NC STATE College of Textiles
JTATM Journal of Textile and Apparel, Technology and Management

Volume 10, Issue 2, 2016

Comparison of Women's Sizes from SizeUSA and ASTM D5585-11 Sizing Standard with Focus on the Potential for Mass Customization

Siming Guo

Ph.D. Program in Textile Technology Management
College of Textiles
North Carolina State University
Raleigh, NC 27695-8301
USA

ABSTRACT

This paper analyzed the data collected from SizeUSA and compared the results with ASTM D5585-11 (2011), which is the newest US female sizing standard. Three dimensional body scanning can be used in the development of sizing standards and support mass customization of apparel for those consumers whose needs cannot be met through normal sizing. Americans have grown bigger and heavier since the original sizing study that was used to develop apparel sizing standards. The results of the comparison of SizeUSA data with the measurements defined for sizes in the ASTM D5585-11 standard found that the waist sizes are smaller than those of actual American women. The linear regression equations discussed in this paper are for waist girth prediction. The size range of the back-waist length is shorter than the average women's measurement because ASTM D5585-11 has been developed for a woman's height of 65 1/2 inches. Companies could design garment patterns based on their target consumers' sizes. Results found in the study could be useful for apparel product development and preparation of garments for mass customization.

Keywords: Apparel sizing standard, 3D body scanning, Regression model, Mass customization

INTRODUCTION

Average American sizes and weights have been increasing. The 3D body scanning technology is helpful in measuring body sizes and could be used to provide the best fitting solution for Americans. This study analyzed the relationship between shape and age, and applied regression models to present relationships between and among different body regions. ASTM D5585-11 (2011) size ranges were then categorized and compared with the analysis of SizeUSA data. The results could be beneficial to American apparel companies and consumers for revision in sizing standards or mass customization. Apparel companies could increase their sales, reduce product returns because of poor fit, and build their competitive advantages in the market by providing better fitting clothing for their customers.

The purpose of this study was to examine the relationship between shape and age and to identify the influence of age on shape, and compare to ASTM D5585-11 to see whether the ASTM D5585-11 standard would provide a good fit for actual American women's body shapes. In spite of the importance of the bust, waist, and hip sizes, the back-waist length is an important measurement to determine whether the apparel pattern is accurate, especially for tight dresses. High hip is the measurement to decide the categorization of the lower body shape (ASTM, 2011). Based on the results from the SizeUSA 2003 data, this study will provide recommendations related to the sizes for apparel companies. Apparel companies could adopt the results to adjust their sizing systems for different target markets, determine the primary sizes, and then establish a strategy for mass customization modeling.

LITERATURE REVIEW

Three dimensional body scanning has been developed to enable the rapid measurements of human bodies and may be beneficial for the apparel industry by allowing precise measurements, collection of data to create better sizing systems and to support mass customization of garments for fit. The biggest advantage of the technology is that it can capture many body measurements without physical contact. In addition, the measurement process is fast and accurate since the body scanners capture the shape of the human body using optical technology and light sensitive devices (Istook & Hwang, 2001; Kim et al., 2015). There are no widely accepted standards for apparel sizing. The reasons are the cost, different body shapes because of demographic factors such as race, age, or nationality (Donaldson, 2014, January 17), and companies' own sizing standards based on their markets (Kennedy, 2009).

One of the earliest sizing systems named CS 215-58 Standard was developed in 1958. Later in 1970, the PS 42-70 Standard was built by utilizing military anthropometric data. However, both sizing systems were eventually outdated because of changing body shapes. ASTM, (formerly the American Society for Testing and Materials) developed the ASTM D5585-94 Standard in 1994, which was based on the O'Brien and Shelton study that was the foundation for the previous two sizing systems, as well as US Army and Navy anthropometrical data (Ashdown, 1998). ASTM has updated to the newest standard ASTM D5585-11 to better support changing body shapes.

