    b) What are the control variables?
    c) What are the key differences between different body shapes that help define a sizing system?
    d) How are the intervals between each size created?
    e) How does the created sizing system work, comparing to ASTM D5585-11^{e1}?
2. What is a sizing strategy that could be used by the industry based on the analysis of SizeUSA and body shapes?

One thing needed to be mentioned is that comparing the created sizing systems with ASTM D5585-11^{e1} (D13 Committee, 2011a), a standard designed for missy sizes, is only for testing purpose. We are not suggesting that females in the SizeUSA data were all missy sizes.

SizeUSA Data Collection

All measurement data used for this study came from SizeUSA, the National Sizing Survey. It was conducted from 2002-2003 and it is the most recent large-scale anthropometric survey conducted in the United States so far. Before introducing the data analysis process, it is important to understand the data collection itself.

Sampling Strategy

The objective of the SizeUSA National Sizing Survey was to collect body measurement data of a sample that represents the U.S. population using the most advanced 3D body scanning technology(([TC]2, 2004)). The scope was to cover 6 age groups (18-25, 26-35, 36-45, 46-55, 56-65, 66+), 2 gender groups (male, female) and 4 ethnic groups (Non-Hispanic White, Non-Hispanic Black, Hispanic or Mexican American, and Other). However, even with the 3D body scanning technology, a random sampling strategy would have taken at least a magnitude larger sample and the cost would have been too expensive. Thus, the sampling strategy for SizeUSA was to model the approximate distribution of height and weight of the National Health and Nutrition Examination Survey (NHANES) III conducted by the National Center for Health Statistics. The NHANES III was conducted in two phases beginning in 1988 through 1991 and continuing in 1992 through 1994 and most analysis combined 6 years of data from 1988-1994 (NHANES III, 1994). NHANES III measured height and weight from 33,994 subjects. In 1999, the NHANES became a continuous program. About 5,000 subjects are examined each year.

It was determined that a sample size of 10,000 would result in a statistically significant sample size for the U.S. population. Thirteen cities were picked to measure volunteers willing to participate in the survey. The plan was to collect 1,000 subjects at each location. More than 200 measurements were coded to be used as measured by the 3D scanner. Weight and height were measured separately with a medical scale and a wall ruler. A questionnaire was designed to collect demographic information including age group, sex, ethnic group, zip code, annual household income, marital status, body structure, lifestyle, education, employment, preferred clothing sizes, preferred stores and types of clothing worn. The participants completed the survey before the scanning ($[TC]^2$, 2004).

To verify the reliability of the body scanner, a comparison of the body scanner measurement and the manual measurement was conducted. It turned out that the body scanner measurement was more repeatable and reliable ([TC]^2, 2004).

Data Description

A total of 10,001 subjects were scanned of which 65% were women and 35% men (Figure 14). More than 1,000 subjects were measured in five cities and less than 500 subjects were measured in four cities (Figure 15). Figure 16 through Figure 23 are some of the Female demographic information from the SizeUSA data. The biggest ethnic group was the Non-Hispanic group, with the Asian subjects included in the other group (Figure 16). The number of subjects that fell within each age group were close except in the senior groups (Figure 17). The income distribution is shown in Figure 18, the lifestyle is in Figure 19 and the marital status is in Figure 20. The most common education levels are "Some college or technical school" and "College graduate" (Figure 21). About the same amount of people thought they were "A little overweight" compared to the number of subjects who thought they were "About the right weight" (Figure 22). "Professional/managerial" was the largest employment group, followed by students (19%) (Figure 23). 15-percentle and 85-percentile were used to group height and weight. It turned out that "the US adult population is getting heavier and taller and changing shape" ([TC]^2, 2004, p. 11).

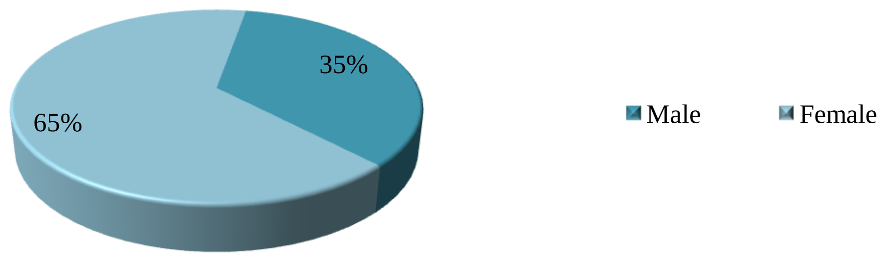


Figure 14. The SizeUSA Demographics – Sex. Source: [TC]^2, 2004, p.8.

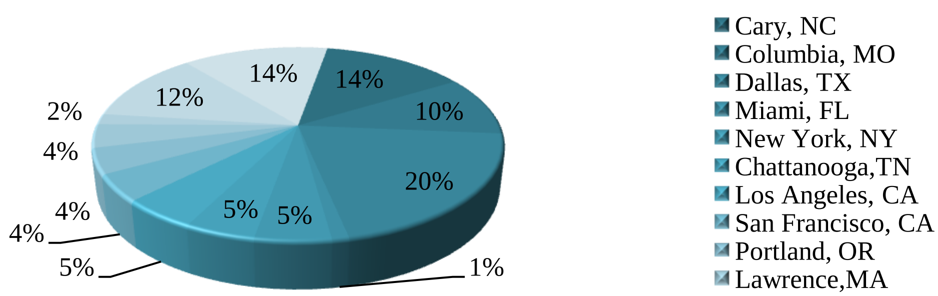


Figure 15. The SizeUSA Demographics – Scan Location. Source: [TC]^2, 2004, p. 39.

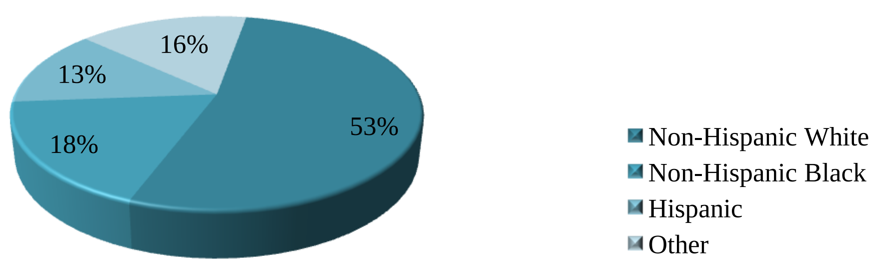


Figure 16. The SizeUSA Demographics – Ethnicity. Source: [TC]^2, 2004, p. 39.

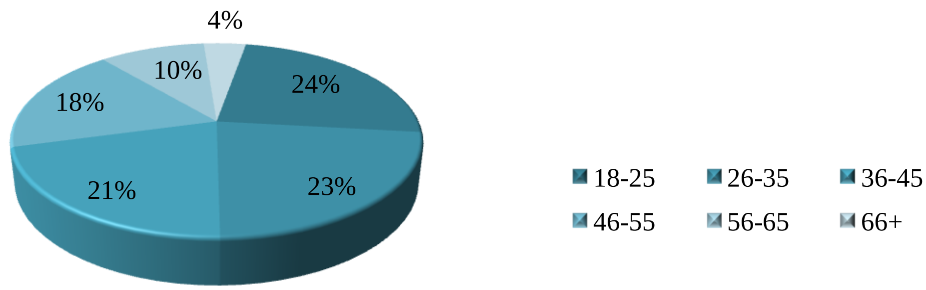


Figure 17. The SizeUSA Demographics – Age. Source: [TC]^2, 2004, p. 39.

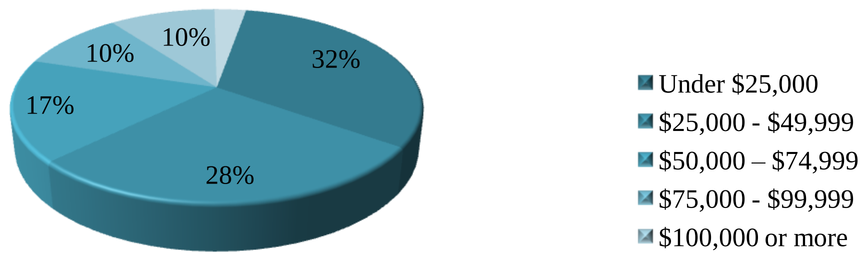


Figure 18. The SizeUSA Demographics – Income. Source: [TC]^2, 2004. p. 39.

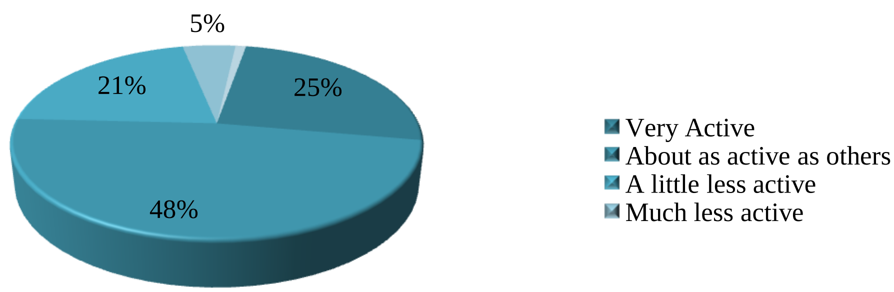


Figure 19. The SizeUSA Demographics – Lifestyle. Source: [TC]^2, 2004. p. 39.

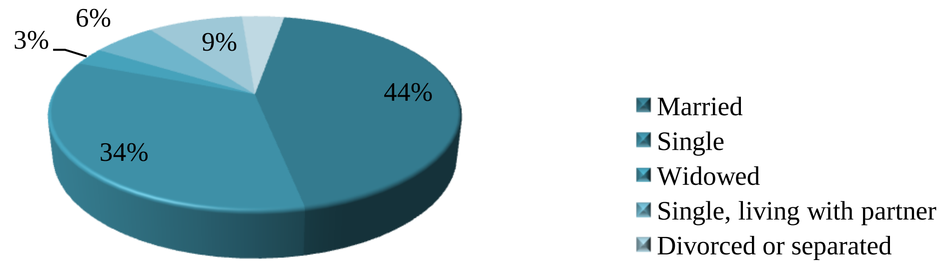


Figure 20. The SizeUSA Demographics – Marrial Status. Source: [TC]^2, 2004. p. 39.

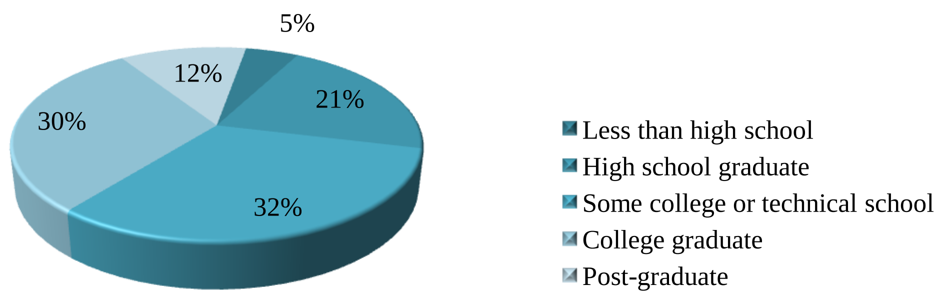


Figure 21. The SizeUSA Demographics – Educational Level. Source: [TC]^2, 2004. p. 39.

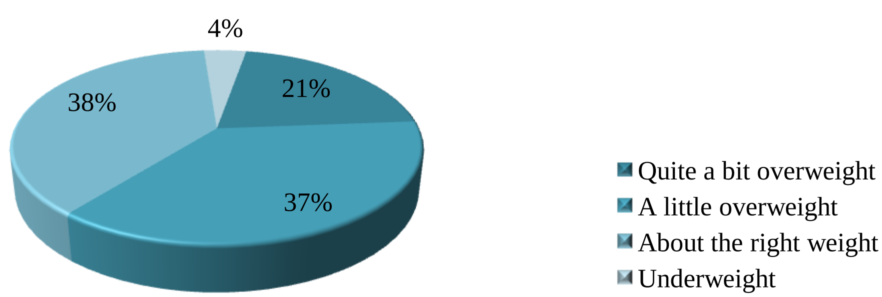


Figure 22. The SizeUSA Demographics – Weight Perception. Source: [TC]^2, 2004. p. 39.

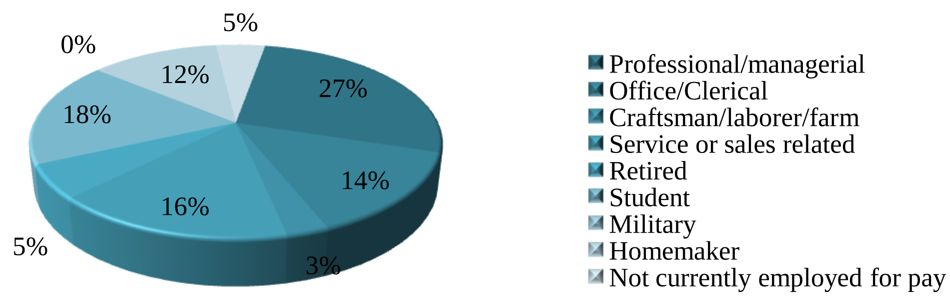


Figure 23. The SizeUSA Demographics – Current Employment. Source: $[TC]^2$, 2004. p. 39.

Data Analysis

This study relied primarily on the use of SizeUSA data, the Female Figure Identification Technique (FFIT©) for Apparel as shape identifier, and the statistical and graphical functions of Microsoft Excel and SPSS (a statistical analysis program developed by IBM) to answer the two research questions presented in Chapter 1. The methodology used to approach each question is presented separately below:

Research Question 1

Can the SizeUSA data be used to create a flexible women's body sizing system that will represent a large population?

To answer this research question, a process for creating a body sizing system was designed based on literature review and then tested on the SizeUSA data. In order to verify the accuracy of the sizing results, the total population, 6310 females, was randomly divided into two groups. Approximately 50% of the subjects were placed in each group using a case selection tool in SPSS. Group one was the training group and group 2 was the validation group.

Five secondary research questions were asked to help design a body sizing system creation method. They were:

a) *What are the key measurements for a sizing system?*

b) *What are the control variables?*

c) *What are the key differences between different body shapes that help define a sizing system?*

d) *How are the intervals between each size created?*

e) *How does the created sizing system work, compared to ASTM D5585-11^{e1}?*

Question 1-a: demographic, measurements and body shapes. A total of 6310 females participated in the SizeUSA anthropometric survey. The data set was included by three parts, the demographic data, the ASTM data and the secondary data. The demographic data was the record of answers for the questionnaire, with 13 items. The ASTM data contained 37 measurements that were extracted based on the ASTM's measurement definition. The secondary data was more detailed and contained more than 200 measurements. Most of the measurement definitions in the secondary data were based on the ISO standard.

Because some measurements in the secondary data can be calculated by another measurement, there was some overlap between the ASTM data and the secondary data. The use of all the data would have made the analysis process complicated. To simplify it, a selection of measurements was made referred to measurements used in the past sizing standard. That is, if the definition of a measurement described in SizeUSA was similar to a measurement's definition in either ASTM or ISO standard, then the measurement was considered as a key measurement.

Body shape was determined based on the FFIT© for Apparel. Five out of the six measurements that were used to determine the body shape were taken in SizeUSA and were also marked as key measurement for this study. They were A1Bust, A2Waist (pants), A3High_Hip, A4Hips (biggest circumference) and B13Midriff (stomach). Because the abdomen girth measurement was not included in SizeUSA data, it was replaced by A3High_Hip measurement for shape defining. This was because among all SizeUSA measurements, the level of the highhip was the closest one to the level of the abdomen.

Six drop value were calculated and used to test the relationship between PCs and drop values. The calculation of drop values were based on the criteria used to define the body shape and are listed in Table 3.

Table 3. Calculation methods of drop values

Variable name	**Calculation method**
Bust-Waist	A1Bust-A2Waist (pants)
Bust-Waist_Ln	lnA1Bust-lnA2Waist (pants)
Hips-Waist	A4Hips (biggest circumference)-A2Waist (pants)
Hips-Waist_Ln	lnA4Hips (biggest circumference)-lnA2Waist (pants)
Bust-Hips	A1Bust-A4Hips (biggest circumference)
Bust-Hips_Ln	lnA1Bust-lnA4Hips (biggest circumference)

Question 1-b: pre-PCA and PCA. A sizing system usually has one or two control variables to guide the distribution of the sizes. O'brien & Shelton (1941) suggested using height and weight as control variables, while Guan et al. (2012) used principal component scores to sort the groups. Within the selected key measurements, some of them were highly correlated to each other. PCA in SPSS was conducted in this research to reduce the large number of body dimensions to a smaller number of principal components (PCs), upon which the sorting of sizes would be based. Varimax rotation was selected to provide independence among PCs (Song & Ashdown, 2011).

A pre-PCA was made before the final PCA to help determine the number of PCs that should be used for clustering. The decision was made with the consideration of number of sizes and percentage of variance explained by PCs. The coefficients matrix was calculated to test the correlation between measurements. A Scree plot was drawn to support the decision making.

Because PCA excludes cases list wise, descriptive analysis was made to check the numbers of missing values. For those measurements who had a lot of missing values. Therefore, these measurements were excluded from the final PCA. The six drop values did not participated in either the pre-PCA or final PCA.

Question 1-c: Regression. Multivariate linear regressions were conducted, with PCs as independents, to predict and calculate the secondary dimensions. The multivariate linear regression assumed that the dependent can be calculated by a linear combination of all independents and a constant. The process of multivariate linear regression was to calculate the coefficient for each independent and the constant, so that a formula can be formed The regression was conducted in both groups first with the whole data set and then within the top three body shapes: Rectangle, Spoon and Bottom hourglass. By comparing the coefficients extracted out from regressions for different body shapes, we can tell how body shapes worked.

In order to test the co-relationship between drop values and PCs, Pearson correlations were calculated. Separate linear regressions were done with PCs as independents and drop values as dependents in the training set. Adjusted R^2 were analyzed.

Question 1-d: natural log transformation and std. deviation. A common strategy used to decide intervals between sizes is to use a larger interval between larger sizes. It is easy to understand that an one inch increase on the waist of a 25" waist person will be more visible than an one inch increase on the waist of a 44" waist person. The reason is because the base values of their waist measurements are different. A natural log calculation ($y = \ln(x)$) of measurements was used for transformation. The idea was to transform the original measurement to new variables so that the same value of the interval in the new variables would have the same effect. This was represented by the ratio of increasing value. Table 4 is an example that demonstrates how the formula works. As you can see, when the transformed value grows the same amount, the fraction of the original increased value divided by the original value stays the same.

The natural log transformation can only be applied to length, width, girth, height and weight measurements. Measurements like BMI and degree cannot be transformed, because they do not follow the rule of bigger value larger interval. A measurements checking was done to make sure all transformed measurements were transformable.

Table 4. An example of natural log transformation

	Group1	Group 2	Group3	Group4	Group5
original value	20.09	24.53	29.96	36.60	44.70
original increased value		4.45	5.43	6.63	8.10
transformed value	3.00	3.20	3.40	3.60	3.80
increased value after transformation		0.20	0.20	0.20	0.20
original increased value/ original value		0.18	0.18	0.18	0.18

K-means cluster analysis was tested for sorting sizes with both PCs calculated together and separately. However it turned out that the result of K-means cluster analysis was too random and not controllable. The K-means cluster analysis was not a suitable method for this research. Mpampa (Mpampa et al., 2010) distributed sizes evenly with the size coverage for each control variables separately. This method, on the other hand, is more controllable which fits this research. Mpampa's idea of using standard deviation (SD) to determine the range of control variables by setting the range of height to mean $\pm$2SD, was also applied in this research. However, this research and Mpampa's research have three differences: 1) Mpampa used "drop value" and "height" as the control variables, while PCs were used in this research; 2) Mpampa used the original data for grouping, while the transformed data was used in this study; and 3) while the cover range used by Mpampa's was mean $\pm$2SD, the cover ranged used in this paper for the PCs was tested to see if it can cover more than 95% of each PC's "population" and alterations could be made if necessary.

A couple of tests were conducted to help determine the number of groups for each control variable. The predicted value of "A2Waist" was compared with the ASTM D5585−11 standard.

Once the size centers were determined, all measurements can be calculated for each size by using the formulas from the regression part. A sizing system was then created. Figure 24 is an illustration of how sizing system was created.

Question 1-e: comparison. In order to see how the created sizing system worked, a comparison was made between the created one and ASTM D5585-11^{e1}. ASTM D5585-11^{e1} is the most updated ASTM sizing standard designed for Adult female misses figure. It contains 2 body shapes and 12 sizes for each shape. Thus, 12 sizes were selected from the created sizing system for the top three body shapes and also the sizes created from the whole data set. The idea was to see how many people fell within each sizes. Subjects from the validation set were used in the comparison to avoid bias.

