The Journal of The Textile Institute

ISSN: 0040-5000 (Print) 1754-2340 (Online) Journal homepage: https://www.tandfonline.com/loi/tjti20

Comparison of body measurements between Chinese and U.S. females

Ling Yin & Katherine Annett-Hitchcock

To cite this article: Ling Yin & Katherine Annett-Hitchcock (2019) Comparison of body measurements between Chinese and U.S. females, The Journal of The Textile Institute, 110:12, 1716-1724, DOI: 10.1080/00405000.2019.1617531

To link to this article: https://doi.org/10.1080/00405000.2019.1617531

Published online: 22 May 2019.

THE JOURNAL OF THE TEXTILE INSTITUTE
2019, VOL. 110, NO. 12, 1716–1724
https://doi.org/10.1080/00405000.2019.1617531

Comparison of body measurements between Chinese and U.S. females

Ling Yin[a] and Katherine Annett-Hitchcock[b]

[a]School of Arts & Textile, Garments Engineering, Changshu Institute of technology, Suzhou, Jiangsu, China; [b]Textile and apparel, technology and management, North Carolina State University, Raleigh, NC, USA

ABSTRACT

The purpose of this study was to analyze the differences of body measurements and body shape between U.S. and Chinese young females and to examine how well national clothing sizing standards used for the apparel industry in each country meet the sizing demands of current young females. 400 Chinese females and 340 U.S. females, aging from 18 to 35, were chosen for comparison. Twenty-four critical body measurements were involved to define the differences or similarities and compare them with national sizing standards. It was found that compared with Chinese young females, U.S. young females were generally taller, heavier and had a higher percentage of *Talls* and much lower percentage of *Petites*. The three most common body types for both U.S. and Chinese young females were: *spoon, bottom hourglass* and *hourglass*, though distribution of body shape was different from each other. Body size of Chinese subjects was consistent with Chinese sizing standards, except for Arm Length and Across Shoulder. Nine body dimensions of U.S. subjects had significant differences from American Society for Testing and Materials (ASTM) standards. This study could provide valuable information for standardizing organizations in their attempts to improve apparel sizing systems, as well as contributing to development of international sizing standards.

ARTICLE HISTORY
Received 12 April 2017
Accepted 3 May 2019

KEYWORDS
Young female; body measurement; body shape; U.S.; Chinese; sizing standards

Introduction

Clothing fit is of current interest both for consumers who are in great demand of the clothing that shape their body figure well and for garment manufacturers who need to acquaint themselves with the body measurements of their target markets. The problem of incorrectly fitting clothing is increasing due to an increase in ethnic markets within the U.S. population and international market expansion of US-based companies.

From 1980 to 2007, the number of immigrants in the United States rose from 14 million to 38 million. Growth in immigration flows in the past three decades has almost tripled the size of the foreign-born population in the United States. By 2007, the foreign-born share had climbed to 13% of the population of the United States (Fortuny, Chaudry, & Jargowsky, 2010). Immigrant populations in the United States represent a variety of ethnic groups, with body types that vary in measurements and proportions. Among all the ethnicities, the Asian population grew faster than other major groups in the United States between 2000 and 2010, growing from 10.2 million to 14.7 million (Humes, Jones, & Ramirez, 2011). The Chinese population was the largest Asian group (Hoeffel, Rastogi, Kim, & Shahid, 2012).

In addition, more U.S. companies are selling overseas than in the past and competing at a global level. The balance between global standardization and local adaptation is an important issue for a global business. Previous research has shown (Lee & Istook, 2007; Makhanya, Klerk, Adamski, & Mastamet-Mason, 2014; Shin & Istook, 2007) that the human body and its proportions are not globally identical. Therefore, garment manufacturers should fully consider the adaptation of local fit and sizing when trading globally. Gap Inc., a leading global retailer in the United States, offers clothing for men, women and children in more than 90 countries worldwide (Gap Inc., 2013). Its success largely depends upon the ability to provide merchandise that satisfies customer demand in a timely manner. It was reported that nearly 30% of Gap products sold in China were different from those sold in the United States, when taking into consideration the tastes and body sizes of Asians. Therefore, U.S. companies should take into consideration body measurements of other countries' populations in order to be more competitive in the global market.