Body-scanning technology has been used for developing and improving sizing systems. The SizeUK study used the $[TC]^2$ 3D body scanner to scan 9,617 participants aged 16-91 in 2002. They investigated the relationship among shape and body mass index (BMI), age, and sex. Their results showed that BMI was related to chest and waist measurements for men, and hip and bust measurements for women (Wells, Treleaven, & Cole, 2007).

Researchers have also utilized body-scanning technology for mass customization. Mpampa, Azariadis & Sapidis (2010) developed a sizing system for male apparel mass customization based on 12,180 Greek men's body scanning anthropometric data. Subjects' ages were between 20 and 30 years old. They adopted a linear regression model to analyze the data, classified the target population's body types, determined the primary sizes, and then established the mass customization models. Their findings could be useful for mass customization of male apparel such as shirts, coats and pants.

METHODOLOGY

SizeUSA collected 6,310 female subjects' measurements with the $[TC]^2$ 3D body scanner through 13 cities in the U.S. in 2003. This data was used in subsequent analyses. Subjects in SizeUSA were categorized into six age groups: 18-25, 26-35, 36-45, 46-55, 56-65, and 66+. The statistical software program, Stata, was employed to analyze the data. Excel was used to create figures that illustrated the relationships. Mean [(Mean - SD), (Mean + SD)] were compared and categorized with ASTM D5585-11. The regression model was adopted to predict waist measurements.

RESULTS AND DISCUSSION

Relationships between body measurement and age were found to be significant, and weight distribution was also associated with age changes (Table 1). Digital girth measurements stratified by age, along with measurements of weight and height, are given in Table 1. The mean with standard deviation (SD) of seven measurements is listed for females in each age category. All dimensions increased with age except height because height has a negative relationship with age.

Table 1. Average SizeUSA values for important body measurements stratified by age

Age(y)	n	Height	Weight	Bust	Waist	Hips	Back-Waist Length	High Hip
18-25	1537	64.03 ±2.8	142.65 ±34.94	38.62 ±4.59	32.04 ±4.7	41.09 ±4.38	17.16 ±1.26	36.97 ±4.88
26-35	1448	64.09 ±2.78	156.08 ±40.5	40.51 ±5.24	33.95 ±5.51	43.03 ±5.09	17.27 ±1.2	39.84 ±5.67
36-45	1341	64.04 ±2.84	162.31 ±40.67	41.56 ±5.06	34.98 ±5.51	43.8 ±5.2	17.39 ±1.09	41.23 ±5.5
46-55	1142	63.85 ±2.73	163.11 ±38.37	42.02 ±5.02	35.83 ±5.55	44.08 ±5.09	17.43 ±1.19	42.11 ±5.36
56-65	606	63.4 ±2.9	159.77 ±32.15	42.06 ±4.39	36.15 ±4.85	44.15 ±4.48	17.26 ±1.13	42.73 ±4.5
66+	236	62.83 ±2.65	152.79 ±31.39	41.01 ±4.18	35.93 ±4.89	43.66 ±4.62	16.93 ±1.16	42.53 ±4.62
				Trend with age				
β per decade		-0.166 ±0.026	4.17 ±0.352	0.825 ±0.046	1.03 ±0.049	0.732 ±0.045	1.41 ±0.049	0.025 ±0.011
p		< 0.0001	0	0	0	0	0	0.0227

Note: A p value <.05 is considered to be significant.

The classification results of the American female population are described in Table 2. The population was divided into eight categories of age. According to statistical analysis, there is a strong relationship (R=0.9364) between the bust girth and waist girth, and a strong relationship among the waist girth and the high hip (R=0.9579) and the hip girth (R=0.8993). Weight is significantly associated with bust, waist, hips, and high hip girth. Based on the value of R, it is possible to reduce the number of independent measurements that show a strong correlation with these measurements.