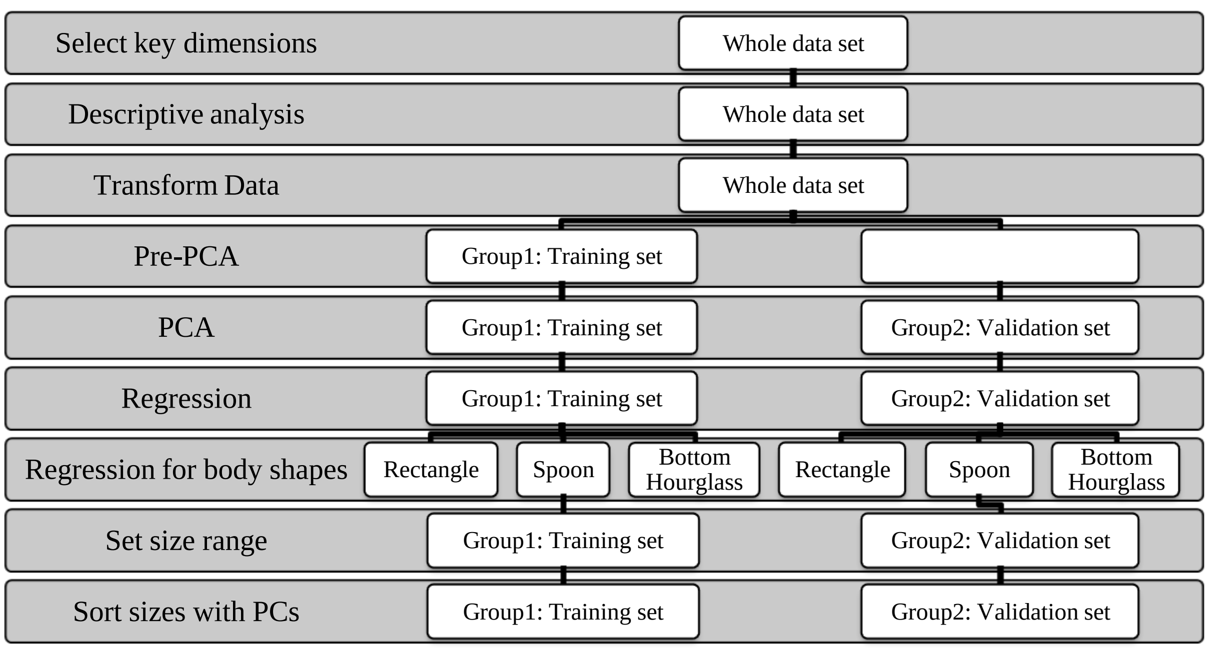


Figure 24. The sizing system creation steps

In comparison one, only height (stature) and waist girth (based on the definition of ASTM) measurements were used as the criteria. For subjects who meet the criteria, size numbers were labeled. The number of subjects that had assigned sizes were counted. Bigger number meant better fit. Same processes were done with 3 criteria measurements (height, waist and bust), 4 criteria measurements (height, waist girth, bust girth and hips girth) and 5 criteria measurements (height, waist girth, bust girth, hips girth and hiphip girth). The reason of choosing these measurements as criteria was because they were important for pattern making.

Research Question 2

What is a sizing strategy that could be used by the industry based on the analysis of SizeUSA and body shapes?

The approach to this question relied primarily on the result of question one. The sizing system created in the study of question one was clustered by the PCs that took into consideration of all key measurements. Regression analysis was done on the whole data set and also on the top three body shapes, therefore, one size actually has four values: 1) the first value represents the whole population without the inclusion of shape difference; 2) the 2nd, 3rd and 4th regressions represented the top three shapes.

To develop a sizing strategy for industry, first, a comparison of the four values for each size was conducted to demonstrate the difference between shapes and to determine if it was necessary to group subjects into shapes. A distribution of people falling within each size was calculated to help determine sizes. Based on the comparison results between the newly created sizing systems with the ASTM D5585-11^{e1} system, some suggestion were made for mass customization.

CHAPTER FOUR: RESULTS

The primary goal of this research was to create a sizing system based on the SizeUSA data with the consideration of body shape differences and to compare the research with the ASTM sizing standard to better understand the current sizing standard. This section of the paper presents the analysis of the data to answer the two research questions developed to guide the study.

Development of Sizing System

Prepare Data

Based on the measurements used in past sizing standards, 64 body measurements were chosen as key dimensions for creating a sizing system. Refer to Appendix A for the 64 key measurements definitions used in SizeUSA and in other sizing standards. Along with the 64 key measurements, 10 demographic items, one body shape and six drop values were added to the data set. All variables are listed in Table 5..

Errors were manually detected and deleted. Refer to Appendix B for a summary of the deleted errors. Natural log transformation was used on the 62 measurements, with the exclusion of BMI and A32Shoulder_Slope_(degrees). The data were then analyzed using SPSS.

Table 6 is a list of demographic items and shape categories that were included in the data.

Table 5. List of key variables used in the study

Basic information	
Survey_ID	Sex
ZipCode	Education Level
Income	Employment
Ethnicity	Lifestyle
Weight Perception	Body Shape
Girth measurements	
A5Mid-Neck	A10Thigh_Max
A6Neck_Base	A11Thigh_Mid
A1Bust	A12Knee
B13Midriff	B211W120R_LowKneeGirth
B192W106_UnderBustGirth	A13Calf
B186M96_Chest_Girth	B215W122R_Minimum_Leg_Girth
B194W108_WaistGirth	A14'Ankle Girth
A2Waist	A7Armscye
A3High_Hip	A8Upper_Arm
B200W114_PtrHipGirth	A9Elbow
A4Hips	B183W100R_WristGirth
Height measurements	
A18Cervicale_Height	B85W29_AbdomenHeight
B165W89_BackNeck	B79W23_PtrHipHeight
B14Midriff_Height	A21MaxHips_Height
B78W22_Waist5_Height	A22Crotch_Height
A19Waist6_Height	A23Knee_Height
B87W30a_wideSeatGirthHeight	A24Ankle_Height
A20High_Hip_Height	
Length measurements	
A16Crotch_Length_Total	A34Arm_Length_CBNeck_to_Wrist
A30Shoulder_Length	A36Neck_to_Bust_Point
B131W61_FrontNecktoWaist5	B145W68R_UnderArmLength
A25Waist_Length_Front	B138W66R_SideWaist5ToHipPtr
B104W41_Neck2Waist5Contoured_Back	B140W66aR_SideWaist5ToSeat
A26Waist6_Length_Back	B83W27_BodyRise(W5Straight)
B117W55R_SideNeckToWaist5Straight	B142W67R_OutsideLegLength
W75aR_BackNeckToElbow	B224W139R_FootLength
A33Arm_Length_(Shoulder_to_Wrist)	
Length measurements	
A27Across_Shoulder	A29Cross_Chest_Width
B157W82_BackShoulderWidth(contoured)	A35Bust_Pt_to_Bust_Pt
B160W84_FrontShoulderWidth	B222W138R_FootWidth
A28Cross_Back_Width	

Table 5. List of key variables used in the study (continue)

Other measurements	
A32Shoulder_Slope_(degrees)	B67W15R_ArmscyeDepthFromBackNeck

Table 6. Options of demographic survey and body shape categories

Demographic Item Name	Options	Demographic Item Name	Options
ZipCode	N/A	Sex	Female
Income	Under $25,000 $25,000 - $49,999 $50,000 – $74,999 $75,000 - $99,999 $100,000 or more	Education Level	Less than high school High school graduate Some college or technical school College graduate Post-graduate
Age	18-25 26-35 36-45 46-55 56-65 66+	Employment	Professional/managerial Office/Clerical Craftsman/laborer/farm Service or sales related Retired Student Military Homemaker Not currently employed for pay
Ethnicity	Non-Hispanic White Non-Hispanic Black Hispanic Other	Marital	Married, Single Widowed Single living with partner Divorced or separated
Weight Perception	Quite a bit overweight A little overweight About the right weight Underweight	Lifestyle	Very Active About as active as others A little less active Much less active
Body Shape	Rectangle Hourglass Bottom Hourglass Top Hourglass Triangle Inverted Triangle Oval Diamond Spoon		

To test the effect of the natural log transformation on the data, histograms were drawn for both the original measurements and the transformed ones. Their skewness values were calculated. Table 7 shows the skewness switch for height, weight, A1Bust, A2Waist (pants) and A4Hips (biggest circumference). Figure 25 illustrates the histogram comparison for A2Waist (pants). Refer to Appendix C for other histograms.

Table 7. Comparison of measurements' skewness before and after transformation

Measurements	HeightIn	Weight	A1Bust	A2Waist	A4Hips
N	6308	6306	6308	6308	6308
Skewness before transformation	0.247	1.273	0.730	0.954	1.102
Skewness after transformation	0.039	0.538	0.390	0.538	0.728

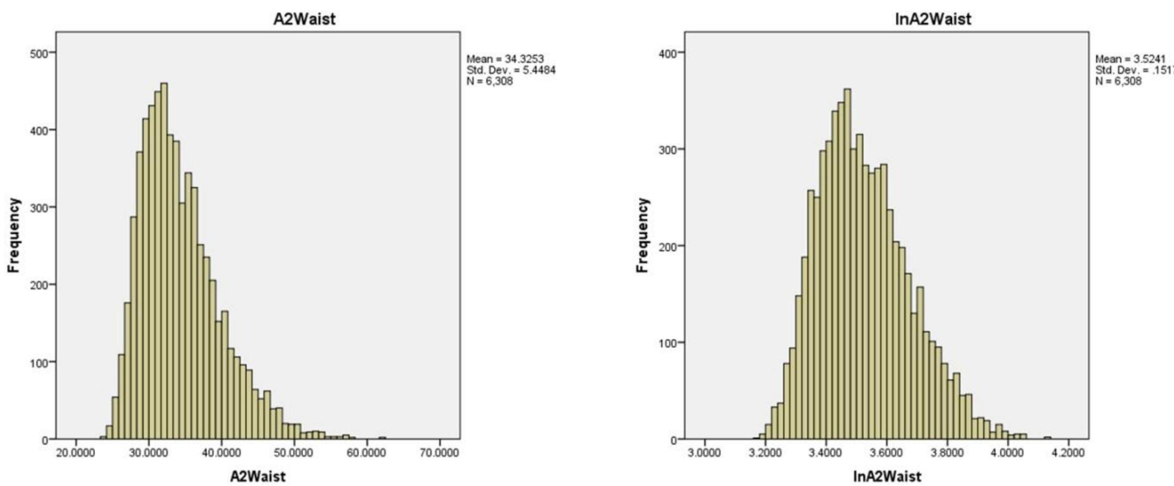


Figure 25. Histogram comparison between A2Waist and transformed lnA2Waist

6308 subjects were then randomly divided into two groups: the training set (labeled as group1) and the validation set (labeled as group2). The training set contained 3133 subjects, and the validation set contained 3175 subjects. The same analysis was done on each group.

Principle Component Analysis

A **pre-PCA** was done on the training set to test the number of PCs. Before running the pre-PCA, a descriptive analysis was done on all 64 measurements. It turned out that lnA24Ankle_Height and lnB183W100R_WristGirth had relatively large numbers of missing values. In addition, they were not primary measurements for pattern making. The values lnA24Ankle_Height and lnB183W100R_WristGirth were excluded from the pre-PCA, as well as from the final PCA. All of the 60 transformed values, along with the non-transformed BMI and Shoulder Degree values, were used as the variables in the data analysis.

The PCs' extraction was based on the eigenvalue. Any factor with an eigenvalue larger than one was exported as a principle component. The Varimax Rotation method and the exclude cases listwise method were applied. A coefficient matrix and a Scree plot were drawn.

Eight PCs were automatically extracted from the pre-PCA. The Pre-PC1 was primarily related to the weight and girth measurements and it explained over 37% of the total variance. The Pre-PC2 was primarily related to height measurements and it explained 22% of the total variance. The Pre-PC3 was primarily related to all waist length measurements and explained 7.4% of the total variance. The Pre-PC4 was primarily related to the shoulder slope measurements and explained 4% of the total variance. The last 4 PCs explained 13% of the total variance, with pre-PC5 primarily related to the lnB138W66R_SideWaist5ToHipPtr measurement, pre-PC6 primarily related to the lnB222W138R_FootWidth measurement, pre-PC7 primarily related to the lnB215W122R_Minimum_Leg_Girth measurement and pre-PC8 primarily related to lnB140W66aR_SideWaist5ToSeat measurement. Figure 26 is the Scree plot for the pre-PCA and Figure 27 is the screen shot of the total variance explanation chart from SPSS.

Considering that the variance was explained by the PCs and the total number of sizes for the final standard, the decision was made to set the number of PCs to two. This represented most of the height and girth measurements.

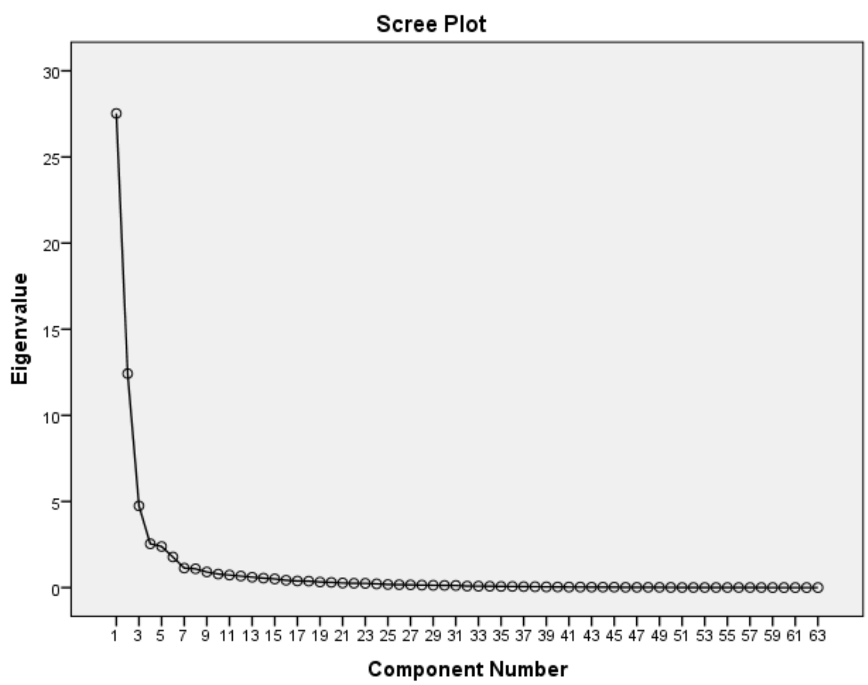


Figure 26. Scree plot of pre-PCA

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	27.526	43.691	43.691	27.526	43.691	43.691	23.728	37.663	37.663
2	12.422	19.717	63.409	12.422	19.717	63.409	14.426	22.898	60.561
3	4.743	7.528	70.937	4.743	7.528	70.937	4.679	7.427	67.989
4	2.543	4.036	74.973	2.543	4.036	74.973	2.551	4.050	72.039
5	2.385	3.786	78.759	2.385	3.786	78.759	2.494	3.959	75.997
6	1.777	2.820	81.579	1.777	2.820	81.579	2.183	3.466	79.463
7	1.130	1.794	83.373	1.130	1.794	83.373	1.872	2.971	82.433
8	1.090	1.730	85.103	1.090	1.730	85.103	1.682	2.669	85.103

Figure 27. Total variance explained by principle components in pre-PCA

Final **PCAs** were done on the training set and validation set with the number of PCs fixed to two. The Varimax Rotation method and the exclude cases list wise method were used. Factor scores were saved using the regression method. PC1 and PC2 were extracted for both groups. PC1 represented most of the girth measurements and PC2 represented most of the height measurements. They were orthogonal with each other. Table 8 lists the mean,

Table 8. Comparison of PCs between the training set and validation set

	Training Set		Validation Set	
	PC1 (girth related)	PC2 (height related)	PC1 (girth related)	PC2 (height related)
Valid N	3112	3112	3147	3147
Missing N	21	21	28	28
Mean	0.00000	0.00000	0.00000	0.00000
Median	-0.12725	0.01789	-0.11332	0.01474
Std. Deviation	1.00000	1.00000	1.00000	1.00000
Skewness	0.61200	-0.05900	0.57900	-0.11800
Std. Error of Skewness	0.04400	0.04400	0.04400	0.04400
Minimum	-2.33537	-3.43261	-2.61653	-3.61687
Maximum	4.02805	3.55563	4.71550	2.99479
Range	6.36342	6.98823	7.33204	6.61166
2.5-percentile	-1.61376	-1.96635	-1.59322	-2.01972
97.5-percentle	2.28895	1.91526	2.27029	1.86958

median, std. deviation, skewness, std. error of skewness, range, minimum, maximum, 2.5-percentile and 97.5-percentile for two PCs in both sets. Because PCs were standardized, the mean value for them was 0 and the std. deviation was one. In the validation set, PC1 tended to have a larger range with a smaller minimum value and a larger maximum value than PC1 in the training set.

Linear Regression

Within the training set and validation set, linear regressions were firstly done using all the subjects' data and then done with the subjects for the top three shapes separately. The top three shapes were rectangle, spoon and bottom hourglass. The number of subjects that fell within the top three shape categories for each data set is listed in Table 9. Finally, both sets had four series of regressions, which were all subject regressions, rectangle shape regression, spoon shape regression and bottom hourglass shape regression.

Table 9. Number of subjects of the top three body shapes in the training set and the validation set

	Total subject number	Rectangle	Spoon	Bottom Hourglass
Training group	3133	1345	790	303
Validation group	3175	1328	792	311

The linear regression analysis was done using PC1 and PC2 as independent variables (predictors) and the 62 natural log transformed variables, plus the untransformed BMI and Shoulder Slope as dependent variables. The stepwise method was applied using a probability of F as the stepping method criteria with 0.05 as the entry level and 0.1 as the removal level. Missing values were excluded pairwise. The statistics obtained included R, R square, adjusted R square, sig. F change and coefficients. Coefficients were then used to form formulas for measurement calculations. Codes used in SPSS to guide the linear regression are included in Appendix D. Coefficients for regression with all subjects can be found in Appendix E.

Within the linear regressions for all subjects of the training set, 48 variables out of 64 had an adjusted R square value larger than 0.5. Twelve variables' adjusted R^2 values were smaller than 0.3. All 12 variables are shown in Table 10. In the linear regression for all subjects in the validation set, there were 11 variables that had adjusted R2 values smaller than 0.3. The 11 variables in the validation set were all included in the 12 variables for the training set.

Pearson correlation analysis was done for all six drop values along with PC1 and PC2. The correlations matrix is shown in Table 11. A separate linear regression was done in the training set for the six drop values with PC1 and PC2 as independent variables. The adjusted R^2 results are listed in Table 12.

Table 10. Variables with adjusted R^2 values smaller than 0.3

Training Set	Adjusted R^2	Validation Set	Adjusted R^2
A32Shoulder_Slope_(degrees)	0.018	A32Shoulder_Slope_(degrees)	0.008
lnB131W61_FrontNecktoWaist5	0.059	lnB131W61_FrontNecktoWaist5	0.060
lnB140W66aR_SideWaist5ToSeat	0.064	lnB140W66aR_SideWaist5ToSeat	0.080
lnB104W41_Neck2Waist5Contoured_Back	0.083	lnB104W41_Neck2Waist5Contoured_Back	0.054
lnA26Waist6_Length_Back	0.096	lnA26Waist6_Length_Back	0.059
lnA25Waist_Length_Front	0.112	lnA25Waist_Length_Front	0.136
lnA24Ankle_Height	0.171	lnA24Ankle_Height	0.177
lnB117W55R_SideNeckToWaist5Straight	0.203	lnB117W55R_SideNeckToWaist5Straight	0.200
lnB222W138R_FootWidth	0.212	lnB222W138R_FootWidth	0.240
lnB67W15R_ArmscyeDepthFromBackNeck	0.244	lnB67W15R_ArmscyeDepthFromBackNeck	0.219
lnB138W66R_SideWaist5ToHipPtr	0.286	lnB138W66R_SideWaist5ToHipPtr	0.304
lnA29Cross_Chest_Width	0.293	lnA29Cross_Chest_Width	0.287

Table 11. Pearson correlations matrix of PCs and drop values

	PC1	PC2	Bust-Hips	Bust-Waist	Hips-Waist	Bust-Hips _Ln	Bust-Waist _Ln	Hips-Waist _Ln
PC1	1	0	0.083	-0.171	-0.227	0.2	-0.486	-0.565
PC2	0	1	-0.172	0.075	0.245	-0.163	0.061	0.189
Bust-Hips	0.083	-0.172	1	0.466	-0.704	0.986	0.323	-0.574
Bust-Waist	-0.171	0.075	0.466	1	0.3	0.453	0.931	0.373
Hips-Waist	-0.227	0.245	-0.704	0.3	1	-0.7	0.399	0.918
Bust-Hips_Ln	0.2	-0.163	0.986	0.453	-0.7	1	0.277	-0.623
Bust-Waist_Ln	-0.486	0.061	0.323	0.931	0.399	0.277	1	0.579
Hips-Waist_Ln	-0.565	0.189	-0.574	0.373	0.918	-0.623	0.579	1

Table 12 R^2 result of regressions to predict drop values

	Regression R^2			
	All data	**Rectangle**	**Spoon**	**Bottom Hourglass**
Bust-Waist	0.034	0.008	0.005	0.054
Bust-Waist_Ln	**0.239**	**0.284**	**0.259**	**0.360**
Hips-Waist	0.111	.922	0.077	0.008
Hips-Waist_Ln	**0.354**	**0.436**	**0.217**	**0.068**
Bust-Hips	0.036	0.941	0.057	0.063
Bust-Hips_Ln	**0.066**	**0.121**	**0.01**	**0.569**

Size Range and Intervals

The standard deviation (SD) method of analysis was used to set the sizing coverage for both sets. The mean±2SD was used on the height related variable PC2. However, because the SizeUSA data tended to have a larger girth measurement than the other sizing standard, the range of PC1 was fixed to [mean-2.3SD, mean+2SD] which added a size to the small side. PC2 was divided into 3 categories evenly, and they are petite, regular and tall. PC1 was divided into 14 categories evenly and were labeled from size 1 to size 14. In total, there were 42 sizes. Table 13 shows how the sizes were labeled and grouped. Because PC1 and PC2 were standardized variables, same values were used for labeling the training set and the validation set. Figure 28 illustrates the size bounds on histograms for PC1 and PC2 in the training set.

Table 14 shows the number of subjects that fell within each sizes. Once the cluster centers were decided, all measurements for each size were predicted based on the formulas from the linear regression analysis. The values were then rounded to the nearest 1/8 inch. A body sizing standard was then exported. Refer to Appendix F for sizing system details. Real means were extracted for each size and were compared with the predicted values. Table 15 shows comparisons between the real mean and the predicted mean for height, A1Bust, A2Waist (pants), A3High_Hip and A4Hips (largest circumference) for the no shape difference size results.