China has the largest population of all countries, equivalent to 18.54% of the total world population (Worldometers, 2018). China maintains the greatest import and export trade communication with United States, especially for clothing. Acquaintance with difference of body size between Chinese and U.S. people is of prime importance for clothing manufacturers and consumers.

The purpose of this paper was to define the actual areas of difference and similarity of body measurements between Chinese and U.S. young females between the ages of 18–35. The comparison could help to improve the sizing systems of each country, as well as contributing to development of international sizing standards that had a significant impact on international garment manufacturers and consumers.

CONTACT Ling Yin 275872416@qq.com, yinling@cslg.edu.cn

Literature review

Comparison and analysis of body measurements and shapes

There has been much research related to clothing fit (Alexander, Connell, & Presley, 2005; Lee, Damhorst, Lee, Kozar, & Martin, 2012; Newcomb & Istook, 2011). Comparison of human body measurements and body types among different countries or ethnic groups, especially between Chinese and U.S., has not been well studied due to difficulties in collecting body sizes from these two different countries. Distribution of body shapes between U.S. and Korean women were compared by analyzing the three-dimensional (3D) data of 6310 women of SizeUSA and 1799 women of SizeKorea. It was found that the largest shape category was the rectangle shape in both countries, but distribution within each shape category was different. More variation in body shape categories was found in the U.S. women than in Korean women (Lee & Istook, 2007). Six body dimensions among different ethnic groups were analyzed by scanning 1335 women in a Misses size range (Shin & Istook, 2007). Their results showed that ethnic groups had different fit problems and significant body shape differences.

Body measurement and 3D body scanning technology

Body measurements can be determined by two available methods, including traditional anthropometry and 3D body scanning technology. For classical anthropometrical measurements, this method is still very difficult, time-consuming and often not accurate, owing to the influence of landmark location, subject positioning, lack of experience and instrument applications. 3D body scanning technology makes it feasible to extract infinite body measurements in seconds. It can be non-contact, instant and accurate, and may enable and encourage the move toward the production of mass customization for fit, especially in the apparel industries. Additionally, when measuring a large number of locations on the human body, the method of no physical contact is most desirable and more acceptable for most people. Textile/Clothing Technology Corporation, $[TC]^2$, is the world's first and the largest 3D body manufacturer in the area of 3D body scanning, 3D body analysis, measurement and visualization ($[TC]^2$, 2018). Its scanners have been adopted among major apparel companies in the United States for custom fit/made-to-measure clothing. Two models are currently available from $[TC]^2$: KX16 and $[TC]^2$-18. Some other body scanners include Cyberware, Hamano, Human Solutions (previously Tecmath), Telmat, Wicks & Wilson, Size Stream and Hamamastu (Istook, 2008). The technology of body scanning has been applied to mass customization in some areas of the apparel industry and has provided advancements in the fields of apparel sizing and fit.

Current U.S. sizing standards

In the United States, early commercial standard CS215-58 defined 20 figure types according to height group and hip type determined by drop values (difference between hip and bust circumference) (U.S. Department of Commerce, 1958). It was then revised to the product standard PS 42-70 in 1970. Eliminating the hip types in the CS 215-58, the PS 42-70 classified the figure types as junior petite, junior, misses petite, misses, misses tall, women's and half-sizes(Chun-Yoon & Jasper, 1993). After PS 42-70, the American Society for Testing and Materials (ASTM) Committee published an updated standard known as D5585-94 in 1994, which was withdrawn in January 2010 and reinstated in July 2011. This standard is called ASTM D5585-11e1 and specifies sizes 2 through 20 to be used by the apparel industry in the classification of Misses' apparel (ASTM Committee, 2011). It is based on the same database used in the creation of the PS 42-70 standard and updates slightly according to designers' experience and market observations in the United States.

A survey of over 6000 women aged 55 and above was conducted by Reich and Goldberry in 1993 and found that PS 42-70 was inadequate for older women. A new standard ASTM D5586-95 was therefore established for this group. (ASTM Committee, 2010; Goldsberry, Shim, & Reich, 1996). Junior's standard, called D6829-02, was released for women's apparel and classified size 0 through 19 to be used in Juniors' apparel (ASTM Committee, 2015). U.S. sizing standards are criticized by both apparel consumers and garment manufacturers, primarily because they are based on decades-old anthropometric data that does not meet the changing demographics of the current U.S. population, including the aging and increasingly diverse ethnicity (Elizabeth, 2005).