Table 2. Correlation coefficients for SizeUSA body dimensions

	Age and Body Dimensions							
	Age	Height	Weight	Bust	Waist	Hips	High-Hip	Back-Waist Length
Age	1.000							
Height	-0.0807	1.000						
Weight	0.1476	0.2939	1.000					
Bust	0.2227	0.1113	**0.9092**	1.000				
Waist	0.2575	0.0978	**0.9116**	**0.9364**	1.000			
Hips	0.1994	0.1835	**0.9480**	**0.8693**	**0.8993**	1.000		
High-Hip	0.3419	0.0917	**0.9179**	**0.9133**	**0.9579**	**0.9422**	1.000	
Back-Waist Length	0.0287	0.4380	0.1247	0.0432	0.1268	0.0608	0.1044	1.000

Note: Bolded items show a strong relationship.

Based on these findings, a measurement that has a strong correlation with the variable can be predicted. The waist girth Y can be predicted from the measurements of bust X_1, hip X_2, and high hip X_3 from equations: $Y_1 = 1.147X_1 - 12.2$ (Figure 1); $Y_2 = 1.3196 X_2 - 22.349$ (Figure 2); $Y_3 = 0.7193 X_3 + 5.3914$ (Figure 3). Based on the bust measurement X_1, the hip girth X_2 or the high hip girth X_3, the waist measurement can be predicted from the linear regression equations Y_1, Y_2 or Y_3.

However, the waist girth cannot be predicted from the measurements of back-waist length or height because there are no relationships between them. Moreover, the back-waist length did not show a strong correlation with other measurements. Therefore, consumers and pattern makers must have the measurement for the back-waist length to choose or make garments related to the upper body such as tight tops and dresses.

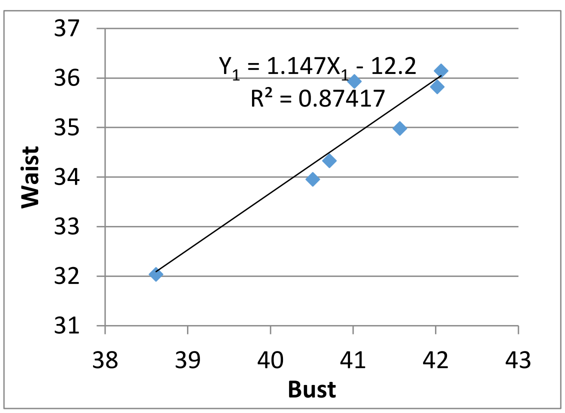

Figure 1. Correlation of mean waist vs bust girth

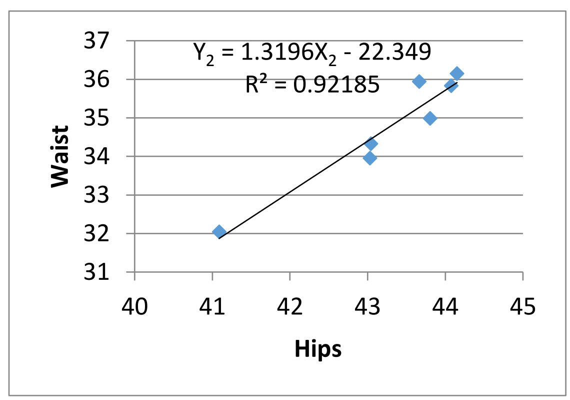

Figure 2. Correlation of mean waist vs. hips girth

The results have shown that shape is particularly related to age (Table 3). As shown in Figure 4, ratios between different body regions such as girths of the bust, waist and hips are greater in older women. The measurements, Mean [(Mean - SD), (Mean + SD)], have been compared with the primary sizes for Misses figure type of ASTM D5585-11, and categorized using the size range 00-20 (Table 3). But Table 3 does not include the height and weight because of the same height value and no weight value for misses' sizes in ASTM D5585-11. Other measurements, such as bust, waist, hip, back-waist length, and high hip, are categorized based on the size table in ASTM D5585-11.