Table 13. Sizes labeling rules

	Label	**Center**	**Lower bound**	**Upper bound**
PC1	MIN	n/a	n/a	-2.30769
	1	-2.15385	-2.30769	-2.00000
	2	-1.84615	-2.00000	-1.69231
	3	-1.53846	-1.69231	-1.38462
	4	-1.23077	-1.38462	-1.07692
	5	-0.92308	-1.07692	-0.76923
	6	-0.61538	-0.76923	-0.46154
	7	-0.30769	-0.46154	-0.15385
	8	0.00000	-0.15385	0.15385
	9	0.30769	0.15385	0.46154
	10	0.61538	0.46154	0.76923
	11	0.92308	0.76923	1.07692
	12	1.23077	1.07692	1.38462
	13	1.53846	1.38462	1.69231
	14	1.84615	1.69231	2.00000
	MAX	n/a	2	n/a
	Label	**Center**	**Lower bound**	**Upper bound**
PC2	MIN	n/a	n/a	-2.00000
	Petite	-1.33333	-2.00000	-0.66667
	Regular	0.00000	-0.66667	0.66667
	Tall	1.33333	0.66667	2.00000
	MAX	n/a	2.00000	n/a

Compare Training Set and Validation Set

In order to test the validity and repeatability of the sizing creation method, the same analysis was done on the training data as was applied to the validation set. Sizing standards created from both sets were compared. Table 16 lists comparisons between the two data sets on height, A1Bust, A2Waist (pants), A3High_Hip and A4Hips (largest circumference) for the no shape difference size results.

Compare sizes from different body shape categories

As mentioned in the former section, regression analysis was done within the top three body shapes separately. Predicted results from different shapes were compared. Table 17 lists the predicted height, bust, waist (pants) and hips (largest circumference) values for the top three body shapes comparing them with the predicted values based on no shape difference. For compared measurements, refer to Appendix F.

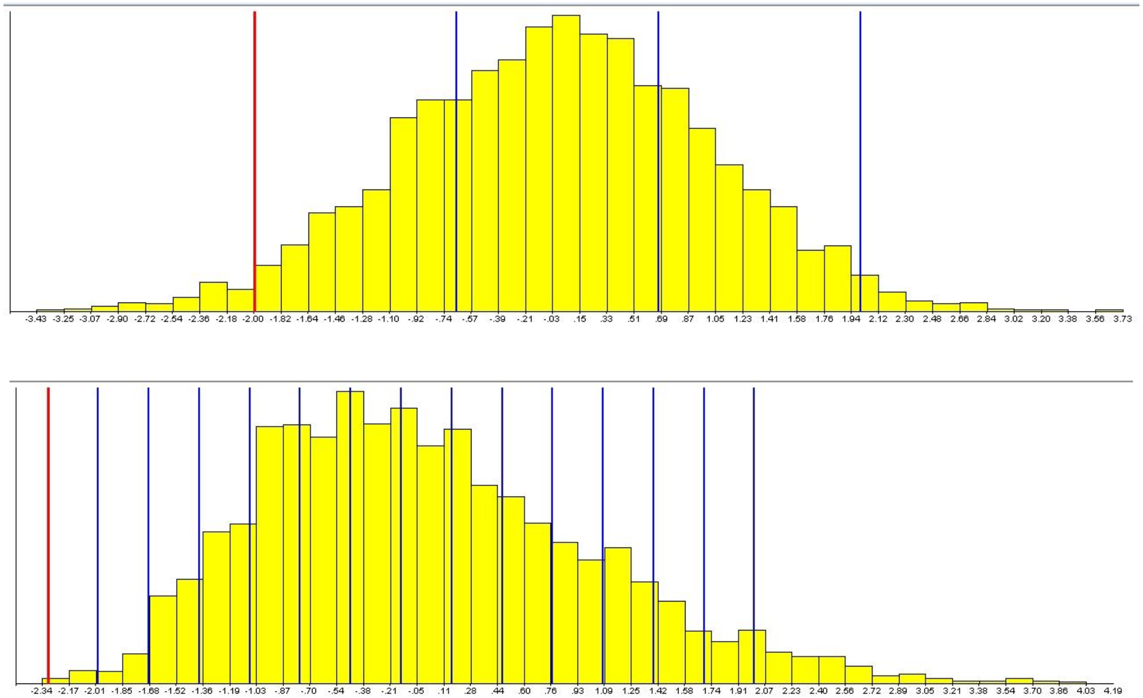


Figure 28. Size bounds on histograms of the training set

Table 14. The number of subjects fell within each size group

	min	1	2	3	4	5	6	7	8	9	10	11	12	13	14	max	total
Training Set: PC1																	
	min	1	2	3	4	5	6	7	8	9	10	11	12	13	14	max	total
PC2-1 Petite	1	5	7	35	56	70	80	81	93	88	51	51	44	24	16	22	724
PC2-2 Regular		6	16	63	107	179	193	196	159	149	118	92	88	41	40	69	1516
PC2-3 Tall		2	3	24	47	90	96	97	91	79	66	38	40	25	16	29	743
Validation Set: PC1																	
	min	1	2	3	4	5	6	7	8	9	10	11	12	13	14	max	total
PC2-1 Petite		2	15	31	58	65	80	71	93	69	64	40	36	29	21	19	693
PC2-2 Regular	1	4	24	49	119	162	195	203	164	159	139	106	70	59	51	57	1562
PC2-3 Tall		2	8	25	61	95	107	91	97	68	51	37	25	30	20	33	750

.

Table 15. Comparison between predicted values and real mean values

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
height: predicted	**63 3/8**	**63 3/8**	**63 4/8**	**63 5/8**	**63 5/8**	**63 6/8**	**63 6/8**	**63 7/8**	**64**	**64**	**64 1/8**	**64 1/8**	**64 2/8**	**64 3/8**
height: real	62 4/8	63 1/8	63 3/8	63 5/8	63 5/8	63 6/8	63 7/8	64	63 7/8	63 7/8	64	64 3/8	64 4/8	64 1/8
A1Bust: predicted	**31 4/8**	**32 5/8**	**33 6/8**	**35**	**36 2/8**	**37 5/8**	**38 7/8**	**40 3/8**	**41 6/8**	**43 2/8**	**44 7/8**	**46 4/8**	**48 1/8**	**49 7/8**
A1Bust: real	31 5/8	32 5/8	33 6/8	34 6/8	36 1/8	37 5/8	39	40 4/8	41 6/8	43 2/8	45	46 4/8	48 1/8	49 4/8
A2Waist: predicted	**24 7/8**	**26**	**27 1/8**	**28 3/8**	**29 5/8**	**31**	**32 3/8**	**33 7/8**	**35 3/8**	**37**	**38 5/8**	**40 3/8**	**42 2/8**	**44 1/8**
A2Waist: real	25 5/8	26	27 3/8	28 4/8	29 5/8	31	32 2/8	33 7/8	35 1/8	37	38 7/8	40 4/8	42 6/8	44 1/8
A3High_Hip: predicted	**30 2/8**	**31 3/8**	**32 5/8**	**34**	**35 3/8**	**36 6/8**	**38 2/8**	**39 6/8**	**41 3/8**	**43**	**44 6/8**	**46 4/8**	**48 3/8**	**50 3/8**
A3High_Hip: real	31 1/8	31 3/8	33	33 7/8	35 3/8	36 7/8	38 2/8	40 1/8	41 3/8	43 2/8	44 5/8	46 6/8	48 4/8	50
A4Hips: predicted	**34 1/8**	**35 2/8**	**36 3/8**	**37 5/8**	**38 6/8**	**40**	**41 3/8**	**42 5/8**	**44**	**45 4/8**	**46 7/8**	**48 3/8**	**50**	**51 5/8**
A4Hips: real	35 4/8	35 6/8	36 5/8	38 1/8	39 1/8	40 1/8	41 2/8	42 4/8	43 4/8	45 2/8	46 5/8	48 2/8	49 7/8	52 1/8

Table 16. Comparison between results from the training set and the results from the validation set

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
height: group1	**63 3/8**	**63 3/8**	**63 4/8**	**63 5/8**	**63 5/8**	**63 6/8**	**63 6/8**	**63 7/8**	**64**	**64**	**64 1/8**	**64 1/8**	**64 2/8**	**64 3/8**
height: group2	63 2/8	63 2/8	63 3/8	63 4/8	63 5/8	63 5/8	63 6/8	63 7/8	63 7/8	64	64 1/8	64 1/8	64 2/8	64 3/8
A1Bust: group1	**31 4/8**	**32 5/8**	**33 6/8**	**35**	**36 2/8**	**37 5/8**	**38 7/8**	**40 3/8**	**41 6/8**	**43 2/8**	**44 7/8**	**46 4/8**	**48 1/8**	**49 7/8**
A1Bust: group2	31 4/8	32 6/8	33 7/8	35 1/8	36 3/8	37 6/8	39 1/8	40 4/8	42	43 4/8	45 1/8	46 6/8	48 3/8	50 1/8
A2Waist: group1	**24 7/8**	**26**	**27 1/8**	**28 3/8**	**29 5/8**	**31**	**32 3/8**	**33 7/8**	**35 3/8**	**37**	**38 5/8**	**40 3/8**	**42 2/8**	**44 1/8**
A2Waist: group2	24 6/8	26	27 1/8	28 3/8	29 6/8	31 1/8	32 4/8	34	35 5/8	37 2/8	38 7/8	40 6/8	42 5/8	44 5/8
A3High_Hip: group1	**30 2/8**	**31 3/8**	**32 5/8**	**34**	**35 3/8**	**36 6/8**	**38 2/8**	**39 6/8**	**41 3/8**	**43**	**44 6/8**	**46 4/8**	**48 3/8**	**50 3/8**
A3High_Hip: group2	30 1/8	31 3/8	32 5/8	34	35 3/8	36 7/8	38 3/8	39 7/8	41 5/8	43 2/8	45	46 7/8	48 7/8	50 7/8
A4Hips: group1	**34 1/8**	**35 2/8**	**36 3/8**	**37 5/8**	**38 6/8**	**40**	**41 3/8**	**42 5/8**	**44**	**45 4/8**	**46 7/8**	**48 3/8**	**50**	**51 5/8**
A4Hips: group2	34 2/8	35 3/8	36 4/8	37 6/8	38 7/8	40 2/8	41 4/8	42 7/8	44 2/8	45 6/8	47 2/8	48 6/8	50 3/8	52

Note: group1 represent the training set and group2 represents the validation set.

Table 17. Comparison of predicted values between different body shapes

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Height	**All**	**63 3/8**	**63 3/8**	**63 4/8**	**63 5/8**	**63 5/8**	**63 6/8**	**63 6/8**	**63 7/8**	**64**	**64**	**64 1/8**	**64 1/8**	**64 2/8**	**64 3/8**
	Rect	63 3/8	63 3/8	63 4/8	63 5/8	63 5/8	63 6/8	63 6/8	63 7/8	64	64	64 1/8	64 2/8	64 2/8	64 3/8
	Spoon	63 5/8	63 5/8	63 5/8	63 5/8	63 6/8	63 6/8	63 6/8	63 7/8	63 7/8	63 7/8	63 7/8	64	64	64
	BH	63	63 1/8	63 2/8	63 3/8	63 3/8	63 4/8	63 5/8	63 6/8	63 7/8	64	64	64 1/8	64 2/8	64 3/8
Bust	**All**	**31 4/8**	**32 5/8**	**33 6/8**	**35**	**36 2/8**	**37 5/8**	**38 7/8**	**40 3/8**	**41 6/8**	**43 2/8**	**44 7/8**	**46 4/8**	**48 1/8**	**49 7/8**
	Rect	32	33 1/8	34 2/8	35 4/8	36 6/8	38 1/8	39 4/8	40 7/8	42 3/8	43 7/8	45 4/8	47 1/8	48 7/8	50 5/8
	Spoon	30 7/8	32	33 1/8	34 2/8	35 4/8	36 6/8	38 1/8	39 3/8	40 7/8	42 2/8	43 6/8	45 3/8	47	48 5/8
	BH	30 6/8	31 6/8	32 7/8	34 1/8	35 2/8	36 4/8	37 7/8	39 1/8	40 4/8	42	43 4/8	45	46 5/8	48 2/8
Waist	**All**	**24 7/8**	**26**	**27 1/8**	**28 3/8**	**29 5/8**	**31**	**32 3/8**	**33 7/8**	**35 3/8**	**37**	**38 5/8**	**40 3/8**	**42 2/8**	**44 1/8**
	Rect	25 4/8	26 5/8	27 6/8	29	30 2/8	31 4/8	32 7/8	34 3/8	35 7/8	37 3/8	39	40 6/8	42 4/8	44 3/8
	Spoon	24 5/8	25 5/8	26 6/8	27 7/8	29 1/8	30 3/8	31 6/8	33 1/8	34 4/8	36	37 4/8	39 1/8	40 7/8	42 5/8
	BH	25	26 1/8	27 2/8	28 3/8	29 5/8	30 7/8	32 1/8	33 4/8	35	36 4/8	38	39 5/8	41 3/8	43 1/8
Highhip	**All**	**30 2/8**	**31 3/8**	**32 5/8**	**34**	**35 3/8**	**36 6/8**	**38 2/8**	**39 6/8**	**41 3/8**	**43**	**44 6/8**	**46 4/8**	**48 3/8**	**50 3/8**
	Rect	30 1/8	31 3/8	32 5/8	33 7/8	35 2/8	36 5/8	38	39 4/8	41 1/8	42 6/8	44 3/8	46 1/8	48	49 7/8
	Spoon	30 5/8	32	33 2/8	34 5/8	36 1/8	37 4/8	39 1/8	40 6/8	42 3/8	44 1/8	46	47 7/8	49 7/8	51 7/8
	BH	29 3/8	30 5/8	31 7/8	33 2/8	34 5/8	36	37 5/8	39 1/8	40 6/8	42 4/8	44 2/8	46 1/8	48 1/8	50 1/8
Hips	**All**	**34 1/8**	**35 2/8**	**36 3/8**	**37 5/8**	**38 6/8**	**40**	**41 3/8**	**42 5/8**	**44**	**45 4/8**	**46 7/8**	**48 3/8**	**50**	**51 5/8**
	Rect	33 4/8	34 4/8	35 5/8	36 6/8	38	39 2/8	40 4/8	41 6/8	43 1/8	44 4/8	45 7/8	47 3/8	48 7/8	50 3/8
	Spoon	34 5/8	35 7/8	37 1/8	38 3/8	39 6/8	41 1/8	42 4/8	44	45 4/8	47 1/8	48 6/8	50 3/8	52 1/8	54
	BH	35 2/8	36 3/8	37 5/8	38 7/8	40 1/8	41 4/8	42 7/8	44 2/8	45 6/8	47 2/8	48 7/8	50 4/8	52 1/8	53 7/8

Note: "All" represents for all subjects without consideration of body shapes; "Rect" represents for the rectangle body shape; "Spoon" represents for the spoon body shape; "BH" represent for the bottom hourglass body shape.

Compare Created Sizing System with ASTM D5585-11^{e1}

In order to test whether the new created sizing system was better than the published standard, a comparison was made between the created sizing standard and ASTM D5585-11^{e1}. Subjects from the validation set were used as participants for this comparison to avoid bias. The total number of subjects was 3,175.

The ASTM D5585-11^{e1} standard only covers the regular height group with 12 sizes and the waist girth measurement ranges only from 23.785" to 40.5" for the 12 sizes. Therefore, only sizes 1 through 12 from the regular height group in the created sizing system were selected for comparison. As described in the methodology, subjects were labeled if they fit the size criteria. Four groups of comparisons were made with different a number of measurements set as the criteria. The result is shown in Table 18 through Table 21. The total labeled subjects is the number of subjects that had a size label. This number is equal to or is smaller than the sum of total number for each body shape, because one subject may have more than one label.

Table 18. Compare Created sizing system with ASTM D5585-11^{e1} with 2 criteria variables

2 measurements: Height and Waist (ASTM definition)															
		00	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**total**	**total labeled subjects**
ASTM	ASTM-Curvy	3	11	10	33	54	96	149	202	155	175	140	95	1123	1124
	ASTM-Straight	0	1	3	12	19	46	115	199	196	180	172	124	1067	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**	**total labeled subjects**
Created Sizing System	no shape difference	8	25	78	135	158	189	160	135	148	121	106	70	1333	1333
	Rectangle	21	41	104	131	166	189	151	129	141	111	99	65	1348	1428
	Spoon	5	23	51	118	137	184	170	146	130	134	103	91	1292	
	Bottom Hourglass	9	27	75	130	151	176	160	124	147	122	95	77	1293	

Table 19. Compare Created sizing system with ASTM D5585-11^{e1} with 3 criteria variables

3 measurements: Height, Bust and Waist (ASTM definition)

		00	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**total**	**total labeled subjects**
ASTM	ASTM-Curvy	0	2	0	8	10	17	34	77	43	71	43	45	350	531
	ASTM-Straight	0	0	0	2	2	9	27	46	41	51	37	33	248	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**	**total labeled subjects**
Created Sizing System	no shape difference	2	7	22	28	43	49	49	32	57	26	43	27	385	385
	Rectangle	6	9	25	28	43	65	49	33	49	37	34	22	400	
	Spoon	1	7	9	28	31	45	50	41	32	49	32	28	353	632
	Bottom Hourglass	0	7	11	21	41	48	36	34	32	39	31	24	324	

Table 20. Compare Created sizing system with ASTM D5585-11^{e1} with 4 criteria variables

4 measurements: Height, Bust, Hips (ASTM definition) and Waist (ASTM definition)

		00	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**total**	**total labeled subjects**
ASTM	ASTM-Curvy	0	0	0	1	2	2	11	18	17	20	14	15	100	123
	ASTM-Straight	0	0	0	1	0	0	3	5	3	7	8	5	32	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**	**total labeled subjects**
Created Sizing System	no shape difference	0	2	4	7	13	10	12	11	15	9	8	3	94	94
	Rectangle	2	2	3	4	5	13	12	11	8	8	5	4	77	
	Spoon	0	1	3	13	10	10	11	7	7	5	0	2	69	182
	Bottom Hourglass	0	3	2	9	9	11	4	11	7	2	0	3	61	

Table 21. Compare Created sizing system with ASTM D5585-11^{e1} with 5 criteria variables

5 measurements: Height, Bust, Highhip, Hips (ASTM definition) and Waist (ASTM definition)

		00	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**total**	**total labeled subjects**
ASTM	ASTM-Curvy	0	0	0	0	1	0	5	7	7	6	3	5	34	38
	ASTM-Straight	0	0	0	1	0	0	1	1	1	2	1	1	8	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**	**total labeled subjects**
Created Sizing System	no shape difference	0	1	1	1	5	4	3	5	5	5	6	3	39	39
	Rectangle	2	2	1	2	3	4	5	4	4	3	2	3	35	
	Spoon	0	0	3	5	3	7	6	3	3	0	0	0	30	82
	Bottom Hourglass	0	2	0	0	1	5	1	2	2	2	0	2	17	

Summary of Results

To solve research question number one, a series of steps were done to create a sizing system. All of the 64 key measurements were selected from the whole data set to simplify the analysis. Ten demographic variables, one body shape variable and six drop values were added to the analyzed data. Errors within the data were manually detected and deleted. Natural log transformations were done for the 62 key measurements. BMI and A32Shoulder_Slope_(degrees) were excluded from the transformation because they were calculation and degree measurements. All of the selected data were then randomly grouped into a training set and a validation set. The training set was used to generate the sizing system, while the validation set was used to test the stability of the creation process.

Descriptive analysis was applied to check the number of missing values for each variable and it turned out that lnA24Ankle_Height and lnB183W100R_WristGirth had a large number of missing values. Therefore, they were excluded from both the pre-PCA and the PCA. Sixty transformed measurements, along with the non-transformed BMI and A32Shoulder_Slope_(degrees) were selected as the variables for the pre-PCA and PCA.

The pre-PCA was done with the training data to help decide the number of PCs. The decision was made to extract 2 PCs. PCA was done with the number of factors set to two and The PCs' factor scores were saved using the regression method. The two PCs were the control variables.

A series of multivariate linear regressions were done with PC1 and PC2 set as the independents and the 62 transformed measurements plus BMI and A32Shoulder_Slope_(degrees) as dependents. Adjusted R^2 and coefficients were saved to verify the performance of the regression and to form the equations of the measurement calculation. This step was done in both the training data and the validation data and for the top three shapes as well as for the data with no shape difference.

The next step was to determine the PC1 and PC2 values for each size. The standard deviation (SD) method was used to set the range of size coverage. The mean ± 2SD was used for PC2 (height related PC) and [mean-2.3SD, mean+2SD] was used to set the range of PC1 (girth related PC). The reason for adding 0.3SD to the small side of the range was because the current standard tended to have smaller girth measurements than the SizeUSA data. The PC2 was then divided into three groups, labeled as tall, regular and petite and the PC1 was divided into 14 groups, labeled using digits from 1 to 14. The total number of sizes was 42 for each shape category. The step was done in both data sets.

The center value of PC1 and PC2 was then used to calculate all 64 measurements. Transformed measurements were then transformed back. The final sizing system results included 42 sizes. There were three height groups and there were 12 sizes for each height group. Every measurement in each size had four values and they were 1) the value of the size center for all data with no shape difference, 2) the value of the size center for the rectangle body shape, 3) the value of the size center for the spoon body shape and 4) the value of the size center for the hourglass body shape. Sizing system results were extracted from both data sets and were compared to see if there was any large difference between them. It turned out that they were similar to each other.

The created sizing system was compared with ASTM D5585-11^{e1} by counting the number of subjects that fell within each size. Four sets of comparison were made and the results showed that the created body sizing system with shape information would fit the population better.

CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND FUTURE RESEARCH

Brief Review of Study

The literature review showed that consumers were not satisfied with the fit of apparel. Reasons included outdated grading rules used by companies, a limited number of sizes choices for ready-to-wear and the consumers' increasing expectations. Moving into the 21st century, the apparel industry's trend is towards mass customization. Solving the fitting issue has become an urgent issue for companies. Body measurement and ease design are two key factors for the fit of apparel. Because it was expensive and time consuming for large scale anthropometric surveys, the majority of past sizing standards were based on outdated body measurement data. With the development of the 3D scanning technique, body measurements data will become more accessible. Updating the body sizing system with the new data is an important issue for the future.

The idea of body shape began to be analyzed in the apparel industry in 1970s. Drop value is a variable commonly used to define body shape. Simmons (2003) defined nine body shapes to cover the whole population. Song & Ashdown (2012) found that patterns altered from on block based on body shape would provide a better fit than a pattern altered from a regular block.

ASTM has studied sizing and published sizing standards for years, however, the fit of apparel does not seem to have improved. The reason could be either the standard does not fit the population very well or the sizing standard is not widely used by companies. A comparison between a sizing system created from the most recent anthropometric data with the ASTM sizing standard gave a clue about the sizing situation in the market.