Chinese national standards

China began a sizing standard for clothing in 1981, including three parts: GB/T 1335.1 for men, GB/T 1335.2 for women and GB/T 1335.3 for children. It has been revised three times from 1981 to now. The current standard sizing systems for women's garments, GB/T 1335.2 was established in 2008 (China National Standard Committee, 2009). According to this standard, the female body is classified into four categories according to the drop value between bust girth and waist girth, which are applied for all women regardless of ages. Body shape classification in the Chinese sizing standards uses the categories Y, A, B and C. For example, Y stands for the slim and thin body type, A is the standard body type, B is the heavy body type and C is the obese body type. The detailed information is shown in Table 1. In Chinese sizing standards, the human body with height of 160 cm, bust girth of 84 cm and body type of A is appointed to the average body size (China National Standard Committee, 2009).

Table 1. Body shapes classification in the Chinese sizing standards.

Body shape categories	Criteria (drop value between bust girth and waist girth, cm)
Y	19–24
A	14–18
B	9–13
C	4–8

Methodology

Sampling and sampling size

In this study, young females, aged 18–35, were selected as subjects. The least quantity (N) of samples depends up the variable coefficient (CV) of body measurements and permitted relative error. It could be estimated by the following formula (Taylor & Francis group, 2014):

$$N = 1.96^2 \times (\mathrm{CV})^2 / A^2 \tag{1}$$

N, number of samples; CV, variance coefficient; A, relative error, usually 2%, used for vital research project. Table 2 showed CV of the body measurements and required minimum sample number according to the formula above.

From Table 2, it can be seen that CV of Shoulder Slope is the greatest both for Chinese and U.S. females, meaning that the Shoulder Slope measurement contains the greatest variance for both ethnicities. The minimums required for U.S. subjects were 336 and Chinese subjects were 176. Therefore, for this study, 409 Chinese females and 364 U.S. Caucasian females were selected. The analysis excluded abnormal data, which was defined as any subject with body measurements that exceeded the range of "mean value ±3σ" (σ, standard deviation from the mean for each body measurement). The abnormal values were generally resulted from tape measuring errors, poor quality of 3D body scan data and incorrect posture in body scanner. For Chinese subjects, nine abnormal values were excluded, and 400 subjects were appropriated for analysis. The number of final U.S. subjects was 340 after excluding twenty four abnormal values. Due to different body shapes among different ethnic groups (Makhanya et al., 2014; Shin & Istook, 2007) and Caucasian covering 72.4% of all the ethnic groups in U.S. (Humes et al., 2011), we mainly selected Caucasian females from the United States as the U.S. subjects.

Table 2. CV of body measurements and required minimum sample number.

	U.S.(Caucasian)		Chinese (Asian)	
Measurement	CV (%)	number of samples	CV (%)	Number of samples
Height	4.01	15	3.50	12
Weight	12.03	139	11.18	120
BMI	11.24	121	10.14	99
Neck base girth	5.67	31	4.26	17
Chest girth	6.10	36	5.23	26
Bust girth	6.46	40	6.33	38
Under bust girth	6.51	41	6.26	38
Waist girth	7.80	58	8.88	76
High hip girth	6.49	41	7.08	48
Hip girth	5.83	33	4.54	20
Thigh girth	8.46	69	6.17	37
Upper arm girth	9.08	79	8.01	62
Back neck height	4.37	18	3.81	14
Crotch height	6.39	39	5.09	25
Waist height	4.84	22	4.35	18
Back waist length	7.11	49	5.49	29
Front waist length	7.65	56	5.76	32
Arm length	7.00	47	4.50	19
Across front width	14.04	189	5.55	30
Across back width	8.00	62	6.45	40
Across shoulder	10.47	105	5.22	26
Shoulder length	7.92	60	8.41	68
Shoulder slope	18.71	336	13.54	176

Body measurement

Twenty four body measurements in metric were collected which were considered critical to analyze the body shapes and design well-fitting garments. Additionally, body mass index (BMI) was calculated by the formula: BMI = weight/height^2 $(\mathrm{kg/m^2})$ and the ratio of Back Waist Length to Back Neck Height (Ratio of Back Waist Length) was used to analyze the proportion between upper body and lower body. Due to availability of technology, body data of Chinese subjects were collected by manual measurement in China, using multiple personnel. The manual measurements were performed in a standing posture with legs close to each other and arms at the sides, according to the method specified by GB16160-2008 (China National Standard Committee, 2008). The [TC]^2 body scanning system was used for scanning U.S. females at a major research university in the United States. NX 16 software version 6 from [TC] ^{2} was used for measuring and extracting each scanned participant's body dimensions.