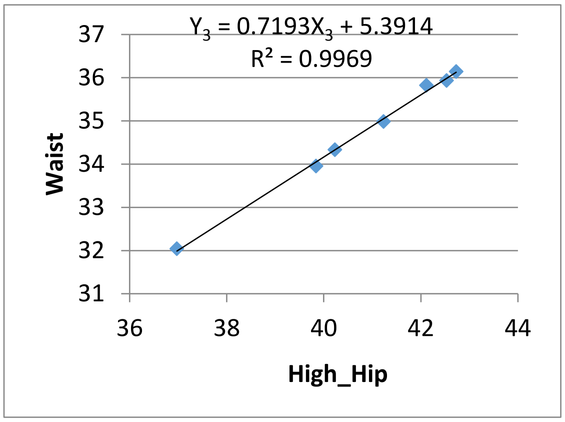

Figure 3. Correlation of mean waist vs. high-hip girth

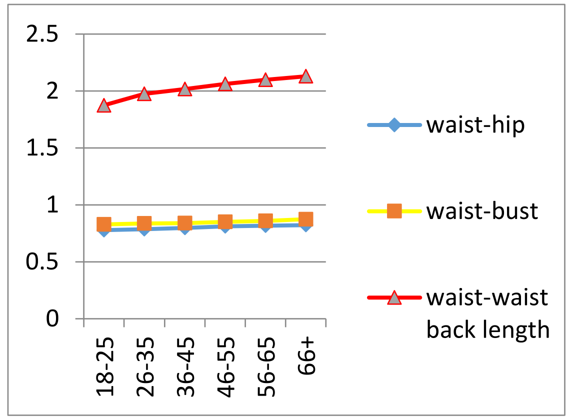

Figure 1. Mean ratio differences in 6310 women across age categories

Table 3. Size ranges of the different ages are categorized according to ASTM D5585-11

Age (Y)	n	Bust	Waist	Hips	Waist-Length Back	High Hip
18-25	1537	38.62 (34.03, 43.21) 12 (4, 18)	32.04 (27.34, 36.74) 14 (6, 18) Curvy 12 (4, 16) Straight	41.09 (36.71, 45.47) 12 (4, 16) Curvy 12 (4, 18) Straight	17.16 (15.9, 18.42) >20 (<00, >20)	36.97 (32.09, 41.85) 12 (4, 18) Curvy 12 (2, 18) Straight
26-35	1448	40.51 (35.27, 45.75) 14 (6, 20)	33.95 (28.44, 39.46) 16 (8, >20) Curvy 14 (6, 20) Straight	43.03 (37.94, 48.12) 14 (6, 20) Curvy 14 (6, >20) Straight	17.27 (16.07, 18.47) >20 (<00, >20)	39.84 (34.17, 45.51) 16 (6, >20) Curvy 14 (6, >20) Straight
36-45	1341	41.56 (36.5, 46.62) 16 (8, >20)	34.98 (29.47, 40.49) 16 (10, >20) Curvy 14 (8, 20) Straight	43.8 (38.6, 49) 14 (6, >20) Curvy 16 (8, >20) Straight	17.39 (16.3, 18.48) >20 (12, >20)	41.23 (35.73, 46.73) 16 (10, >20) Curvy 16 (10, >20) Straight
46-55	1142	42.02 (37, 47.04) 16 (10, >20)	35.83 (30.28, 41.38) 18 (12, >20) Curvy 16 (10, >20) Straight	44.08 (38.99, 49.17) 14 (8, >20) Curvy 16 (8, >20) Straight	17.43 (16.24, 18.62) >20 (12, >20)	42.11 (36.75, 47.47) 18 (12, >20) Curvy 18 (10 or 12, >20) Straight
56-65	606	42.06 (37.67, 46.45) 16 (10, >20)	36.15 (31.3, 41) 18 (12, >20) Curvy 16 (10, >20) Straight	44.15 (39.67, 48.63) 16 (10, 20) Curvy 16 (10, >20) Straight	17.26 (16.13, 18.39) >20 (00, >20)	42.73 (38.23, 47.23) 18 (14, >20) Curvy 18 (12, >20) Straight
66+	236	41.01 (36.83, 45.19) 14 (8, 20)	35.93 (31.04,40.82) 18 (12, >20) Curvy 16 (10, >20) Straight	43.66 (39.04, 48.28) 14 (8, 20) Curvy 14 (10, >20) Straight	16.93 (15.77, 18.09) >20 (<00, 20)	42.53 (37.91, 47.15) 18 (12, >20) Curvy 18 (12, >20) Straight