Discussion of Results

Discussion of the Development Process of the Sizing System

To create a sizing system from a SizeUSA data, key measurements were first selected to minimize the number of variables. The selection was based on past sizing standards. Measurements included in ASTM 5219-09 and ISO 8559 were selected. SizeUSA data did not cover all the measurements listed in ASTM 5219-09 and ISO 8559. Because the Female Figure Identification Technique (FFIT©) for Apparel was used to identify the body shape. Measurements used as criteria were also included in the key measurements group. A total number of 64 measurements, one body shape item, ten demographic items and six drop values formed the final analyzed data. The six drop values were used to test the relationships when body shapes classification was necessary or not. Errors were detected and deleted manually.

Natural log transformations were done for the 62 measurements, except for BMI and A32Shoulder_Slope_(degrees), so that interval can be evenly distributed later. The result of skewness comparison between transformed measurements and non-transformed measurements showed that the skewness decreased after the transformation and the histograms of transformed measurements looked more normalized. This proved that it was necessary to do the transformation.

In order to test the validity of the method used to create the sizing system, 6308 subjects were randomly divided into a training group and a validation group. The training group had 3133 subjects and the validation group had 3175 subjects. Each group went through the same analysis process, and the results were compared. If the results were similar with each other, then it meant that the method was repeatable and reliable.

The first step for the analysis was the pre-PCA done for the training set on the 60 transformed measurements, BMI and A32Shoulder_Slope_(degrees). lnA24Ankle_Height and lnB183W100R_WristGirth were excluded because they had too many missing values. The pre-PCA was applied to help determine the number of PCs used for clustering. The number was finally set to 2. This was because if only one PC was selected, it would only cover the variance of some girth related measurements. With the second PC, height related measurements could be included too and this followed most published sizing standards. However, if the third PC was added, it would increase the number of sizes dramatically. Therefore, only 2 PCs were selected.

The final PCA was done in both groups with the number of factors set to two. Factor scores were saved as new variables. Multivariate linear regressions were done by using PC1 and PC2 as independents and all 62 measurements were transformed, along with BMI and A32Shoulder_Slope_(degrees). Four series of multivariate linear regressions were done separately with the whole data set, the rectangle body shape data set, the spoon body shape data set and the bottom hourglass body shape data set. This was because for different body shape data, the calculated coefficients were different and it would lead different drop values. This step was done in both the training group and the validation group.

Separate regressions and Pearson correlation analysis was done with the whole data from the training set to test the co-relationship between PCs and drop values. It turned out that PC1 was somewhat related to the drop value of the transformed bust to waist and the drop value of the transformed hips to waist. The co-relationship between PC1 and the other drop value was not strong. However, PCs were not able to predict drop values very well by the multivariate linear regression method. This proved that it was necessary to divide subjects into groups based on body shapes (drop values).

Sizes centers were then determined by evenly distributed the PC1 and PC2 within the size coverage. The size coverage was set to be mean ± 2SD for PC2 and [mean-2.3SD, mean+2SD] for PC1. An additional 0.3SD was added to the small side of PC1 which means an extra size was added. This was because the published sizing standard tended to start from a smaller size. PC2 was divided into three groups and PC1 was divided into 14 groups. The number of groups was determined by the trial and error method. If PC1 was divided into 15 groups the interval of the waist measurement from 28" to 35" would be too small to compare to the published sizing standard.

Once the size centers were decided, the measurement values for each size were calculated based on formulas generated from the regression analysis. Transformed measurements were then transformed back. All subjects were labeled with a size number based on their PCs score. The number of subjects that fell within each size were counted and the means of the measurements for each size were calculated.

Discussion of the Comparisons and Sizing Strategy

By comparing the real mean with the predicted mean, we found that when the size number was below 6, the predicted values tended to be smaller than the real mean values. Between size 6 to size 10, both values were about the same. When the size number was greater than 10, the predicted values tended to be larger than the real mean value. This was because when the size number was below 6, within the size, there were more subjects distributed on the larger end of the size than on the smaller end. This would increase the mean value. Whereas, when the size number was greater than 10, more subjects was distributed on the small side of the size range, and this made the mean value smaller than the median value. A sizing strategy for this would be to increase the measurement's value for the small sizes so that it will serve the population better.

By comparing the training data result with the validation data result, we found that two results were similar with each other. This proved that the method used in the study was repeatable, reliable and can be used in future anthropometric data analysis.

By comparing the predicted values from different shape categories, we found that the values for the same size from different shape categories differed more on measurements related to waist, bust and hips. For example, the difference between bust measurement values from each size category was about 0.5" to 1" for small sizes and about 1" to 2"for large sizes. For some other measurements, such as A7Armscye, the values of the same measurement in the same size between different shape groups were about the same. This was because the body shapes were defined to differ the drop value of bust to waist, the drop value of bust to hips and the drop value of hips to waist. The results also prove that the body shape categorization method works.

By comparing the ASTM D5585-11^{e1} standard with the sizing system created in the study, we found that the new created sizing system did a better job than the ASTM standard on predicting subjects from the validation set. Twelve sizes from the regular height group in the created sizing system were picked to match the number of sizes built in the ASTM standard. Subjects were labeled with a size number if they met the criteria. Numbers of labeled subjects were counted to demonstrate the fit of sizing systems. Four sets of comparisons were done with different numbers of criteria measurements. The comparisons were done between the ASTM standard, created sizing system with no body shape information and created sizing system with body shape information.

The first one used height (stature) and waist (ASTM definition) as criteria measurements. The result showed that the created sizing system with body shape information performed the best with 1428 labeled subjects, followed by the created sizing system without shape information with 1333 subjects labeled, followed by ASTM standard with 1124 subjects labeled. The reason for this was because the created sizing system had a wider height range than the ASTM standard.

The second one used height, bust and waist (ASTM definition) as criteria measurements. Within the result, the created sizing system was the best with 632 subjects , followed by ASTM standard with 531 subjects, followed by the created sizing system without shape information with 385 subjects. The reason why ASTM was higher was because there were two shapes in ASTM and it proved that sizing system with the inclusion of shapes would fit the population better.

The third one used height, bust, hips (ASTM definition) and waist (ASTM definition) and the fourth one used height, bust, highhip, hips (ASTM definition) and waist (ASTM definition). Less than 100 subjects were labeled when five criteria measurements were used. The created sizing system with shape information ranked at the first place again with 82 subjects covered and the created sizing system without shape information ranked the second with 39 subjects covered. The ASTM standard labeled only 38 subjects. This demonstrated that the created sizing system did a better job for fitting multi-measurements. It also demonstrated that with a limited number of sizes, it was hard to fit subjects for more than four measurements. Customization or alterations were needed for better fit.

In summary, compared to ASTM standard, the ASTM D5585-11^{e1} was not so bad and it represented part of the population. Second, a sizing system with body shape information works better than a sizing system created from average values. By using PCs to group sizes, many measurements can be considered at the same time. When the number of criteria measurements increased, the created sizing system tended to work better than the ASTM standard. However, both the ASTM standard and the created sizing system can only cover a small number of subjects when using six criteria measurements. This means that it is necessary to apply mass customization if a company wants to fit the population very well patterns can be altered from sizes in the created sizing system for this purpose.

Response to Research Questions

1. *Can the SizeUSA data be used to create a flexible women's body sizing system that will represent a large population?*

   Yes. The method used in the paper to create a sizing system was repeatable and applicable based on the comparison result of the training set and the validation set. The sizing system covers 95% of PC2 and more than 97.5% of PC1.

   a) *What are the key measurements for a sizing system?*

Sixty-four measurements that have been used in past sizing standards were used as important measurements to create a sizing system. Some of these dimensions were criteria measurements used to define body shape.

b) *What are the control variables?*

Two Principle Components were calculated by the transformed key measurements. PC1 was equivalent to a height dimension. PC2 was equivalent to a waist girth dimension.

c) *What are the key differences between different body shapes that help define a sizing system?*

The main difference would be the regression coefficients for the bust, waist and hips related measurements, which lead to a different value for the size centers.

d) *How were the intervals between each size created?*

Mean±2SD was used to set the range of PC2 and [mean-2.3SD, mean+2SD] was used to set the range of PC1. Three groups were created based on PC2 and this was because PC2 was height related and there was a common group number used for stature. PC1 was divided into 14 groups and it was referred to on the interval used in ASTM standards.

e) *How does the created sizing system work, compared to ASTM D5585-11^{e1}?*

Overall, the three shape sizing systems provided a better fit than the two shape ASTM D5585-11^{e1} system for subjects in the validation set.

2. *What is a sizing strategy that could be used by the industry based on the analysis of SizeUSA and body shapes?*

This study has demonstrated that a sizing system that includes body shape information would work better than a sizing system with no body shape information.

To answer research question number two, the sizing systems designed in this study can be used to work as the sizing library for companies when they select sizes related to their target consumers and generate patterns based on the body sizes. The size library can also work for the mass customized sizing strategy.

Conclusion and Implication

In conclusion, sizing systems were created in this study. The sizing systems were in four categories, the average shape category, the rectangle shape category, the spoon shape category and the bottom hourglass shape category. Each category was formed by three height groups and within each height group, 14 sizes were designed. The method used for creating the sizing system was tested for repeatability and the created sizing system was proved to serve the validation subjects better than ASTM D5585-11^{e1} standard. The body shape categories were tested to determine that they were important for size design.

This study is extremely beneficial to the apparel industry. By using the created sizing systems, companies can build their own sizing library when the anthropometric data becomes more accessible. With the created sizing systems, companies can improve the fit of their apparel and also to build a mass customization business from it.

Future Research

This study has alluded to several areas for future research. This study focused on SizeUSA data, however, the method can be used to study any other anthropometric data set and help in creating sizing systems so as to improve the fit of apparel. For example, the sizing creation method can be used to study difference between populations in difference countries and help set an international sizing system.

All of the 64 measurements used in the PCA weighted evenly, while they were not necessarily of the same importance. In the future study, fewer measurements can be used to generate PCs. A combination of different measurements can be applied and compared to see which combination works better.

Only three out of nine body shapes were studied in the paper. More studies can be done on the other body shapes. Also, studies can be focused on demographic differences, for example, how sizes differ between people from various age groups.

An additional aspect to study would be to determine the best way to apply the sizing system. Because sizes were divided based on measurements and body shapes, how size information can be explained to consumers clearly and easily is important. Also, because ready-to-wear cannot achieve perfect fit, solving the problem of how a sizing system can be applied to mass customization is beneficial.

REFERENCES

Aldrich, W. (2000). Tailors' cutting manuals and the growing provision of popular clothing 1770-1870: Falling apart like a ready-made. *Textile history*, *31*(2), 163–201.

Aldrich, W. (2003). The Impact of Fashion on the Cutting Practices for the Woman's Tailored Jacket 1800-1927. *Textile History*, *34*(2), 134–170. doi:10.1179/004049603235001580

Aldrich, W. (2007). History of sizing systems and ready-to-wear garments. *Sizing in Clothing: Developing Effective Sizing Systems for Ready-to-wear Clothing, Cambridge: Woodhead Publishing Limited*, 1–56.

Alexander, M., Connell, L. J., & Presley, A. B. (2005). Clothing fit preferences of young female adult consumers. *International Journal of Clothing Science and Technology*, *17*(1), 52–64. doi:10.1108/09556220510577961

Anderson, L. J., Brannon, E. L., Marshall, T., Staples, N., Grasso, M., Butenhoff, P., & Beninati, M. (1997). Discovering the process of mass customization: A paradigm shift for competitive manufacturing. Retrieved from http://infohouse.p2ric.org/ref/08/07074.pdf

Anderson-Connell, L. J., Ulrich, P. V., & Brannon, E. L. (2002). A consumer-driven model for mass customization in the apparel market. *Journal of Fashion Marketing and Management*, *6*(3), 240–258. doi:10.1108/13612020210441346

Armstrong, H. J. (c2010.). *Patternmaking for fashion design* (5th ed.). Upper Saddle River, N.J.: Pearson Education/Prentice Hall,. Retrieved from http://catalog.lib.ncsu.edu/record/NCSU2239755

Ashdown, S., & Loker, S. (2010). Mass-customized Target Market Sizing: Extending the Sizing Paradigm for Improved Apparel Fit. *Fashion Practice: The Journal of Design, Creative Process & the Fashion*, *2*(2), 147–174. doi:10.2752/175693810X12774625387396

Ashdown, S. P. (1998). An investigation of the structure of sizing systems: A comparison of three multidimensional optimized sizing systems generated from anthropometric data with the ASTM standard D5585-94. *International Journal of Clothing Science and Technology*, *10*(5), 324–341. doi:10.1108/09556229810239324

Ashdown, S. P., & DeLong, M. (1995). Perception testing of apparel ease variation. *Applied Ergonomics*, *26*(1), 47–54. doi:10.1016/0003-6870(95)95750-T

ASTM. (2013, September 30). ASTM International - About ASTM International. Retrieved September 30, 2013, from http://www.astm.org/ABOUT/overview.html

Bradley, P. S., & Fayyad, U. M. (1998). Refining Initial Points for K-Means Clustering. In *ICML* (Vol. 98, pp. 91–99). Retrieved from ftp://ftp.research.microsoft.com/pub/tr/.../TR-98-36.pdf

Byfield, R. (1825). *Sectum: the universal directory in the art of cutting*.

Chen-Yu, H. J., Williams, G., & Kincade, D. H. (1999). Determinants of Consumer Satisfaction/Dissatisfaction with the Performance of Apparel Products. *Family and Consumer Sciences Research Journal*, *28*(2), 167–192. doi:10.1177/1077727X99282003

Choy, R., & Loker, S. (2004). Mass Customization of Wedding Gowns: Design Involvement on the Internet. *Clothing and Textiles Research Journal*, *22*(1-2), 79–87. doi:10.1177/0887302X0402200110

Chun, J. (2007). Communication of sizing and fit. *Sizing in clothing. Developing effective sizing systems for ready-to-wear clothing*, 220–245.

Cook. (1826). *The London and Paris union rule, or, The tailor's assistant and unerring instructor: containing a synthesis of the art of cutting to fit the human form with ease and elegance: designed upon geometrical principles and anatomical proportions: illustrated with engraved plates, calculated for every practical purpose* (First American edition.). Boston: Printed for and sold by J.D. Yates, professor and teacher of the art of cutting.

D13 Committee. (1995a). *Table of Body Measurements for Adult Female Misses Figure Type, Sizes 2-20*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?HISTORICAL/D5585-95.htm

D13 Committee. (1995b). *Tables of Body Measurements for Women Aged 55 and Older (All Figure Types)*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?HISTORICAL/D5586-95.htm

D13 Committee. (2008). *Standard Tables of Body Measurements for Juniors, Sizes 0 to 19*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D6829.htm

D13 Committee. (2009). *Terminology Relating to Body Dimensions for Apparel Sizing*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D5219.htm

D13 Committee. (2011a). *Tables of Body Measurements for Adult Female Misses Figure Type, Size Range 00-20*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D5585.htm

D13 Committee. (2011b). *Tables of Body Measurements for Girls, Sizes 2 to 20 (Reg & Slim) and Girls Plus*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D6192.htm

D13 Committee. (2012a). *Tables of Body Measurements for Boys, Sizes 8 to 14 Slim and 8 to 20 Regular*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D6458.htm

D13 Committee. (2012b). *Tables of Body Measurements for Mature Men, ages 35 and older, Sizes Thirty-Four to Fifty-Two (34 to 52) Short, Regular, and Tall*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D6240D6240M.htm

D13 Committee. (2013a). *Standard Tables for Body Measurements for Adult Female Misses Petite Figure Type, Size Range 00P - 20P*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D7878D7878M.htm

D13 Committee. (2013b). *Table of Body Measurements for Misses Maternity Sizes Two to Twenty-Two (2-22)*. ASTM International. Retrieved from http://enterprise.astm.org.prox.lib.ncsu.edu/SUBSCRIPTION/filtrexx40.cgi?REDLINE_PAGES/D7197.htm

Devarajan, P. (2004). Validation of'Female Figure Identification Technique (FFIT) for Apparel'Methodology. Retrieved from http://repository.lib.ncsu.edu.prox.lib.ncsu.edu/ir/handle/1840.16/2577

Douty, H. I. (1968). Visual somatometry in health related research. *Journal of Alabama Academy of Science*, *39*(1), 21–34.

Duffy, M. (1987). *The HOAX Fashion Formula: Dress the Body Type You Have to Look Like the Body You Want*. Body Press. Retrieved from http://www.getcited.org/pub/102604336

Esfandarani, M. S., & Shahrabi, J. (2012). Developing a new suit sizing system using data optimization techniques. *International Journal of Clothing Science and Technology*, *24*(1), 27–35. doi:10.1108/09556221211194327

Faust, M.-E., & Carrier, S. (2010). Women's wear sizing: a new labelling system. *Journal of Fashion Marketing and Management*, *14*(1), 88–126. doi:10.1108/13612021011025456

Godley, A. (1997). The Development of the Clothing Industry: technology and fashion. *Textile History*, *28*(1), 3–10.

Goldsberry, E., Shim, S., & Reich, N. (1996). Women 55 Years and Older: Part II. Overall Satisfaction and Dissatisfaction with the Fit of Ready-to-Wear. *Clothing and Textiles Research Journal*, *14*(2), 121–132. doi:10.1177/0887302X9601400203

Gordon, C. C., Churchill, T., Clauser, C. E., Bradtmiller, B., & McConville, J. T. (1989). *Anthropometric survey of US army personnel: methods and summary statistics 1988*. DTIC Document. Retrieved from http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA225094

Guan, J., Hsiao, H., Bradtmiller, B., Kau, T.-Y., Reed, M. R., Jahns, S. K., … Piamonte, D. P. T. (2012). U.S. Truck Driver Anthropometric Study and Multivariate Anthropometric Models for Cab Designs. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(5), 849–871. doi:10.1177/0018720812442685

Gupta, D., & Gangadhar, B. R. (2004). A statistical model for developing body size charts for garments. *International Journal of Clothing Science and Technology*, *16*(5), 458–469. doi:10.1108/09556220410555641

Hadfield, H. (1826). *The tailors preceptor: or, the Art of culting garments to fit the human form with ease and With Elegance: Illustrated with 12 Copper*. Longman. Retrieved from http://books.google.com/books?hl=en&lr=&id=4MhRAAAAcAAJ&oi=fnd&pg=PA10&dq=The+Tailor%27s+Preceptor%3B+or+the+art+of+cutting+garments+to+fit+the+human+form+with+ease+and+with+elegance&ots=ALyEyZNxk2&sig=74d_9iOc7YnBiNGT9O58Lnz5mrY

Healthy Weight: Assessing Your Weight: BMI: About Adult BMI | DNPAO | CDC. (n.d.). Retrieved September 29, 2013, from http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Hinds, B. K., McCartney, J., & Woods, G. (1991). Pattern development for 3D surfaces. *Computer-Aided Design*, *23*(8), 583–592. doi:10.1016/0010-4485(91)90060-A

Honeyman, K. (2000). *Well suited: a history of the Leeds clothing industry, 1850-1990*. Oxford; New York: Pasold Research Fund : Oxford University Press.

Hsu, C.-H., & Wang, M.-J. J. (2005). Using decision tree-based data mining to establish a sizing system for the manufacture of garments. *The International Journal of Advanced Manufacturing Technology*, *26*(5-6), 669–674. doi:10.1007/s00170-003-2032-0

Humphries, M. (2013, September 29). Missing Data & How to Deal: An overview of missing data. Retrieved from http://www.utexas.edu/cola/centers/prc/_files/cs/Missing-Data.pdf

Istook, C. L. (2002). Enabling mass customization: computer-driven alteration methods. *International Journal of Clothing Science and Technology*, *14*(1), 61–76. doi:10.1108/09556220210420345

Jolliffe, I. T. (1982). A Note on the Use of Principal Components in Regression. *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, *31*(3), 300–303. doi:10.2307/2348005

Kamali, N., & Loker, S. (2002). Mass Customization: On-line Consumer Involvement in Product Design. *Journal of Computer-Mediated Communication*, *7*(4), 0–0.

Kang, T. J., & Kim, S. M. (2000). Development of three-dimensional apparel CAD system: Part 1: flat garment pattern drafting system. *International Journal of Clothing Science and Technology*, *12*(1), 26–38. doi:10.1108/EUM0000000005318

Kim, S. H., Pyun, J. K., & Choi, H. Y. (2010). Digital human body model for seat comfort simulation. *International Journal of Automotive Technology*, *11*(2), 239–244. doi:10.1007/s12239-010-0030-4

k-Means clustering Algorithm. (2013, September 29). Retrieved September 29, 2013, from http://cs.gmu.edu/cne/modules/dau/stat/clustgalgs/clust5_bdy.html

Ko, E., & Kincade, D. H. (1998). Product Line Characteristics as Determinants of Quick Response Implementation for U.S. Apparel Manufacturers. *Clothing and Textiles Research Journal*, *16*(1), 11–18. doi:10.1177/0887302X9801600102

Koblyakova, E. B. (1980). Osnovi konstruirovaniya odejdi (Basics of clothing construction). *Moskva, USSR: Legkaya industriya*.

Kwong, M. Y. (2004). Garment Design for Individual Fit. In *Clothing Appearance and Fit: Science and Technology* (pp. 198–233). England: Woodhead Publishing in association with The Ttile Institute ; CRC Press,ex.

LaBat, K. L. (2007). Sizing Standardisation. *Sizing in Clothing: Developing Effective Sizing Systems for Ready-to-Wear Clothing, Cambridge: Woodhead Publishing Limited*, 88–107.

Lectra. (2013). Product Information Documentation - Fashion Product Development. Retrieved September 29, 2013, from http://www.lectra.com/en/solutions/product-development/product-information.html

Lee, J. Y., Istook, C. L., Nam, Y. J., & Park, S. M. (2007). Comparison of body shape between USA and Korean women. *International Journal of Clothing Science and Technology*, *19*(5), 374–391. doi:10.1108/09556220710819555

Lee, S.-E., & Chen, J. C. (1999). Mass-customization methodology for an apparel industry with a future. *Journal of Industrial Technology*, *16*(1), 2–8.

Lemire, B. (1984). Developing consumerism and the ready-made clothing trade in Britain, 1750-1800. *Textile History*, *15*(1), 21–44.

Lindsay, W. (1828). *Begs leave to submit to tailors in general his new and improved system of cutting*. London.