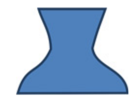
Many papers (Han, Nam, & Choi, 2010; Park, 2004) have been involved in analyzing the differences between 3D body scan measurements and manual measurements. Although there are some slight differences owing to posture, soft tissue, landmark and so on, 3D body scans are gradually becoming a substitute for manual measuring methods, and are increasingly being used worldwide for quickly capturing the body measurements both in large apparel companies and in large-scale anthropometric surveys in recent years (Elizabeth, Karel, & Marilyn, 2006; Susan & Lucy, 2006).

Methods of analysis

The statistical and graphical functions of SPSS 16 and Excel 2010 were used to analyze the body data. Mean values of each measurement for both countries' young females were compared by the independent-samples T test. The asterisk had been placed to indicate that these pairs show statistically significant differences at the 95% confidence level. In the analysis of statistical results, in a real world situation, one important principle is that when there is significant statistical difference, it does not indicate that the difference is important from point of view of pattern design (Elizabeth, 2005). Large sample sizes often increase the chances of finding significance, even when the differences might not be important. Therefore, conclusion should be drawn with fully consideration of both statistical results and context. In this study, we marked those body measurements with significant differences in bold text.

This study relied primarily on the use of Female Figure Identification Technique (FFIT) developed by NCSU (Simmons, 2002) to analyze the body shapes, which was developed to create a methodology for the characterization of body types that would more appropriately replicate the diverse shapes of U.S. females. Nine shape categories were identified. The bust, waist, hip and abdomen girth were used in combination to describe each shape. The accuracy of the FFIT for apparel had been validated to be around 90% by using a large population as a test sample (Devarajan & Istook, 2004). Table 3 showed the detailed classification.

Table 3. Nine body shape categories developed in FFIT.

Shape categories	Description	Illustration
Hourglass	A very small difference in the comparison of the circumferences of the bust and hip and the ratios of bust-to-waist and hips-to-waist are about equal and significant	
Bottom hourglass	A subject has a larger hips circumference than bust circumference and the ratios of the bust-to-waist and hips-to-waist are significant enough to produce a definite waistline.	
Top hourglass	A subject has a larger bust circumference than hips girth, the ratios of their bust-to-waist and hips-to-waist measurements are significant enough to produce a definite waistline	
Spoon	A subject has a larger circumferential difference in their hips and bust, their bust-to-waist ratios is lower than the hourglass shape and the high hip to waist ratio is great	
Triangle	A subject has a larger hips circumference than their bust, the ratio of their hips-to-waist is small, without having a defined waistline	
Inverted triangle	A subject has a larger bust circumference than hips girth, the ratios of their bust-to-waist is small, without having a defined waistline	
Rectangle	The bust and hips girth are fairly equal and bust-to-waist and hips-to-waist ratios are low, not having a clearly discernible waistline	
Oval	The average of the subject's stomach, waist and abdomen measures are less than the bust measure	
Diamond	The average of the subject's stomach, waist and abdomen measures are more than their bust measure, several large rolls of flesh in the midsection of the body that protrude away from the body at the waist area would make the subject distinct	

Result and discussion

Comparison of average body measurements

Table 4 showed average body dimensions of both Chinese and U.S. females in this study, including mean value, standard deviation (SD), maximum value (Max), and minimum value (Min). Mean deviation (MD) was the difference obtained by subtracting Chinese mean value from U.S. average (MD) for each of the measurements. Figure1 showed the MD graphic description and followed Table 4

Table 4 and Figure1 showed that most of the body dimensions of the U.S. young females were greater than that of the Chinese young females, especially for waist girth, bust girth, chest girth and hip girth. Waist girth had the largest difference among all the body measurements between Chinese and U.S. females. It showed that U.S. young females were significantly larger than Chinese within the same age ranges. U.S. young females' body measurements, including height, Back Neck Height, Back Waist Length and Front Waist Length were significantly greater than those of Chinese. It suggested that U.S. young females were significantly taller than Chinese within the same age ranges.