Note: Size >20 refers to the size that is bigger than 20; Size <00 refers to the size that is smaller than 00

The results have proven that actual American women's waist sizes are bigger than the waist sizes in ASTM D5585-11. The rule table does not fit women's size measurements bigger than size 20. Moreover, ASTM D5585-11 is for women whose height is 65 1/2 inches, so the actual American female back-waist length has a bigger range than 16 1/8-16 3/4 inches in ASTM D5585-11. Therefore, apparel companies need to adjust the patterns for their target consumers. For example, the results showed that the mean size is 12 and the basic size range is size 4-18 for females aged 18-25 (Table 3). It is recommended that the apparel companies build their pattern sizes between 4 and 18 for target consumers aged 18-25.

The waist measurement also can be identified from the multiple linear regression equation (Table 4) because the waist girth (Y) has strong relationships with the bust (X_1), the hip (X_2) and the high hip girth (X_3). By analyzing the measurements of 1,537 females aged 18-25, the multiple regression equation for target consumers aged 18-25 is $Y=0.327X_1-0.146X_2+0.774X_3-3.209$.

Table 4. Multiple regression results of subjects aged 18-25

Variables	Bust (X_1)	Hips (X_2)	High Hip (X_3)	Constant	Observations	R^2
Waist (Y)	0.327*** (0.0141)	-0.146*** (0.0173)	0.774*** (0.0173)	-3.209*** (0.279)	1,537	0.948

Note: Standard errors in parentheses; *** p<0.01

CONCLUSION

Body-scanning technology has many applications such as car design, health monitoring, and apparel sizing and fitting. Companies need to know the consumers' anthropometry to design garments and ergonomic products. For example, Cad Modeling Ergonomics in Italy, a good example for mass customization, provides the industry mannequins and heads for pattern making, fitting and ergonomic testing (http://www.cadmodelling.it).

As a deep anthropometric survey in various regions, SizeUSA could be very useful for mass customization in the apparel industry. Based on the results, apparel companies could adopt the sizing standards for their target consumers. The linear regression equations can be used for measurement prediction of the waist. The results could be applied to the development of mass customization and help reduce or minimize consumers' dissatisfaction related to apparel sizing.

REFERENCES

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.

ASTM D5585-11. (2011). *Standard tables of body measurements for adult female misses figure type, size range 00-20.* West Conshohocken, PA: ASTM International.

Donaldson, T. (2014, January 17). Using fit for faster fashion. *Sourcing Journal*. Retrieved from https://www.sourcingjournalonline.com/alvanon-using-fit-faster-fashion-td/

Istook, C. L., & Hwang, S. J. (2001). 3D body scanning systems with application to the apparel industry. *Journal of Fashion Marketing and Management: An International Journal*, *5*(2), 120-132.

Kennedy, K. (2009). What size am I? Decoding women's clothing standards. *Fashion Theory: The Journal of Dress, Body & Culture*, *13*(4), 511-530.

Kim, D. E., LaBat, K., Bye, E., Sohn, M., & Ryan, K. (2015). A study of scan garment accuracy and reliability. *The Journal of The Textile Institute*, *106*(8), 853-861.

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.

Wells, J. C., Treleaven, P., & Cole, T. J. (2007). BMI compared with 3-dimensional body shape- the UK National Sizing Survey. *The American journal of clinical nutrition*, *85*(2), 419-425.