Loker, S. (2007). Mass customization and sizing. *Sizing in clothing: Developing effective sizing system for ready-to-wear clothing*, 246–263.

McCartney, J., Hinds, B. ., Seow, B. ., & Gong, D. (2000). Dedicated 3D CAD for garment modelling. *Journal of Materials Processing Technology*, *107*(1–3), 31–36. doi:10.1016/S0924-0136(00)00695-6

Moses. (1860). *The Growth of an Important Branch of British Industry. (The Ready-made Clothing System.).*

Mpampa, M. L., Azariadis, P. N., & Sapidis, N. S. (2010). A new methodology for the development of sizing systems for the mass customization of garments. *International Journal of Clothing Science and Technology*, *22*(1), 49–68. doi:10.1108/09556221011008802

Newcomb, E. A. (2006). Body shape analysis of Hispanic women in the United States. Retrieved from http://repository.lib.ncsu.edu.prox.lib.ncsu.edu/ir/handle/1840.16/1820

NHANES III. (1994). National Health and Nutrition Examination Survey III (1994) U.S. Department of Health and Human Services. Retrieved September 29, 2013, from http://www.cdc.gov/nchs/nhanes/nh3data.htm

O’Brien, R. (1930). *An annotated list of literature references on garment sizes and body measurements*. US Dept. of Agriculture. Retrieved from http://books.google.com/books?hl=en&lr=&id=-KhojCN0HTcC&oi=fnd&pg=PA20&dq=An+annotated+list+of+literature+references+on+garment+sizes+and+body+measurements&ots=gACTvA_Q-J&sig=Tt7KwzxQ2CO3-KPKvcZG0uJt7Gg

O'Brien, R., Girshick, M. A., & Hunt, E. M. P. (1941). *Body measurements of American boys and girls for garment and pattern construction: comprehensive report of measuring procedures and statistical analysis of data on 147,000 American children*. US Dept. of Agriculture. Retrieved from http://books.google.com/books?hl=en&lr=&id=Ozyv9teGYVsC&oi=fnd&pg=PR7&dq=o%27brien+1941+women%27s+measurements+for+garment+and+pattern+construction&ots=TR0_nkPrE5&sig=-ErJVpZX0WlCwsWgKCvfn-7NiEI

O'brien, R., & Shelton, W. C. (1941). *Women's measurements for garment and pattern construction*. US Department of Agriculture. Retrieved from http://books.google.com/books?hl=en&lr=&id=8YUoAAAAYAAJ&oi=fnd&pg=PA1&dq=o%27brien+1941+women%27s+measurements+for+garment+and+pattern+construction&ots=_2dFVrryYP&sig=pVDi8z-vAWuZja9-hyX5WarpfaQ

Ogden, C. L., Fryar, C. D., Carroll, M. D., & Flegal, K. M. (2004). *Mean body weight, height, and body mass index: United States 1960-2002*. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. Retrieved from http://www.naturalheightgrowth.com/wp-content/uploads/2012/12/Height19602002.pdf

Okabe, H., Imaoka, H., Tomiha, T., & Niwaya, H. (1992). Three dimensional apparel CAD system. *SIGGRAPH Comput. Graph.*, *26*(2), 105–110. doi:10.1145/142920.134019

Peppers, D., & Rogers, M. (c2011.). *Managing customer relationships [electronic resource] : a strategic framework* (2nd ed.). Hoboken, N.J.: Wiley,. Retrieved from http://catalog.lib.ncsu.edu/record/NCSU2470143

Petrova, A. (2007). Creating sizing systems. *Sizing in clothing: Developing effective sizing systems for ready-to-wear clothing*, 57–87.

Pine, B. J. (1993). *Mass customization: the new frontier in business competition*. Boston, Mass.: Harvard Business School Press.

Read, B. (1815). *The proportionate and universal table*. sold.

Reich, N. A., & Goldsberry, E. (1993). *ISR project for the development of body measurement tables for women 55 years and older and the relationship to ready-to-wear garment size*. ASTM Institute for Standards Research.

Robinette, K. M., Blackwell, S., Daanen, H., Boehmer, M., & Fleming, S. (2002). *Civilian American and European Surface Anthropometry Resource (CAESAR), Final Report. Volume 1. Summary*. DTIC Document. Retrieved from http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA406704

Scranton, P. (1994). Transition from custom to ready to wear clothing in Philadelphia, 1890-1930. *Textile history*, *25*(2), 243+–31.

Shin, S.-J. H., & Istook, C. L. (2007). The importance of understanding the shape of diverse ethnic female consumers for developing jeans sizing systems. *International Journal of Consumer Studies*, *31*(2), 135–143. doi:10.1111/j.1470-6431.2006.00581.x

Simmons, K., Istook, C. L., & Devarajan, P. (2004). Female figure identification technique (FFIT) for apparel, part II: development of shape sorting software. *Journal of Textile and Apparel, Technology and Management*, *4*(1), 1–16.

Simmons, K. P. (2003). Body shape analysis using three-dimensional body scanning technology. Retrieved from http://repository.lib.ncsu.edu.prox.lib.ncsu.edu/ir/handle/1840.16/5555

Simonson, I. (2005). Determinants of Customers' Responses to Customized Offers: Conceptual Framework and Research Propositions. *Journal of Marketing*, *69*(1), 32–45. doi:10.2307/30162031

Song, H. K., & Ashdown, S. P. (2011). Categorization of lower body shapes for adult females based on multiple view analysis. *Textile Research Journal*, *81*(9), 914–931. doi:10.1177/0040517510392448

Song, H. K., & Ashdown, S. P. (2012). Development of Automated Custom-Made Pants Driven by Body Shape. *Clothing and Textiles Research Journal*, *30*(4), 315–329. doi:10.1177/0887302X12462058

SPSS. (2013, September 30). IBM SPSS Statistics. Retrieved September 30, 2013, from http://www-01.ibm.com/software/analytics/spss/products/statistics/

SPSS Statistics. (2011). *Eclipse help system*. IBM.

Stone, C. J. [from old catalog. (1897). *Superlative system of cutting ladies' garments ..* Chicago, The C. J. Stone co. cutting school. Retrieved from http://archive.org/details/superlativesyste00ston

Stoudt, H. W., Damon, A., McFarland, R., & Roberts, J. (1965). *Weight, Height, and Selected Body Dimensions of Adults United States-1960-1962*. DTIC Document. Retrieved from http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA433581

Taylor, C. (2013, September 28). With $1.9M From Venrock And Others, Trumaker Wants To Bring Made-To-Measure To The Masses | TechCrunch. *TechCrunch*. Retrieved September 29, 2013, from http://techcrunch.com/2013/06/17/trumaker/

Taylor, S. E. (1998). Multivariate Statistical Methods Applied to Sizing and Fit Testing. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *42*(10), 732–735. doi:10.1177/154193129804201015

[TC]2. (2004). *SizeUSA The National Sizing Survey Women Body Measurement and Data Analysis Reports on the U.S. Population* (No. unpublished report).

The Society of Adepts in the Profession. (1796). *The taylor's complete guide, or, A comprehensive analysis of beauty and elegance in dress*. London.

Toffler, A., Longul, W., & Forbes, H. (1981). *The third wave*. Bantam books New York. Retrieved from http://calculemus.org/lect/07pol-gosp/arch/proby-dawne/materialy/waves.htm

Tom James Company. (2013, September 28). Your Career With Tom James - Who We Are. Retrieved September 29, 2013, from http://www.tomjamescareers.com/who_we_are.asp

U.S. Department of Commerce. (1958). National Bureau of Standards Commercial Standard CS215-58: Body measurements for the sizing of women's patterns and apparel. U.S. Government Printing Office. Retrieved from http://gsi.nist.gov/global/docs/stds/womens-ps42-70.pdf

U.S. Department of Commerce. (1970). National Bureau of Standards Commercial Standard PS42-70: Body measurements for the sizing of women's patterns and apparel. U.S. Government Printing Office. Retrieved from http://gsi.nist.gov/global/docs/stds/womens-ps42-70.pdf

Warkentin, M., Bapna, R., & Sugumaran, V. (2000). The role of mass customization in enhancing supply chain relationship in B2C e-commerce markets. *Journal of Electronic Commerce Research*, 1–17.

Weiss, A., Hirshberg, D., & Black, M. J. (2013). Home 3D Body Scans from a Single Kinect. In A. Fossati, J. Gall, H. Grabner, X. Ren, & K. Konolige (Eds.), *Consumer Depth Cameras for Computer Vision* (pp. 99–117). Springer London. Retrieved from http://link.springer.com.prox.lib.ncsu.edu/chapter/10.1007/978-1-4471-4640-7_6

Winks, J. M. (1997). *Clothing sizes : international standardization*. Manchester, UK: The Textile Institute,. Retrieved from http://catalog.lib.ncsu.edu/record/NCSU984070

Workman, J. E., & Lentz, E. S. (2000). Measurement Specifications for Manufacturers' Prototype Bodies. *Clothing and Textiles Research Journal*, *18*(4), 251–259. doi:10.1177/0887302X0001800404

Wray, M. (1957). *The women's outerwear industry*. G. Duckworth.

Wyatt, J. (1822). *The Tailor's Friendly Instructor: Being an Casy Guide for Finding the Principal and Leading Points Essential to the Art of Fitting the Human Shape Forming a Complete System...* J. Harris.

Yu, W. (2004). Human anthropometrics and sizing systems. *Clothing appearance and fit: Science and Technology*, 169–195.

Yunchu, Y., & Weiyuan, Z. (2007). Prototype garment pattern flattening based on individual 3D virtual dummy. *International Journal of Clothing Science and Technology*, *19*(5), 334–348. doi:10.1108/09556220710819528

APPENDICES

Appendix A: List of key measurement definitions and using frequencies in ASTM 5219-09 and ISO 8559 standards (source: ([TC]2, 2004))

		Basic measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
1	Height		ASTM	ASTM
2	Weight		ASTM	ASTM
3	BMI			

		Girth measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
4	A5Mid-Neck	Circumference of the neck measured above the neck base as for a shirt collar.	ASTM	ISO
5	A6Neck_Base	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).	ASTM	ISO
6	B165W89_BackNeck	Distance between side neck shoulder points over the center back neck point.		
7	A1Bust	Measure the bust circumference horizontally around the body under the arms, across the nipples, and parallel to the floor.	ASTM	ISO
8	B13Midriff	Torso circumference measured 4 inches below bust line.		
9	B192W106_UnderBustGirth	Circumference of the body immediately below the breasts.	ASTM	ISO
10	B186M96_Chest_Girth	Maximum circumference of chest, measured from the bust level at center back under the armpits and above the breasts.	ASTM	ISO
11	B194W108_WaistGirth	Full waist circumference measure parallel to the floor at the waist level	ASTM	
12	A2Waist	Circumference measured around the body at the waist level following the pant waist		ISO
13	A3High_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.	ASTM	
14	B200W114_PtrHipGirth	Circumference of the hip measured around the fullest part of the buttocks.	ASTM	
15	A4Hips	Maximum circumference of the body measured between the waist and crotch, parallel to the floor.		
16	A10Thigh_Max	Measure the circumference of the upper leg 1 inch below the crotch.	ASTM	ISO
17	A11Thigh_Mid	Circumference of the upper leg measured midway between the knee and crotch.	ASTM	ISO
18	A12Knee	With the leg straight, measure the knee circumference over the kneecap and parallel to the floor	ASTM	ISO
19	B211W120R_LowKneeGirth	Circumference of the right leg measured immediately below the kneecap.		ISO
20	A13Calf	Measure the maximum circumference of the lower leg between the knee and ankle and parallel to the floor	ASTM	ISO
21	B215W122R_Minimum_Leg_Girth	Minimum girth of the right lower leg measured above the ankle.		ISO

Appendix A: List of key measurement definitions and using frequencies in ASTM 5219-09 and ISO 8559 standards (source: ([TC]2, 2004)) (continued)

		Girth measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
22	A14'Ankle Girth	Measure the ankle circumference over the inner and outer bony prominence at the lower end of the lower leg	ASTM	ISO
23	A7Armscye	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	ASTM	ISO
24	A8Upper_Arm	Measure the maximum arm circumference between the shoulder point and the elbow	ASTM	ISO
25	A9Elbow	Measure the circumference of the elbow.	ASTM	ISO
26	B183W100R_WristGirth	Circumference of the right wrist measured at level of crease of hand.	ASTM	ISO
		Height measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
27	A18Cervicale_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.	ASTM	ISO
28	B14Midriff_Height	Vertical distance from floor of Midriff measurement.		
29	B78W22_Waist5_Height	Distance between waist level at center back and ground.	ASTM	
30	A19Waist6_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.		ISO
31	B87W30a_wideSeatGirthHeight	Distance between maximum back seat prominence and ground level.		ISO
32	A20High_Hip_Height	Measured from the high-hip circumference level vertically to the floor.	ASTM	
33	B85W29_AbdomenHeight	Distance between maximum front prominence level and ground		
34	B79W23_PtrHipHeight	Distance between fullest part of buttocks and ground.	ASTM	
35	A21MaxHips_Height	At the side of the body, measure from the full hip level to the soles of the feet.		
36	A22Crotch_Height	While standing erect without shoes and with feet slightly apart, measure from the crotch straight down to the soles of the feet.	ASTM	ISO
37	A23Knee_Height	Measured from the knee circum-ference level vertically to the floor.	ASTM	ISO
38	A24Ankle_Height	Measure from the middle of the outer ankle bone to the soles of the feet.	ASTM	ISO
		Length measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
39	A16Crotch_Length_Total	Measure from the center front waist level through the crotch to the center back waist level	ASTM	ISO
40	A30Shoulder_Length	Measured from the side neck points to the armscye line at the shoulder points.	ASTM	ISO

Appendix A: List of key measurement definitions and using frequencies in ASTM 5219-09 and ISO 8559 standards (source: ([TC]2, 2004)) (continued)

		Length measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
41	B131W61_FrontNecktoWaist5	Distance down the center front between the base of the front neck and the waist level (Contoured)	ASTM	
42	A25Waist_Length_Front	Measure from the center front neck base line to the center front waist level.		
43	B104W41_Neck2Waist5Contoured_Back	Distance between the center back neck point and the waist level. Measured on the contour of the center back (Small of back Waist Level)	ASTM	
44	A26Waist6_Length_Back	Measure from the cervicale following the contour of the spinal column to the center back waist level.		ISO
45	B117W55R_SideNeckToWaist5Straight	Distance from the right neck shoulder point, over the breast point then straight to the front waist.(small of back waist level)		ISO
46	W75aR_BackNeckToElbow	Distance from the center back neck to the top of the shoulder and along the arm to the elbow		
47	A33Arm_Length_(Shoulder_to_Wrist)	With the arm hanging in the scan position, measure from the shoulder point along the outside of the arm to the wrist joint	ASTM	ISO
48	A34Arm_Length_CBNeck_to_Wrist	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.	ASTM	ISO
49	A36Neck_to_Bust_Point	Measure from the side neck points to the bust apex.	ASTM	ISO
50	B145W68R_UnderArmLength	Distance between the right under arm level at back and the level of the inside of the wrist at the same level as the crease of the hand immediately below the prominent wrist bones.	ASTM	ISO
51	B138W66R_SideWaist5ToHipPtr	Distance along the right side of the body from the small of back waist level to the hip level.	ASTM	
52	B140W66aR_SideWaist5ToSeat	Distance along the right side of the body from the small of back waist level to the seat level.		ISO
53	B83W27_BodyRise(W5Straight)	Distance between waist level at center back and crotch height.	ASTM	ISO
54	B142W67R_OutsideLegLength	Distance from the right side waist level to the ground following the contour of the hip then straight to the ground.		ISO
55	B224W139R_FootLength	Distance between the most prominent toe and the most prominent part of the heel on the right foot.	ASTM	ISO

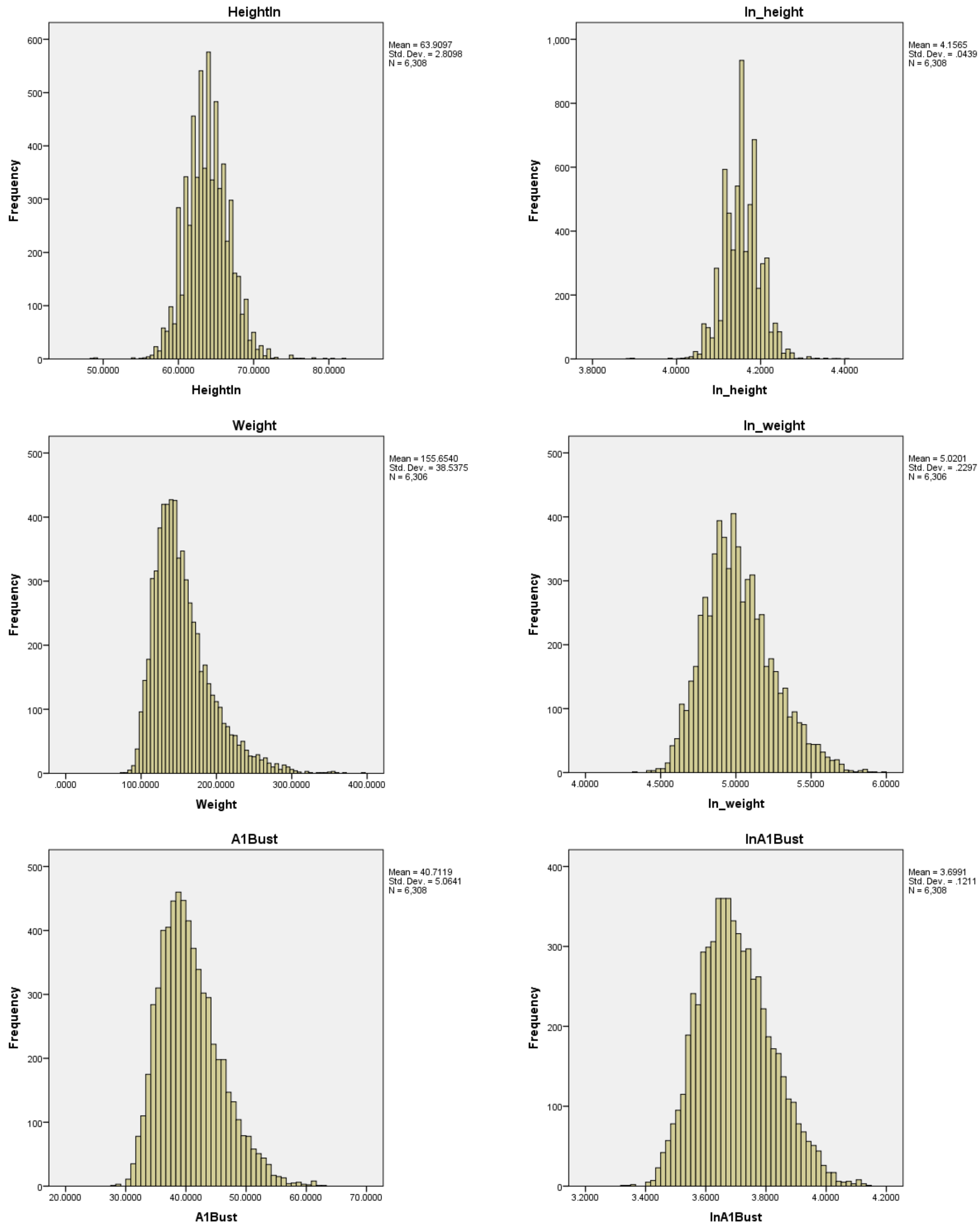
Appendix A: List of key measurement definitions and using frequencies in ASTM 5219-09 and ISO 8559 standards (source: ([TC]2, 2004)) (continued)

No.	Name	Definition of SizeUSA	ASTM 5219-09	ISO 8559
		Width measurements		
56	A27Across_Shoulder	Measure across the back from one shoulder point to the other on a line at approximately 45 degrees.	ASTM	
57	B157W82_BackShoulderWidth(contoured)	Shortest horizontal distance between the back shoulders, following the contour of the back.	ASTM	ISO
58	B160W84_FrontShoulderWidth	Horizontal distance between the front shoulders.	ASTM	
59	A28Cross_Back_Width	Measure across the back from armscye to armscye at the back-break point level	ASTM	ISO
60	A29Cross_Chest_Width	Measure across the front from armscye to armscye at the front-break point level	ASTM	
61	A35Bust_Pt_to_Bust_Pt	Measure horizontally from one bust apex to the other.	ASTM	ISO
62	B222W138R_FootWidth	Width of the foot.	ASTM	
		Other measurements		
No.	**Name**	**Definition of SizeUSA**	**ASTM 5219-09**	**ISO 8559**
63	A32Shoulder_Slope_(degrees)	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.	ASTM	ISO
64	B67W15R_ArmscyeDepthFromBackNeck	Distance between center back neck and armscye underarm level.	ASTM	ISO

Appendix B: Errors deleted from SizeUSA data

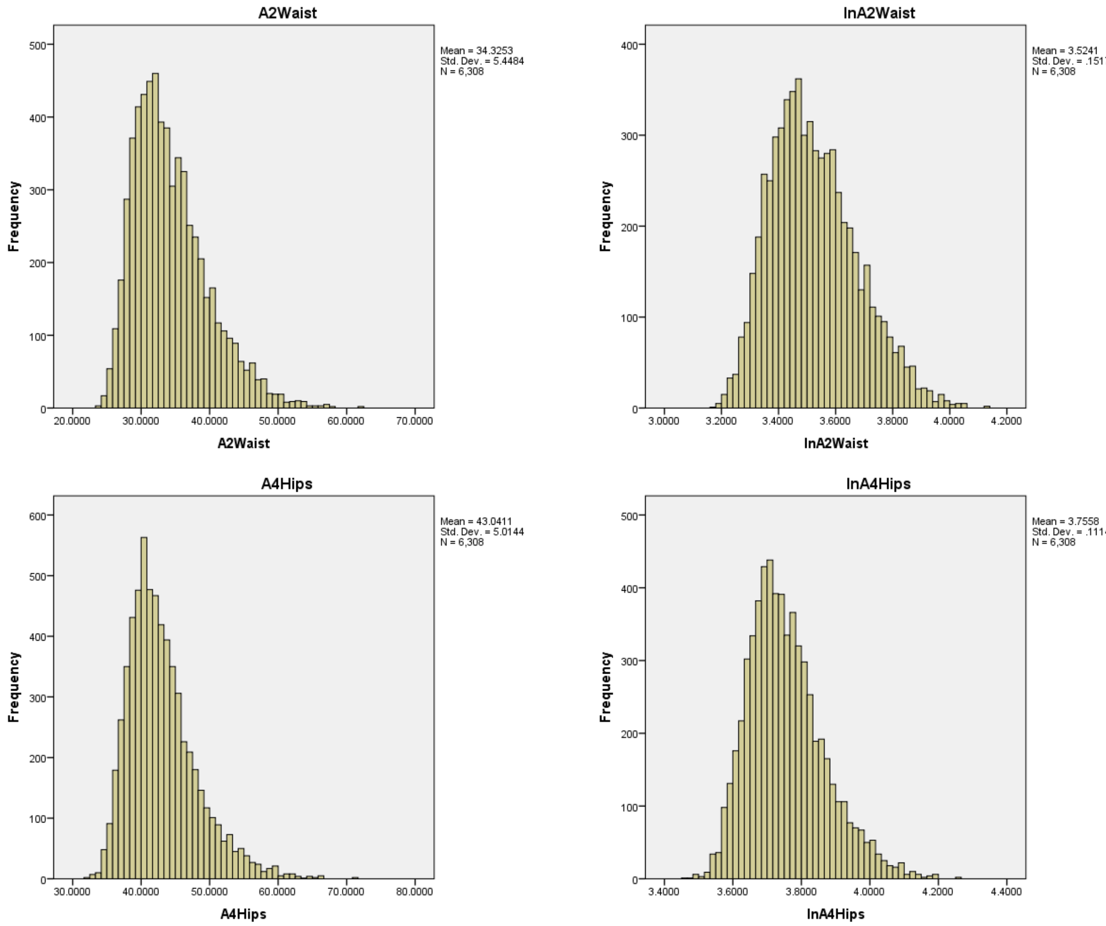
Survey_ID	Deleted measurement	Reason
1110	**all**	too many outliers
1491	B102W39_Back_Seat_Angle	56.4000
3912	**all**	wrong waist location
3920	B230W145CFrontNeckToBustLine	2.8600
4097	A9Elbow	24.3754
4162	B96W35R_Calf_Height	1.3800
	B222W138R_FootWidth	0.7900
4543	A5Mid-Neck	25.8361
	A6Neck_Base	25.9848
	B165W89_BackNeck	13.7600
	B166W90_NeckWidth	9.1300
4770	A5Mid-Neck	47.6386
4833	A25Waist_Length_Front	7.5881
	B131W61_FrontNecktoWaist5	9.2200
4922	A7Armscye	50.3086
5118	Weight	32.0000
	BMI	5.1644
5167	A5Mid-Neck	32.5450
5252	B222W138R_FootWidth	0.2900
5311	B224W139R_FootLength	2.7700
5366	B131W61_FrontNecktoWaist5	71.7100
5412	A13Calf	36.9213
5427	A35Bust_Pt_to_Bust_Pt	0.8229
5525	B220W137R_FootGirth	0.4300
05-00007	B104W41_Neck2Waist5Contoured_Back	31.6500
05-00104	B148W72R_CrownHeight	13.4500
05-00114	B218W135R_LongHeelGirth	67.9500
05-01018	B121W56R_SideNeck2UnderBust2Waist5	57.0100
05-01597	B224W139R_FootLength	3.5600
05-02602	B131W61_FrontNecktoWaist5	31.0500
05-04154	B215W122R_Minimum_Leg_Girth	3.2900
05-04402	B121W56R_SideNeck2UnderBust2Waist5	44.7300
05-04684	A7Armscye	38.7659
05-04743	Weight	29.0000
	BMI	4.9773
05-05092	B215W122R_Minimum_Leg_Girth	2.3100
	B220W137R_FootGirth	0.4300
05-05092	B224W139R_FootLength	2.4800
05-05219	B220W137R_FootGirth	0.4300
05-05281	B218W135R_LongHeelGirth	67.4800
05-05339	B88W31R_ThighHeight	0.1000
	B169W92R_LongShoulder_Length	10.4200
	B132W62R_SideWaist5ToThigh	39.4600
05-05468	B215W122R_Minimum_Leg_Girth	2.8100
	B220W137R_FootGirth	0.4300
05-05748	A5Mid-Neck	36.6683
05-06512	B148W72R_CrownHeight	10.3800

Appendix C: Histograms of transformed vales compared to values before transformation



Appendix C: Histograms of transformed vales compared to values before transformation

(continue)



Appendix D: Codes for SPSS analysis

```
REGRESSION
  /MISSING PAIRWISE
  /STATISTICS COEFF R CHANGE
  /CRITERIA=PIN(.05) POUT(0.1)
  /NOORIGIN
  /DEPENDENT BMI
A32Shoulder_Slope_degrees
ln_height
ln_weight
lnA10Thigh_Max
lnA11Thigh_Mid
lnA12Knee
lnA13Calf
lnA14AnkleGirth
lnA16Crotch_Length_Total
lnA18Cervicale_Height
lnA19Waist6_Height
lnA1Bust
lnA20High_Hip_Height
lnA21MaxHips_Height
lnA22Crotch_Height
lnA23Knee_Height
lnA24Ankle_Height
lnA25Waist_Length_Front
lnA26Waist6_Length_Back
lnA27Across_Shoulder
lnA28Cross_Back_Width
lnA29Cross_Chest_Width
lnA2Waist
lnA30Shoulder_Length
lnA33Arm_Length_Shoulder_to_Wrist
lnA34Arm_Length_CBNeck_to_Wrist
lnA35Bust_Pt_to_Bust_Pt
lnA36Neck_to_Bust_Point
lnA3High_Hip
lnA4Hips
lnA5MidNeck
lnA6Neck_Base
lnA7Armscye
lnA8Upper_Arm
lnA9Elbow
lnB104W41_Neck2Waist5Contoured_Back
lnB117W55R_SideNeckToWaist5Straight
lnB131W61_FrontNecktoWaist5
lnB138W66R_SideWaist5ToHipPtr
lnB13Midriff
lnB140W66aR_SideWaist5ToSeat
lnB142W67R_OutsideLegLength
lnB145W68R_UnderArmLength
lnB14Midriff_Height
```

```
lnB157W82_BackShoulderWidthcontoured
lnB160W84_FrontShoulderWidth
lnB165W89_BackNeck
lnB183W100R_WristGirth
lnB186M96_Chest_Girth
lnB192W106_UnderBustGirth
lnB194W108_WaistGirth
lnB200W114_PtrHipGirth
lnB211W120R_LowKneeGirth
lnB215W122R_Minimum_Leg_Girth
lnB222W138R_FootWidth
lnB224W139R_FootLength
lnB67W15R_ArmscyeDepthFromBackNeck
lnB78W22_Waist5_Height
lnB79W23_PtrHipHeight
lnB83W27_BodyRiseW5Straight
lnB85W29_AbdomenHeight
lnB87W30a_wideSeatGirthHeight
lnW75aR_BackNeckToElbow
  /METHOD=STEPWISE FAC1G1gir FAC2G1hgt.
```

Appendix E: Coefficients results of PCs with all subjects (without consideration of shapes)

	the training set				the validation set			
Variables	Constant	Coefficient of PC1	Coefficient of PC2	Adjusted R^2	Constant	Coefficient of PC1	Coefficient of PC2	Adjusted R^2
height	4.1569	0.0038	0.0401	0.8220	4.1561	0.0044	0.0382	0.7870
weight	5.0169	0.2172	0.0567	0.9667	5.0233	0.2200	0.0558	0.9642
BMI	26.6603	5.9643	-0.6316	0.9219	26.8823	6.0361	-0.5174	0.9170
A5Mid-Neck	2.6371	0.0812		0.7284	2.6388	0.0822		0.7402
A6Neck_Base	2.7074	0.0682	0.0044	0.6944	2.7083	0.0686	0.0048	0.7033
A1Bust	3.6968	0.1149	0.0043	0.9120	3.7013	0.1159	0.0057	0.9074
B13Midriff	3.5160	0.1432	-0.0032	0.9152	3.5225	0.1461	-0.0016	0.9147
B192W106_UnderBustGirth	3.5177	0.1331		0.9028	3.5233	0.1350		0.9000
B186M96_Chest_Girth	3.6787	0.1124	0.0052	0.9095	3.6819	0.1125	0.0053	0.9076
B194W108_WaistGirth	3.5415	0.1425		0.9052	3.5467	0.1464	0.0024	0.9121
A2Waist	3.5216	0.1434		0.9107	3.5265	0.1465	0.0025	0.9150
A3High_Hip	3.6832	0.1278		0.9082	3.6869	0.1309		0.9069
B200W114_PtrHipGirth	3.7354	0.1065	0.0133	0.8900	3.7395	0.1082	0.0137	0.8870
A4Hips	3.7534	0.1029	0.0144	0.8825	3.7581	0.1044	0.0142	0.8800
A10Thigh_Max	3.1925	0.0969	0.0240	0.7457	3.1948	0.0953	0.0245	0.7299
A11Thigh_Mid	2.9934	0.0967	0.0199	0.6962	2.9962	0.0964	0.0199	0.6813
A12Knee	2.7249	0.0754	0.0186	0.7038	2.7266	0.0764	0.0192	0.6892
B211W120R_LowKneeGirth	2.6573	0.0821	0.0146	0.7029	2.6595	0.0830	0.0148	0.6902
A13Calf	2.6999	0.0813	0.0154	0.6906	2.7024	0.0819	0.0151	0.6889
B215W122R_Minimum_Leg_Girth	2.1920	0.0519	0.0140	0.4274	2.1931	0.0547	0.0115	0.4365
A14'Ankle Girth	2.3024	0.0584	0.0164	0.5010	2.3037	0.0618	0.0139	0.5074
A7Armscye	2.8017	0.0876	0.0194	0.6023	2.8035	0.0897	0.0188	0.6101
A8Upper_Arm	2.4802	0.1454	0.0072	0.8374	2.4874	0.1467	0.0079	0.8292
A9Elbow	2.3303	0.1006	0.0119	0.8039	2.3320	0.1018	0.0106	0.8042
B183W100R_WristGirth	1.8791	0.0693		0.5771	1.8806	0.0696		0.5644
A18Cervicale_Height	4.0436	0.0077	0.0444	0.9222	4.0430	0.0087	0.0430	0.9088
B165W89_BackNeck	1.8863	0.0842		0.4833	1.8879	0.0842		0.4877
B14Midriff_Height	3.7318	-0.0009	0.0547	0.8863	3.7305		0.0529	0.8729
B78W22_Waist5_Height	3.6586	0.0115	0.0537	0.9087	3.6596	0.0121	0.0536	0.9170
A19Waist6_Height	3.6709	0.0077	0.0556	0.8698	3.6717	0.0080	0.0554	0.8764
B87W30a_wideSeatGirthHeight	3.4746	0.0115	0.0573	0.8914	3.4749	0.0132	0.0562	0.8806
A20High_Hip_Height	3.5843	0.0108	0.0587	0.9080	3.5853	0.0113	0.0588	0.9181
B85W29_AbdomenHeight	3.5934		0.0575	0.7247	3.5936	0.0016	0.0575	0.7188

Appendix E: Coefficients results of PCs with all subjects (without consideration of shapes) (continue)

Variables	the training set				the validation set			
	Constant	Coefficient of PC1	Coefficient of PC2	Adjusted R^2	Constant	Coefficient of PC1	Coefficient of PC2	Adjusted R^2
B79W23_PtrHipHeight	3.4824	0.0114	0.0569	0.8914	3.4826	0.0131	0.0557	0.8806
A21MaxHips_Height	3.4603	0.0427	0.0479	0.6052	3.4610	0.0451	0.0471	0.6074
A22Crotch_Height	3.3599	-0.0100	0.0622	0.9212	3.3583	-0.0095	0.0612	0.9108
A23Knee_Height	2.8546	-0.0014	0.0594	0.6993	2.8530		0.0594	0.6763
A24Ankle_Height	0.9969	-0.0163	0.0603	0.1709	0.9966	-0.0160	0.0592	0.1768
A16Crotch_Length_Total	3.3365	0.0874	0.0288	0.5883	3.3434	0.0854	0.0315	0.5699
A30Shoulder_Length	1.6094	0.0623	0.0168	0.3451	1.6101	0.0626	0.0129	0.3302
B131W61_FrontNecktoWaist5	2.7323	0.0154	0.0129	0.0592	2.7288	0.0196	0.0076	0.0598
A25Waist_Length_Front	2.6870	0.0366		0.1125	2.6836	0.0418		0.1360
B104W41_Neck2Waist5Contoured_Back	2.8548	0.0067	0.0187	0.0826	2.8499	0.0084	0.0140	0.0542
A26Waist6_Length_Back	2.8495	0.0051	0.0203	0.0960	2.8451	0.0074	0.0150	0.0590
B117W55R_SideNeckToWaist5Straight	2.8835	0.0252	0.0160	0.2025	2.8802	0.0281	0.0118	0.1999
W75aR_BackNeckToElbow	3.0320	0.0232	0.0394	0.7218	3.0315	0.0249	0.0384	0.7072
A33Arm_Length_(Shoulder_to_Wrist)	3.0431	0.0084	0.0583	0.6694	3.0425	0.0089	0.0578	0.6476
A34Arm_Length_CBNeck_to_Wrist	3.3487	0.0252	0.0463	0.7339	3.3487	0.0259	0.0454	0.7158
A36Neck_to_Bust_Point	2.3890	0.0841	0.0076	0.6343	2.3923	0.0880	0.0079	0.6649
B145W68R_UnderArmLength	2.8679	-0.0039	0.0671	0.7122	2.8669	-0.0022	0.0672	0.6953
B138W66R_SideWaist5ToHipPtr	1.9348	-0.1519	0.0882	0.2860	1.9353	-0.1597	0.0875	0.3036
B140W66aR_SideWaist5ToSeat	1.8339		0.0384	0.0641	1.8374		0.0437	0.0797
B83W27_BodyRise(W5Straight)	2.3286	0.0716	0.0260	0.4965	2.3365	0.0711	0.0294	0.4867
B142W67R_OutsideLegLength	3.6671	0.0118	0.0534	0.8968	3.6681	0.0124	0.0533	0.9058
B224W139R_FootLength	2.2593	0.0169	0.0385	0.5459	2.2595	0.0165	0.0353	0.5423
A27Across_Shoulder	2.7039	0.0710	0.0131	0.7154	2.7051	0.0722	0.0107	0.7191
B157W82_BackShoulderWidth(contoured)	2.7339	0.0717	0.0126	0.7318	2.7355	0.0729	0.0105	0.7393
B160W84_FrontShoulderWidth	2.6985	0.0414	0.0231	0.5576	2.6976	0.0428	0.0213	0.5693
A28Cross_Back_Width	2.6635	0.0750	0.0166	0.5888	2.6650	0.0760	0.0138	0.5961
A29Cross_Chest_Width	2.6862	0.0717	0.0072	0.2928	2.6881	0.0714	0.0059	0.2874
A35Bust_Pt_to_Bust_Pt	2.1045	0.0884	0.0093	0.6160	2.1067	0.0858	0.0107	0.5843
B222W138R_FootWidth	1.2806	0.0330	0.0132	0.2119	1.2835	0.0331	0.0126	0.2397
A32Shoulder_Slope_(degrees)	21.2151	-0.2892	0.4239	0.0180	21.2039	-0.1723	0.2988	0.0079
B67W15R_ArmscyeDepthFromBackNeck	1.8815	0.0276	0.0351	0.2442	1.8798	0.0303	0.0326	0.2189

Appendix F: The created Sizing System[1] (for regular height)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
1	**height**	**All**	**63 3/8**	**63 3/8**	**63 4/8**	**63 5/8**	**63 5/8**	**63 6/8**	**63 6/8**	**63 7/8**	**64**	**64**	**64 1/8**	**64 1/8**	**64 2/8**	**64 3/8**
		Rect	63 3/8	63 3/8	63 4/8	63 5/8	63 5/8	63 6/8	63 6/8	63 7/8	64	64	64 1/8	64 2/8	64 2/8	64 3/8
		Spoon	63 5/8	63 5/8	63 5/8	63 5/8	63 6/8	63 6/8	63 6/8	63 7/8	63 7/8	63 7/8	63 7/8	64	64	64
		BH	63	63 1/8	63 2/8	63 3/8	63 3/8	63 4/8	63 5/8	63 6/8	63 7/8	64	64	64 1/8	64 2/8	64 3/8
2	**weight**	**All**	**94 4/8**	**101 1/8**	**108 1/8**	**115 4/8**	**123 4/8**	**132**	**141 1/8**	**151**	**161 3/8**	**172 4/8**	**184 4/8**	**197 2/8**	**210 7/8**	**225 3/8**
		Rect	94 1/8	100 4/8	107 4/8	114 6/8	122 5/8	131	140	149 5/8	159 7/8	170 6/8	182 4/8	195	208 2/8	222 4/8
		Spoon	94 1/8	101	108 2/8	116	124 3/8	133 3/8	142 7/8	153 2/8	164 2/8	176 1/8	188 6/8	202 3/8	216 7/8	232 4/8
		BH	95 3/8	102 1/8	109 3/8	117 1/8	125 4/8	134 3/8	144	154 2/8	165 2/8	177	189 4/8	203	217 4/8	232 7/8
3	**BMI**	**All**	**13.88**	**15.63**	**17.50**	**19.38**	**21.13**	**23.00**	**24.88**	**26.63**	**28.50**	**30.38**	**32.13**	**34.00**	**35.88**	**37.63**
		Rect	13.88	15.63	17.50	19.25	21.00	22.75	24.50	26.25	28.00	29.75	31.63	33.38	35.13	36.88
		Spoon	14.25	16.13	17.88	19.75	21.63	23.38	25.25	27.13	28.88	30.75	32.63	34.38	36.25	38.13
		BH	13.63	15.63	17.63	19.63	21.63	23.63	25.63	27.63	29.63	31.63	33.63	35.63	37.63	39.63
4	**A5Mid-Neck**	**All**	**11 6/8**	**12**	**12 3/8**	**12 5/8**	**13**	**13 2/8**	**13 5/8**	**14**	**14 3/8**	**14 6/8**	**15**	**15 4/8**	**15 7/8**	**16 2/8**
		Rect	11 6/8	12	12 3/8	12 6/8	13	13 3/8	13 6/8	14	14 3/8	14 6/8	15 1/8	15 5/8	16	16 3/8
		Spoon	11 6/8	12	12 3/8	12 5/8	12 7/8	13 2/8	13 4/8	13 7/8	14 1/8	14 4/8	14 7/8	15 2/8	15 4/8	15 7/8
		BH	11 6/8	12	12 3/8	12 5/8	12 7/8	13 1/8	13 4/8	13 6/8	14 1/8	14 3/8	14 6/8	15	15 3/8	15 6/8
5	**A6Neck_Base**	**All**	**13**	**13 2/8**	**13 4/8**	**13 6/8**	**14 1/8**	**14 3/8**	**14 5/8**	**15**	**15 2/8**	**15 5/8**	**16**	**16 2/8**	**16 5/8**	**17**
		Rect	13	13 2/8	13 4/8	13 7/8	14 1/8	14 3/8	14 6/8	15 1/8	15 3/8	15 6/8	16 1/8	16 3/8	16 6/8	17 1/8
		Spoon	13	13 2/8	13 4/8	13 6/8	14	14 3/8	14 5/8	14 7/8	15 2/8	15 4/8	15 6/8	16 1/8	16 3/8	16 6/8
		BH	13	13 2/8	13 4/8	13 6/8	14	14 2/8	14 4/8	14 6/8	15	15 3/8	15 5/8	15 7/8	16 2/8	16 4/8
7	**A1Bust**	**All**	**31 4/8**	**32 5/8**	**33 6/8**	**35**	**36 2/8**	**37 5/8**	**38 7/8**	**40 3/8**	**41 6/8**	**43 2/8**	**44 7/8**	**46 4/8**	**48 1/8**	**49 7/8**
		Rect	32	33 1/8	34 2/8	35 4/8	36 6/8	38 1/8	39 4/8	40 7/8	42 3/8	43 7/8	45 4/8	47 1/8	48 7/8	50 5/8
		Spoon	30 7/8	32	33 1/8	34 2/8	35 4/8	36 6/8	38 1/8	39 3/8	40 7/8	42 2/8	43 6/8	45 3/8	47	48 5/8
		BH	30 6/8	31 6/8	32 7/8	34 1/8	35 2/8	36 4/8	37 7/8	39 1/8	40 4/8	42	43 4/8	45	46 5/8	48 2/8
8	**B13Midriff**	**All**	**24 6/8**	**25 7/8**	**27**	**28 2/8**	**29 4/8**	**30 6/8**	**32 2/8**	**33 5/8**	**35 1/8**	**36 6/8**	**38 3/8**	**40 1/8**	**42**	**43 7/8**
		Rect	25 1/8	26 2/8	27 3/8	28 5/8	29 7/8	31 2/8	32 5/8	34	35 5/8	37 1/8	38 6/8	40 4/8	42 2/8	44 1/8
		Spoon	24 5/8	25 5/8	26 6/8	27 7/8	29 1/8	30 3/8	31 5/8	33	34 3/8	35 7/8	37 3/8	39	40 6/8	42 4/8
		BH	24 2/8	25 2/8	26 3/8	27 5/8	28 6/8	30	31 3/8	32 6/8	34 1/8	35 5/8	37 2/8	38 7/8	40 4/8	42 3/8

[1] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[2] (for regular height) (continue)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
9	**B192W106_UnderBustGirth**	**All**	**25 2/8**	**26 3/8**	**27 4/8**	**28 5/8**	**29 6/8**	**31**	**32 3/8**	**33 6/8**	**35 1/8**	**36 5/8**	**38 1/8**	**39 6/8**	**41 3/8**	**43 1/8**
		Rect	25 5/8	26 6/8	27 7/8	29	30 1/8	31 3/8	32 6/8	34 1/8	35 4/8	37	38 4/8	40 1/8	41 6/8	43 4/8
		Spoon	25 2/8	26 2/8	27 2/8	28 3/8	29 4/8	30 5/8	31 6/8	33	34 2/8	35 5/8	37	38 3/8	39 7/8	41 4/8
		BH	24 5/8	25 6/8	26 6/8	27 7/8	29 1/8	30 2/8	31 4/8	32 7/8	34 2/8	35 5/8	37 1/8	38 6/8	40 3/8	42
10	**B186M96_Chest_Girth**	**All**	**31 1/8**	**32 1/8**	**33 2/8**	**34 4/8**	**35 6/8**	**37**	**38 2/8**	**39 5/8**	**41**	**42 3/8**	**43 7/8**	**45 4/8**	**47 1/8**	**48 6/8**
		Rect	31 3/8	32 4/8	33 5/8	34 7/8	36	37 3/8	38 5/8	40	41 3/8	42 7/8	44 3/8	46	47 5/8	49 2/8
		Spoon	30 7/8	32	33	34 1/8	35 2/8	36 3/8	37 5/8	38 7/8	40 1/8	41 4/8	42 7/8	44 2/8	45 6/8	47 2/8
		BH	30 4/8	31 5/8	32 5/8	33 6/8	35	36 2/8	37 4/8	38 6/8	40 1/8	41 4/8	42 7/8	44 3/8	45 7/8	47 4/8
11	**B194W108_WaistGirth**	**All**	**25 3/8**	**26 4/8**	**27 6/8**	**29**	**30 2/8**	**31 5/8**	**33**	**34 4/8**	**36 1/8**	**37 5/8**	**39 3/8**	**41 1/8**	**43**	**44 7/8**
		Rect	25 7/8	27 1/8	28 2/8	29 4/8	30 6/8	32 1/8	33 4/8	35	36 4/8	38 1/8	39 6/8	41 4/8	43 3/8	45 2/8
		Spoon	25 2/8	26 2/8	27 3/8	28 5/8	29 6/8	31	32 3/8	33 6/8	35 2/8	36 6/8	38 2/8	39 7/8	41 5/8	43 3/8
		BH	25 5/8	26 6/8	27 7/8	29	30 2/8	31 4/8	32 7/8	34 2/8	35 6/8	37 2/8	38 6/8	40 3/8	42 1/8	43 7/8
12	**A2Waist**	**All**	**24 7/8**	**26**	**27 1/8**	**28 3/8**	**29 5/8**	**31**	**32 3/8**	**33 7/8**	**35 3/8**	**37**	**38 5/8**	**40 3/8**	**42 2/8**	**44 1/8**
		Rect	25 4/8	26 5/8	27 6/8	29	30 2/8	31 4/8	32 7/8	34 3/8	35 7/8	37 3/8	39	40 6/8	42 4/8	44 3/8
		Spoon	24 5/8	25 5/8	26 6/8	27 7/8	29 1/8	30 3/8	31 6/8	33 1/8	34 4/8	36	37 4/8	39 1/8	40 7/8	42 5/8
		BH	25	26 1/8	27 2/8	28 3/8	29 5/8	30 7/8	32 1/8	33 4/8	35	36 4/8	38	39 5/8	41 3/8	43 1/8
13	**A3High_Hip**	**All**	**30 2/8**	**31 3/8**	**32 5/8**	**34**	**35 3/8**	**36 6/8**	**38 2/8**	**39 6/8**	**41 3/8**	**43**	**44 6/8**	**46 4/8**	**48 3/8**	**50 3/8**
		Rect	30 1/8	31 3/8	32 5/8	33 7/8	35 2/8	36 5/8	38	39 4/8	41 1/8	42 6/8	44 3/8	46 1/8	48	49 7/8
		Spoon	30 5/8	32	33 2/8	34 5/8	36 1/8	37 4/8	39 1/8	40 6/8	42 3/8	44 1/8	46	47 7/8	49 7/8	51 7/8
		BH	29 3/8	30 5/8	31 7/8	33 2/8	34 5/8	36	37 5/8	39 1/8	40 6/8	42 4/8	44 2/8	46 1/8	48 1/8	50 1/8
14	**B200W114_PtrHipGirth**	**All**	**33 3/8**	**34 3/8**	**35 5/8**	**36 6/8**	**38**	**39 2/8**	**40 4/8**	**41 7/8**	**43 2/8**	**44 6/8**	**46 2/8**	**47 6/8**	**49 3/8**	**51**
		Rect	32 6/8	33 7/8	35	36 1/8	37 2/8	38 4/8	39 6/8	41 1/8	42 3/8	43 6/8	45 2/8	46 6/8	48 2/8	49 7/8
		Spoon	33 5/8	34 7/8	36 1/8	37 4/8	38 7/8	40 2/8	41 5/8	43 1/8	44 6/8	46 3/8	48	49 6/8	51 5/8	53 4/8
		BH	34	35 1/8	36 3/8	37 6/8	39	40 3/8	41 7/8	43 3/8	44 7/8	46 4/8	48 1/8	49 7/8	51 5/8	53 3/8
15	**A4Hips**	**All**	**34 1/8**	**35 2/8**	**36 3/8**	**37 5/8**	**38 6/8**	**40**	**41 3/8**	**42 5/8**	**44**	**45 4/8**	**46 7/8**	**48 3/8**	**50**	**51 5/8**
		Rect	33 4/8	34 4/8	35 5/8	36 6/8	38	39 2/8	40 4/8	41 6/8	43 1/8	44 4/8	45 7/8	47 3/8	48 7/8	50 3/8
		Spoon	34 5/8	35 7/8	37 1/8	38 3/8	39 6/8	41 1/8	42 4/8	44	45 4/8	47 1/8	48 6/8	50 3/8	52 1/8	54
		BH	35 2/8	36 3/8	37 5/8	38 7/8	40 1/8	41 4/8	42 7/8	44 2/8	45 6/8	47 2/8	48 7/8	50 4/8	52 1/8	53 7/8
16	**A10Thigh_Max**	**All**	**19 6/8**	**20 3/8**	**21**	**21 5/8**	**22 2/8**	**23**	**23 5/8**	**24 3/8**	**25 1/8**	**25 7/8**	**26 5/8**	**27 3/8**	**28 2/8**	**29 1/8**
		Rect	19 3/8	20	20 5/8	21 1/8	21 7/8	22 4/8	23 1/8	23 7/8	24 5/8	25 3/8	26 1/8	26 7/8	27 6/8	28 4/8
		Spoon	19 5/8	20 3/8	21 1/8	21 7/8	22 5/8	23 4/8	24 2/8	25 1/8	26 1/8	27	28	29	30	31 1/8
		BH	20 3/8	21	21 6/8	22 4/8	23 2/8	24	24 6/8	25 5/8	26 4/8	27 2/8	28 2/8	29 1/8	30 1/8	31 1/8

[2] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[3] (for regular height) (continue)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
17	**A11Thigh_ Mid**	**All**	**16 2/8**	**16 6/8**	**17 2/8**	**17 6/8**	**18 2/8**	**18 6/8**	**19 3/8**	**20**	**20 4/8**	**21 1/8**	**21 7/8**	**22 4/8**	**23 1/8**	**23 7/8**
		Rect	15 7/8	16 3/8	16 7/8	17 3/8	17 7/8	18 3/8	19	19 4/8	20 1/8	20 6/8	21 3/8	22	22 5/8	23 3/8
		Spoon	16 1/8	16 6/8	17 2/8	17 7/8	18 4/8	19 2/8	19 7/8	20 5/8	21 2/8	22	22 7/8	23 5/8	24 4/8	25 3/8
		BH	16 6/8	17 2/8	17 7/8	18 4/8	19	19 6/8	20 3/8	21	21 6/8	22 4/8	23 2/8	24	24 6/8	25 5/8
18	**A12Knee**	**All**	**13**	**13 2/8**	**13 5/8**	**13 7/8**	**14 2/8**	**14 5/8**	**14 7/8**	**15 2/8**	**15 5/8**	**16**	**16 3/8**	**16 6/8**	**17 1/8**	**17 4/8**
		Rect	12 7/8	13 1/8	13 4/8	13 6/8	14 1/8	14 3/8	14 6/8	15	15 3/8	15 6/8	16 1/8	16 4/8	16 6/8	17 2/8
		Spoon	13	13 3/8	13 5/8	14	14 3/8	14 6/8	15 1/8	15 5/8	16	16 3/8	16 7/8	17 2/8	17 6/8	18 2/8
		BH	13 2/8	13 5/8	13 7/8	14 2/8	14 5/8	15	15 3/8	15 6/8	16 2/8	16 5/8	17	17 4/8	17 7/8	18 3/8
19	**B211W120 R_LowKne eGirth**	**All**	**12**	**12 2/8**	**12 5/8**	**12 7/8**	**13 2/8**	**13 4/8**	**13 7/8**	**14 2/8**	**14 5/8**	**15**	**15 3/8**	**15 6/8**	**16 1/8**	**16 5/8**
		Rect	11 7/8	12 1/8	12 4/8	12 6/8	13	13 3/8	13 6/8	14	14 3/8	14 6/8	15 1/8	15 4/8	15 7/8	16 2/8
		Spoon	11 7/8	12 2/8	12 5/8	13	13 3/8	13 6/8	14 1/8	14 5/8	15	15 4/8	15 7/8	16 3/8	16 7/8	17 3/8
		BH	12 2/8	12 4/8	12 7/8	13 2/8	13 5/8	14	14 3/8	14 6/8	15 2/8	15 5/8	16 1/8	16 4/8	17	17 4/8
20	**A13Calf**	**All**	**12 4/8**	**12 6/8**	**13 1/8**	**13 4/8**	**13 6/8**	**14 1/8**	**14 4/8**	**14 7/8**	**15 2/8**	**15 5/8**	**16**	**16 4/8**	**16 7/8**	**17 2/8**
		Rect	12 3/8	12 5/8	13	13 2/8	13 5/8	14	14 2/8	14 5/8	15	15 3/8	15 6/8	16 1/8	16 4/8	17
		Spoon	12 3/8	12 6/8	13 1/8	13 4/8	14	14 3/8	14 6/8	15 2/8	15 5/8	16 1/8	16 5/8	17 1/8	17 5/8	18 1/8
		BH	12 6/8	13	13 3/8	13 6/8	14 1/8	14 5/8	15	15 3/8	15 7/8	16 2/8	16 6/8	17 1/8	17 5/8	18 1/8
22	**A14'Ankle Girth**	**All**	**8 7/8**	**9**	**9 1/8**	**9 2/8**	**9 4/8**	**9 5/8**	**9 7/8**	**10**	**10 1/8**	**10 3/8**	**10 4/8**	**10 6/8**	**11**	**11 1/8**
		Rect	8 7/8	9	9 1/8	9 2/8	9 4/8	9 5/8	9 6/8	10	10 1/8	10 2/8	10 4/8	10 5/8	10 7/8	11
		Spoon	8 6/8	9	9 1/8	9 3/8	9 4/8	9 5/8	9 7/8	10	10 2/8	10 3/8	10 5/8	10 7/8	11	11 2/8
		BH	8 6/8	9	9 1/8	9 3/8	9 4/8	9 6/8	9 7/8	10 1/8	10 2/8	10 4/8	10 5/8	10 7/8	11 1/8	11 2/8
23	**A7Armscy e**	**All**	**13 5/8**	**14**	**14 3/8**	**14 6/8**	**15 2/8**	**15 5/8**	**16**	**16 4/8**	**16 7/8**	**17 3/8**	**17 7/8**	**18 3/8**	**18 7/8**	**19 3/8**
		Rect	13 5/8	14	14 3/8	14 7/8	15 2/8	15 5/8	16 1/8	16 4/8	17	17 4/8	18	18 4/8	19	19 4/8
		Spoon	13 4/8	13 7/8	14 2/8	14 6/8	15 1/8	15 4/8	16	16 3/8	16 7/8	17 2/8	17 6/8	18 2/8	18 6/8	19 2/8
		BH	13 4/8	13 6/8	14 1/8	14 4/8	15	15 3/8	15 6/8	16 2/8	16 5/8	17 1/8	17 4/8	18	18 4/8	19
24	**A8Upper_ Arm**	**All**	**8 6/8**	**9 1/8**	**9 4/8**	**10**	**10 4/8**	**10 7/8**	**11 3/8**	**12**	**12 4/8**	**13**	**13 5/8**	**14 2/8**	**14 7/8**	**15 5/8**
		Rect	8 6/8	9 1/8	9 4/8	10	10 3/8	10 7/8	11 3/8	11 7/8	12 3/8	13	13 4/8	14 1/8	14 7/8	15 4/8
		Spoon	8 5/8	9	9 4/8	10	10 4/8	11	11 4/8	12 1/8	12 6/8	13 3/8	14	14 6/8	15 3/8	16 2/8
		BH	8 6/8	9 1/8	9 4/8	10	10 4/8	11	11 4/8	12 1/8	12 5/8	13 2/8	13 7/8	14 5/8	15 2/8	16
25	**A9Elbow**	**All**	**8 2/8**	**8 4/8**	**8 6/8**	**9 1/8**	**9 3/8**	**9 5/8**	**10**	**10 2/8**	**10 5/8**	**10 7/8**	**11 2/8**	**11 5/8**	**12**	**12 3/8**
		Rect	8 2/8	8 4/8	8 6/8	9	9 3/8	9 5/8	9 7/8	10 2/8	10 4/8	10 7/8	11 2/8	11 4/8	11 7/8	12 2/8
		Spoon	8 2/8	8 4/8	8 6/8	9 1/8	9 3/8	9 6/8	10	10 3/8	10 5/8	11	11 3/8	11 6/8	12 1/8	12 4/8
		BH	8 2/8	8 4/8	8 7/8	9 1/8	9 3/8	9 6/8	10	10 3/8	10 6/8	11 1/8	11 3/8	11 6/8	12 2/8	12 5/8

[3] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[4] (for regular height) (continue)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
26	**B183W100**	**All**	**5 5/8**	**5 6/8**	**5 7/8**	**6**	**6 1/8**	**6 2/8**	**6 3/8**	**6 4/8**	**6 6/8**	**6 7/8**	**7**	**7 1/8**	**7 2/8**	**7 4/8**
	R_WristGi	Rect	5 5/8	5 6/8	5 7/8	6	6 1/8	6 2/8	6 3/8	6 5/8	6 6/8	6 7/8	7	7 1/8	7 3/8	7 4/8
	rth	Spoon	5 5/8	5 6/8	5 7/8	6	6 1/8	6 2/8	6 3/8	6 4/8	6 5/8	6 6/8	6 7/8	7 1/8	7 2/8	7 3/8
		BH	5 5/8	5 6/8	5 7/8	6	6 1/8	6 2/8	6 3/8	6 4/8	6 5/8	6 6/8	6 7/8	7	7 1/8	7 2/8
27	**A18Cervic**	**All**	**56 1/8**	**56 2/8**	**56 3/8**	**56 4/8**	**56 5/8**	**56 6/8**	**56 7/8**	**57**	**57 1/8**	**57 2/8**	**57 4/8**	**57 5/8**	**57 6/8**	**57 7/8**
	ale_Height	Rect	56	56 1/8	56 2/8	56 3/8	56 4/8	56 5/8	56 6/8	57	57 1/8	57 2/8	57 3/8	57 4/8	57 5/8	57 6/8
		Spoon	56 2/8	56 3/8	56 4/8	56 5/8	56 6/8	56 7/8	57	57 1/8	57 2/8	57 3/8	57 4/8	57 5/8	57 6/8	57 7/8
		BH	56 2/8	56 3/8	56 4/8	56 5/8	56 6/8	56 7/8	57 1/8	57 2/8	57 3/8	57 4/8	57 5/8	57 7/8	58	58 1/8
28	**B14Midriff**	**All**	**41 7/8**	**41 7/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 6/8**	**41 5/8**
	_Height	Rect	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8	41 6/8
		Spoon	41 7/8	41 7/8	41 6/8	41 6/8	41 6/8	41 5/8	41 5/8	41 5/8	41 5/8	41 4/8	41 4/8	41 4/8	41 4/8	41 3/8
		BH	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8	41 7/8
29	**B78W22_**	**All**	**37 7/8**	**38**	**38 1/8**	**38 2/8**	**38 3/8**	**38 4/8**	**38 5/8**	**38 6/8**	**39**	**39 1/8**	**39 2/8**	**39 3/8**	**39 4/8**	**39 5/8**
	Waist5_He	Rect	37 7/8	38	38 1/8	38 2/8	38 3/8	38 4/8	38 5/8	38 6/8	38 7/8	39	39 1/8	39 2/8	39 4/8	39 5/8
	ight	Spoon	37 6/8	37 7/8	38	38 2/8	38 3/8	38 4/8	38 6/8	38 7/8	39	39 2/8	39 3/8	39 5/8	39 6/8	39 7/8
		BH	37 6/8	37 7/8	38	38 2/8	38 3/8	38 4/8	38 5/8	38 6/8	39	39 1/8	39 2/8	39 3/8	39 5/8	39 6/8
30	**A19Waist6**	**All**	**38 5/8**	**38 6/8**	**38 7/8**	**38 7/8**	**39**	**39 1/8**	**39 2/8**	**39 2/8**	**39 3/8**	**39 4/8**	**39 5/8**	**39 5/8**	**39 6/8**	**39 7/8**
	_Height	Rect	38 5/8	38 5/8	38 6/8	38 6/8	38 7/8	39	39	39 1/8	39 1/8	39 2/8	39 2/8	39 3/8	39 4/8	39 4/8
		Spoon	38 4/8	38 6/8	38 7/8	39	39 1/8	39 3/8	39 4/8	39 5/8	39 7/8	40	40 1/8	40 2/8	40 4/8	40 5/8
		BH	38 4/8	38 5/8	38 6/8	38 7/8	39	39 2/8	39 3/8	39 4/8	39 5/8	39 6/8	40	40 1/8	40 2/8	40 3/8
32	**A20High_**	**All**	**35 2/8**	**35 3/8**	**35 4/8**	**35 4/8**	**35 5/8**	**35 6/8**	**35 7/8**	**36**	**36 1/8**	**36 2/8**	**36 3/8**	**36 4/8**	**36 5/8**	**36 6/8**
	Hip_Heigh	Rect	35 2/8	35 3/8	35 4/8	35 4/8	35 5/8	35 6/8	35 7/8	36	36 1/8	36 2/8	36 2/8	36 3/8	36 4/8	36 5/8
	t	Spoon	35 1/8	35 2/8	35 3/8	35 4/8	35 5/8	35 7/8	36	36 1/8	36 2/8	36 4/8	36 5/8	36 6/8	36 7/8	37 1/8
		BH	35 1/8	35 2/8	35 3/8	35 4/8	35 6/8	35 7/8	36	36 1/8	36 2/8	36 3/8	36 4/8	36 6/8	36 7/8	37
34	**B79W23_P**	**All**	**31 6/8**	**31 7/8**	**32**	**32 1/8**	**32 2/8**	**32 2/8**	**32 3/8**	**32 4/8**	**32 5/8**	**32 6/8**	**32 7/8**	**33**	**33 1/8**	**33 2/8**
	trHipHeigh	Rect	32	32	32 1/8	32 2/8	32 3/8	32 3/8	32 4/8	32 5/8	32 6/8	32 7/8	32 7/8	33	33 1/8	33 2/8
	t	Spoon	31 5/8	31 6/8	31 7/8	32	32 1/8	32 2/8	32 3/8	32 3/8	32 4/8	32 5/8	32 6/8	32 7/8	33	33 1/8
		BH	31 4/8	31 5/8	31 5/8	31 6/8	31 7/8	32	32 1/8	32 2/8	32 3/8	32 4/8	32 6/8	32 7/8	33	33 1/8
35	**A21MaxHi**	**All**	**29**	**29 3/8**	**29 6/8**	**30 2/8**	**30 5/8**	**31**	**31 3/8**	**31 7/8**	**32 2/8**	**32 5/8**	**33 1/8**	**33 4/8**	**34**	**34 3/8**
	ps_Height	Rect	29 2/8	29 5/8	30	30 4/8	30 7/8	31 2/8	31 6/8	32 2/8	32 5/8	33 1/8	33 5/8	34	34 4/8	35
		Spoon	28 7/8	29 2/8	29 5/8	30	30 2/8	30 5/8	31 1/8	31 4/8	31 7/8	32 2/8	32 5/8	33	33 4/8	33 7/8
		BH	28 5/8	29	29 2/8	29 4/8	29 7/8	30 1/8	30 4/8	30 6/8	31 1/8	31 3/8	31 6/8	32 1/8	32 3/8	32 6/8

[4] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[5] (for regular height) (continue)

	size label		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
36	**A22Crotch_Height**	**All**	**29 3/8**	**29 3/8**	**29 2/8**	**29 1/8**	**29**	**29**	**28 7/8**	**28 6/8**	**28 6/8**	**28 5/8**	**28 4/8**	**28 3/8**	**28 3/8**	**28 2/8**
		Rect	29 4/8	29 3/8	29 3/8	29 2/8	29 1/8	29 1/8	29	28 7/8	28 6/8	28 6/8	28 5/8	28 4/8	28 4/8	28 3/8
		Spoon	29 3/8	29 2/8	29 1/8	29	29	28 7/8	28 6/8	28 5/8	28 4/8	28 3/8	28 3/8	28 2/8	28 1/8	28
		BH	29 2/8	29 1/8	29 1/8	29	28 7/8	28 7/8	28 6/8	28 5/8	28 5/8	28 4/8	28 3/8	28 3/8	28 2/8	28 1/8
37	**A23Knee_Height**	**All**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**
		Rect	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8
		Spoon	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8	17 2/8
		BH	17 4/8	17 4/8	17 4/8	17 3/8	17 3/8	17 3/8	17 3/8	17 2/8	17 2/8	17 2/8	17 2/8	17 1/8	17 1/8	17 1/8
38	**A24Ankle_Height**	**All**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 6/8**	**2 5/8**	**2 5/8**	**2 5/8**	**2 5/8**	**2 5/8**
		Rect	2 7/8	2 7/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 5/8
		Spoon	2 6/8	2 6/8	2 6/8	2 6/8	2 6/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8
		BH	2 7/8	2 7/8	2 7/8	2 6/8	2 6/8	2 6/8	2 6/8	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 4/8	2 4/8
39	**A16Crotch_Length_Total**	**All**	**23 2/8**	**23 7/8**	**24 5/8**	**25 2/8**	**26**	**26 5/8**	**27 3/8**	**28 1/8**	**28 7/8**	**29 5/8**	**30 4/8**	**31 2/8**	**32 1/8**	**33**
		Rect	23	23 5/8	24 2/8	24 7/8	25 4/8	26 1/8	26 6/8	27 4/8	28 1/8	28 7/8	29 5/8	30 3/8	31 1/8	31 7/8
		Spoon	23 3/8	24 1/8	24 7/8	25 6/8	26 4/8	27 3/8	28 2/8	29 1/8	30	31	32	33	34	35 1/8
		BH	23 4/8	24 2/8	25	25 6/8	26 4/8	27 3/8	28 2/8	29 1/8	30	30 7/8	31 7/8	32 7/8	33 7/8	35
40	**A30Shoulder_Length**	**All**	**4 3/8**	**4 4/8**	**4 4/8**	**4 5/8**	**4 6/8**	**4 6/8**	**4 7/8**	**5**	**5 1/8**	**5 2/8**	**5 2/8**	**5 3/8**	**5 4/8**	**5 5/8**
		Rect	4 3/8	4 4/8	4 5/8	4 5/8	4 6/8	4 7/8	5	5	5 1/8	5 2/8	5 3/8	5 4/8	5 5/8	5 6/8
		Spoon	4 3/8	4 4/8	4 4/8	4 5/8	4 6/8	4 6/8	4 7/8	5	5	5 1/8	5 2/8	5 2/8	5 3/8	5 4/8
		BH	4 3/8	4 3/8	4 4/8	4 5/8	4 5/8	4 6/8	4 7/8	4 7/8	5	5 1/8	5 2/8	5 2/8	5 3/8	5 4/8
41	**B131W61_FrontNecktoWaist5**	**All**	**14 7/8**	**15**	**15**	**15 1/8**	**15 1/8**	**15 2/8**	**15 2/8**	**15 3/8**	**15 4/8**	**15 4/8**	**15 5/8**	**15 5/8**	**15 6/8**	**15 6/8**
		Rect	14 6/8	14 7/8	15	15 1/8	15 1/8	15 2/8	15 3/8	15 4/8	15 4/8	15 5/8	15 6/8	15 7/8	15 7/8	16
		Spoon	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8	15 1/8
		BH	14 6/8	14 7/8	14 7/8	15	15 1/8	15 1/8	15 2/8	15 2/8	15 3/8	15 3/8	15 4/8	15 4/8	15 5/8	15 6/8
42	**A25Waist_Length_Front**	**All**	**13 5/8**	**13 6/8**	**13 7/8**	**14**	**14 2/8**	**14 3/8**	**14 4/8**	**14 5/8**	**14 7/8**	**15**	**15 2/8**	**15 3/8**	**15 4/8**	**15 6/8**
		Rect	13 4/8	13 6/8	13 7/8	14 1/8	14 3/8	14 4/8	14 6/8	15	15 2/8	15 3/8	15 5/8	15 7/8	16 1/8	16 3/8
		Spoon	13 6/8	13 6/8	13 7/8	13 7/8	14	14	14 1/8	14 1/8	14 2/8	14 2/8	14 3/8	14 3/8	14 4/8	14 4/8
		BH	13 5/8	13 6/8	13 6/8	13 7/8	14	14	14 1/8	14 2/8	14 2/8	14 3/8	14 4/8	14 5/8	14 5/8	14 6/8
43	**B104W41_Neck2Waist5Contoured_Back**	**All**	**17 1/8**	**17 1/8**	**17 2/8**	**17 2/8**	**17 2/8**	**17 2/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 4/8**	**17 4/8**	**17 4/8**	**17 4/8**	**17 5/8**
		Rect	17	17	17 1/8	17 1/8	17 2/8	17 2/8	17 3/8	17 3/8	17 4/8	17 4/8	17 5/8	17 5/8	17 6/8	17 6/8
		Spoon	17 4/8	17 4/8	17 3/8	17 3/8	17 3/8	17 3/8	17 2/8	17 2/8	17 2/8	17 1/8	17 1/8	17 1/8	17	17
		BH	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8	17 3/8

[5] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[6] (for regular height) (continue)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
44	**A26Waist6_Length_Back**	**All**	**17 1/8**	**17 1/8**	**17 1/8**	**17 1/8**	**17 2/8**	**17 2/8**	**17 2/8**	**17 2/8**	**17 2/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 3/8**	**17 4/8**
		Rect	17	17	17 1/8	17 1/8	17 2/8	17 2/8	17 2/8	17 3/8	17 3/8	17 3/8	17 4/8	17 4/8	17 5/8	17 5/8
		Spoon	17 4/8	17 3/8	17 3/8	17 3/8	17 2/8	17 2/8	17 2/8	17 1/8	17 1/8	17	17	17	16 7/8	16 7/8
		BH	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8	17 1/8
45	**B117W55R_SideNeckToWaist5Straight**	**All**	**16 7/8**	**17 1/8**	**17 2/8**	**17 3/8**	**17 4/8**	**17 5/8**	**17 6/8**	**17 7/8**	**18**	**18 1/8**	**18 2/8**	**18 4/8**	**18 5/8**	**18 6/8**
		Rect	16 7/8	17	17 2/8	17 3/8	17 4/8	17 5/8	17 7/8	18	18 1/8	18 3/8	18 4/8	18 5/8	18 7/8	19
		Spoon	17 1/8	17 2/8	17 2/8	17 3/8	17 3/8	17 4/8	17 4/8	17 5/8	17 5/8	17 6/8	17 6/8	17 7/8	18	18
		BH	16 7/8	17	17 1/8	17 2/8	17 3/8	17 4/8	17 5/8	17 5/8	17 6/8	17 7/8	18	18 1/8	18 2/8	18 3/8
46	**W75aR_BackNeckToElbow**	**All**	**19 6/8**	**19 7/8**	**20**	**20 1/8**	**20 2/8**	**20 4/8**	**20 5/8**	**20 6/8**	**20 7/8**	**21**	**21 2/8**	**21 3/8**	**21 4/8**	**21 5/8**
		Rect	19 6/8	19 7/8	20	20 1/8	20 2/8	20 4/8	20 5/8	20 6/8	20 7/8	21	21 2/8	21 3/8	21 4/8	21 6/8
		Spoon	19 6/8	19 7/8	20	20 1/8	20 3/8	20 4/8	20 5/8	20 6/8	20 7/8	21	21 1/8	21 2/8	21 3/8	21 5/8
		BH	19 6/8	19 7/8	20	20 1/8	20 2/8	20 3/8	20 4/8	20 6/8	20 7/8	21	21 1/8	21 2/8	21 3/8	21 5/8
47	**A33Arm_Length_(Shoulder_to_Wrist)**	**All**	**20 5/8**	**20 5/8**	**20 6/8**	**20 6/8**	**20 6/8**	**20 7/8**	**20 7/8**	**21**	**21**	**21 1/8**	**21 1/8**	**21 2/8**	**21 2/8**	**21 2/8**
		Rect	20 5/8	20 6/8	20 6/8	20 7/8	20 7/8	20 7/8	21	21	21 1/8	21 1/8	21 2/8	21 2/8	21 2/8	21 3/8
		Spoon	20 5/8	20 5/8	20 6/8	20 6/8	20 6/8	20 6/8	20 7/8	20 7/8	20 7/8	20 7/8	20 7/8	21	21	21
		BH	20 4/8	20 5/8	20 5/8	20 5/8	20 6/8	20 6/8	20 6/8	20 7/8	20 7/8	20 7/8	21	21	21	21 1/8
48	**A34Arm_Length_CBNeck_to_Wrist**	**All**	**27**	**27 1/8**	**27 3/8**	**27 5/8**	**27 7/8**	**28**	**28 2/8**	**28 4/8**	**28 6/8**	**28 7/8**	**29 1/8**	**29 3/8**	**29 5/8**	**29 7/8**
		Rect	27	27 2/8	27 4/8	27 5/8	27 7/8	28 1/8	28 3/8	28 5/8	28 7/8	29	29 2/8	29 4/8	29 6/8	30
		Spoon	27 1/8	27 2/8	27 3/8	27 5/8	27 6/8	27 7/8	28 1/8	28 2/8	28 3/8	28 5/8	28 6/8	29	29 1/8	29 3/8
		BH	26 7/8	27 1/8	27 2/8	27 4/8	27 5/8	27 7/8	28	28 2/8	28 3/8	28 5/8	28 7/8	29	29 2/8	29 3/8
49	**A36Neck_to_Bust_Point**	**All**	**9 1/8**	**9 3/8**	**9 5/8**	**9 7/8**	**10 1/8**	**10 3/8**	**10 5/8**	**10 7/8**	**11 2/8**	**11 4/8**	**11 6/8**	**12 1/8**	**12 3/8**	**12 6/8**
		Rect	9 1/8	9 3/8	9 5/8	9 7/8	10 1/8	10 3/8	10 6/8	11	11 2/8	11 5/8	11 7/8	12 2/8	12 4/8	12 7/8
		Spoon	9 1/8	9 3/8	9 4/8	9 6/8	10	10 2/8	10 5/8	10 7/8	11 1/8	11 3/8	11 5/8	12	12 2/8	12 5/8
		BH	8 7/8	9 1/8	9 3/8	9 4/8	9 7/8	10 1/8	10 3/8	10 5/8	10 7/8	11 1/8	11 4/8	11 6/8	12 1/8	12 3/8
50	**B145W68R_UnderArmLength**	**All**	**17 6/8**	**17 6/8**	**17 6/8**	**17 5/8**	**17 5/8**	**17 5/8**	**17 5/8**	**17 5/8**	**17 5/8**	**17 4/8**	**17 4/8**	**17 4/8**	**17 4/8**	**17 4/8**
		Rect	17 6/8	17 6/8	17 6/8	17 6/8	17 5/8	17 5/8	17 5/8	17 5/8	17 5/8	17 4/8	17 4/8	17 4/8	17 4/8	17 4/8
		Spoon	17 7/8	17 6/8	17 6/8	17 6/8	17 6/8	17 5/8	17 5/8	17 5/8	17 4/8	17 4/8	17 4/8	17 4/8	17 3/8	17 3/8
		BH	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8	17 6/8
51	**B138W66R_SideWaist5ToHipPtr**	**All**	**9 5/8**	**9 1/8**	**8 6/8**	**8 3/8**	**8**	**7 5/8**	**7 2/8**	**6 7/8**	**6 5/8**	**6 2/8**	**6**	**5 6/8**	**5 4/8**	**5 2/8**
		Rect	9 3/8	8 7/8	8 4/8	8	7 5/8	7 2/8	6 7/8	6 4/8	6 1/8	5 6/8	5 4/8	5 2/8	5	4 6/8
		Spoon	9 4/8	9 2/8	8 7/8	8 5/8	8 3/8	8 1/8	7 7/8	7 5/8	7 3/8	7 2/8	7	6 6/8	6 4/8	6 3/8
		BH	9 6/8	9 4/8	9 2/8	9	8 7/8	8 5/8	8 4/8	8 2/8	8 1/8	7 7/8	7 6/8	7 4/8	7 3/8	7 2/8

[6] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[7] (for regular height) (continue)

	size label		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
53	**B83W27_BodyRise(W5Straight)**	**All**	**8 6/8**	**9**	**9 2/8**	**9 3/8**	**9 5/8**	**9 7/8**	**10**	**10 2/8**	**10 4/8**	**10 6/8**	**11**	**11 2/8**	**11 4/8**	**11 6/8**
		Rect	8 6/8	8 7/8	9 1/8	9 2/8	9 4/8	9 6/8	9 7/8	10 1/8	10 3/8	10 5/8	10 6/8	11	11 2/8	11 4/8
		Spoon	8 6/8	9	9 2/8	9 4/8	9 6/8	10	10 2/8	10 4/8	10 6/8	11 1/8	11 3/8	11 5/8	12	12 2/8
		BH	8 7/8	9	9 2/8	9 4/8	9 6/8	9 7/8	10 1/8	10 3/8	10 5/8	10 7/8	11 1/8	11 3/8	11 5/8	11 7/8
54	**B142W67R_OutsideLegLength**	**All**	**38 1/8**	**38 2/8**	**38 4/8**	**38 5/8**	**38 6/8**	**38 7/8**	**39**	**39 1/8**	**39 2/8**	**39 3/8**	**39 5/8**	**39 6/8**	**39 7/8**	**40**
		Rect	38 1/8	38 2/8	38 3/8	38 4/8	38 5/8	38 6/8	38 7/8	39	39 1/8	39 3/8	39 4/8	39 5/8	39 6/8	39 7/8
		Spoon	38	38 2/8	38 3/8	38 5/8	38 6/8	39	39 1/8	39 3/8	39 5/8	39 6/8	40	40 1/8	40 3/8	40 5/8
		BH	38	38 1/8	38 3/8	38 4/8	38 5/8	38 7/8	39	39 1/8	39 3/8	39 4/8	39 5/8	39 7/8	40	40 1/8
55	**B224W139R_FootLength**	**All**	**9 2/8**	**9 2/8**	**9 3/8**	**9 3/8**	**9 3/8**	**9 4/8**	**9 4/8**	**9 5/8**	**9 5/8**	**9 5/8**	**9 6/8**	**9 6/8**	**9 7/8**	**9 7/8**
		Rect	9 2/8	9 2/8	9 3/8	9 3/8	9 4/8	9 4/8	9 4/8	9 5/8	9 5/8	9 6/8	9 6/8	9 6/8	9 7/8	9 7/8
		Spoon	9 2/8	9 2/8	9 2/8	9 3/8	9 3/8	9 4/8	9 4/8	9 4/8	9 5/8	9 5/8	9 6/8	9 6/8	9 6/8	9 7/8
		BH	9 3/8	9 3/8	9 3/8	9 4/8	9 4/8	9 4/8	9 4/8	9 5/8	9 5/8	9 5/8	9 6/8	9 6/8	9 6/8	9 7/8
56	**A27Across_Shoulder**	**All**	**12 7/8**	**13 1/8**	**13 3/8**	**13 5/8**	**14**	**14 2/8**	**14 5/8**	**14 7/8**	**15 2/8**	**15 5/8**	**16**	**16 2/8**	**16 5/8**	**17**
		Rect	12 7/8	13 1/8	13 3/8	13 6/8	14	14 3/8	14 6/8	15	15 3/8	15 6/8	16 1/8	16 4/8	16 7/8	17 2/8
		Spoon	12 7/8	13 1/8	13 3/8	13 5/8	13 7/8	14 2/8	14 4/8	14 6/8	15 1/8	15 3/8	15 5/8	16	16 2/8	16 5/8
		BH	12 6/8	13	13 2/8	13 4/8	13 7/8	14 1/8	14 3/8	14 6/8	15	15 3/8	15 5/8	16	16 3/8	16 5/8
57	**B157W82_BackShoulderWidth(contoured)**	**All**	**13 2/8**	**13 4/8**	**13 6/8**	**14 1/8**	**14 3/8**	**14 6/8**	**15**	**15 3/8**	**15 6/8**	**16 1/8**	**16 4/8**	**16 7/8**	**17 2/8**	**17 5/8**
		Rect	13 2/8	13 4/8	13 7/8	14 1/8	14 4/8	14 7/8	15 1/8	15 4/8	15 7/8	16 2/8	16 5/8	17	17 3/8	17 6/8
		Spoon	13 2/8	13 4/8	13 6/8	14 1/8	14 3/8	14 5/8	14 7/8	15 2/8	15 4/8	15 7/8	16 1/8	16 4/8	16 6/8	17 1/8
		BH	13 1/8	13 3/8	13 5/8	14	14 2/8	14 4/8	14 7/8	15 1/8	15 4/8	15 7/8	16 1/8	16 4/8	16 7/8	17 2/8
58	**B160W84_FrontShoulderWidth**	**All**	**13 5/8**	**13 6/8**	**14**	**14 1/8**	**14 2/8**	**14 4/8**	**14 5/8**	**14 7/8**	**15**	**15 2/8**	**15 3/8**	**15 5/8**	**15 7/8**	**16**
		Rect	13 4/8	13 6/8	13 7/8	14 1/8	14 2/8	14 4/8	14 5/8	14 7/8	15	15 2/8	15 4/8	15 5/8	15 7/8	16 1/8
		Spoon	13 5/8	13 7/8	14	14 1/8	14 2/8	14 4/8	14 5/8	14 6/8	15	15 1/8	15 2/8	15 4/8	15 5/8	15 7/8
		BH	13 5/8	13 7/8	14	14 2/8	14 3/8	14 4/8	14 6/8	14 7/8	15 1/8	15 2/8	15 4/8	15 5/8	15 7/8	16
59	**A28Cross_Back_Width**	**All**	**12 2/8**	**12 4/8**	**12 6/8**	**13 1/8**	**13 3/8**	**13 6/8**	**14**	**14 3/8**	**14 5/8**	**15**	**15 3/8**	**15 6/8**	**16 1/8**	**16 4/8**
		Rect	12 1/8	12 4/8	12 6/8	13 1/8	13 3/8	13 6/8	14 1/8	14 3/8	14 6/8	15 1/8	15 4/8	15 7/8	16 2/8	16 5/8
		Spoon	12 4/8	12 5/8	12 7/8	13 1/8	13 3/8	13 6/8	14	14 2/8	14 4/8	14 6/8	15 1/8	15 3/8	15 5/8	16
		BH	12	12 3/8	12 5/8	12 7/8	13 1/8	13 3/8	13 6/8	14	14 3/8	14 5/8	15	15 2/8	15 5/8	16
60	**A29Cross_Chest_Width**	**All**	**12 5/8**	**12 7/8**	**13 1/8**	**13 3/8**	**13 6/8**	**14**	**14 3/8**	**14 5/8**	**15**	**15 3/8**	**15 5/8**	**16**	**16 3/8**	**16 6/8**
		Rect	12 6/8	13	13 3/8	13 5/8	14	14 2/8	14 5/8	15	15 2/8	15 5/8	16	16 3/8	16 6/8	17 1/8
		Spoon	12 2/8	12 4/8	12 6/8	13 1/8	13 3/8	13 5/8	14	14 2/8	14 4/8	14 7/8	15 2/8	15 4/8	15 7/8	16 2/8
		BH	12 4/8	12 6/8	13 1/8	13 3/8	13 5/8	13 7/8	14 1/8	14 4/8	14 6/8	15 1/8	15 3/8	15 6/8	16	16 3/8

[7] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)

Appendix F: The created Sizing System[8] (for regular height) (continue)

	size label		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	number of subjects	**All**	**6**	**16**	**63**	**107**	**179**	**193**	**196**	**159**	**149**	**118**	**92**	**88**	**41**	**40**
		Rect	1	4	26	30	55	73	84	85	76	58	45	42	23	13
		Spoon	4	9	27	42	65	56	59	43	36	31	14	18	5	6
		BH	0	2	4	11	23	21	17	4	8	8	13	5	1	10
61	**A35Bust_Pt_to_Bust_Pt**	**All**	**6 6/8**	**7**	**7 1/8**	**7 3/8**	**7 4/8**	**7 6/8**	**8**	**8 2/8**	**8 3/8**	**8 5/8**	**8 7/8**	**9 1/8**	**9 3/8**	**9 5/8**
		Rect	6 7/8	7 1/8	7 2/8	7 4/8	7 5/8	7 7/8	8 1/8	8 2/8	8 4/8	8 6/8	9	9 2/8	9 4/8	9 6/8
		Spoon	6 5/8	6 6/8	7	7 1/8	7 3/8	7 5/8	7 7/8	8	8 2/8	8 4/8	8 6/8	9	9 2/8	9 5/8
		BH	6 6/8	6 7/8	7 1/8	7 2/8	7 4/8	7 5/8	7 7/8	8 1/8	8 2/8	8 4/8	8 6/8	9	9 2/8	9 4/8
62	**B222W138R_FootWidth**	**All**	**3 3/8**	**3 3/8**	**3 3/8**	**3 4/8**	**3 4/8**	**3 4/8**	**3 4/8**	**3 5/8**	**3 5/8**	**3 5/8**	**3 6/8**	**3 6/8**	**3 6/8**	**3 7/8**
		Rect	3 3/8	3 3/8	3 3/8	3 4/8	3 4/8	3 4/8	3 5/8	3 5/8	3 5/8	3 5/8	3 6/8	3 6/8	3 6/8	3 7/8
		Spoon	3 3/8	3 3/8	3 3/8	3 4/8	3 4/8	3 4/8	3 4/8	3 5/8	3 5/8	3 5/8	3 6/8	3 6/8	3 6/8	3 6/8
		BH	3 3/8	3 3/8	3 4/8	3 4/8	3 4/8	3 4/8	3 5/8	3 5/8	3 5/8	3 5/8	3 6/8	3 6/8	3 6/8	3 6/8
63	**A32Shoulder_Slope_(degrees)**	**All**	**21.88**	**21.75**	**21.63**	**21.63**	**21.50**	**21.38**	**21.25**	**21.25**	**21.13**	**21.00**	**21.00**	**20.88**	**20.75**	**20.63**
		Rect	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88
		Spoon	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13	22.13
		BH	22.13	22.00	21.88	21.75	21.63	21.50	21.38	21.25	21.25	21.13	21.00	20.88	20.75	20.63
64	**B67W15R_ArmscyeDepthFromBackNeck**	**All**	**6 1/8**	**6 2/8**	**6 2/8**	**6 3/8**	**6 3/8**	**6 4/8**	**6 4/8**	**6 5/8**	**6 5/8**	**6 5/8**	**6 6/8**	**6 6/8**	**6 7/8**	**6 7/8**
		Rect	6 1/8	6 2/8	6 2/8	6 3/8	6 3/8	6 4/8	6 4/8	6 5/8	6 5/8	6 6/8	6 6/8	6 7/8	6 7/8	7
		Spoon	6 2/8	6 2/8	6 3/8	6 3/8	6 3/8	6 4/8	6 4/8	6 5/8	6 5/8	6 6/8	6 6/8	6 7/8	6 7/8	7
		BH	6 1/8	6 1/8	6 2/8	6 2/8	6 3/8	6 3/8	6 3/8	6 4/8	6 4/8	6 4/8	6 5/8	6 5/8	6 5/8	6 6/8

[8] Units: inch, except for BMI and A32Shoulder_Slope_(degrees)