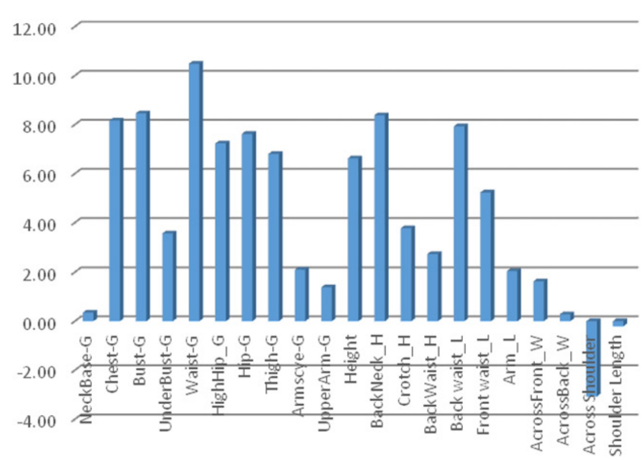


Figure 1. Graphic of mean difference of body measurements between Chinese and United States.

The ratio of Back Waist to Back Neck Height for U.S. young females was significantly larger than that of Chinese young females, which showed that proportion of upper body of U.S. young females was greater than that of Chinese. MD value of Across Shoulder, Shoulder Length and Shoulder Slope were negative, which suggested that U.S. young females had narrower and slightly flatter shoulders, compared with Chinese young females. Less SD values and the range of each measurement (maximum–minimum) for Chinese young

Table 4. Body measurements of Chinese and U.S. subjects (unit: cm).

	Chinese (Asian)				U.S. (Caucasian)					t Test ($a < 0.05$)	
Measurement	Average	SD	Min	Max	Average	SD	Min	Max	MD	t value	Sig.
Weight (kg)	52.40	5.86	40.50	69.50	61.20	7.36	39.46	81.65	**8.80***	17.77	0.00
BMI (kg m^{-2})	20.47	2.08	15.13	26.56	22.07	2.48	15.78	28.34	1.59*	9.36	0.00
Neck base girth	35.38	1.51	31.20	40.00	35.73	2.03	29.08	41.86	0.35*	2.67	0.01
Chest girth	81.82	4.28	71.40	93.60	89.99	5.49	76.90	105.71	**8.17***	22.25	0.00
Bust girth	82.66	5.23	69.20	99.00	91.12	5.89	76.43	107.19	**8.46***	20.51	0.00
Under bust girth	73.04	4.57	63.10	86.40	76.60	4.98	63.12	91.36	**3.56***	10.10	0.00
Waist girth	68.03	6.04	56.60	86.20	78.51	6.13	61.82	96.95	**10.48***	23.37	0.00
High hip girth	82.07	5.81	68.20	102.00	89.30	5.80	75.26	110.46	**7.23***	16.87	0.00
Hip girth	89.31	4.05	80.00	102.50	96.93	5.65	81.15	113.16	**7.62***	20.75	0.00
Thigh girth	51.53	3.18	43.70	61.70	58.33	4.93	44.89	74.02	**6.80***	21.85	0.00
Upper arm girth	27.00	2.16	21.50	32.80	28.37	2.58	21.73	37.26	1.38*	7.80	0.00
Height	159.99	5.60	146.70	177.60	166.61	6.69	149.86	185.42	**6.62***	14.44	0.00
Back neck height	133.97	5.11	121.20	149.50	142.35	6.22	127.66	160.10	**8.38***	19.78	0.00
Crotch height	72.90	3.71	64.10	84.80	76.67	4.90	65.48	91.29	**3.77***	11.61	0.00
Back waist height	97.82	4.25	85.80	110.80	100.56	4.86	85.90	114.97	**2.74***	8.09	0.00
Back waist length	37.15	2.04	31.90	43.90	45.08	3.20	35.18	55.04	**7.93***	39.36	0.00
Front waist length	34.43	1.98	28.30	40.30	39.66	3.03	31.78	48.30	**5.23***	27.23	0.00
Arm length	51.74	2.33	46.40	58.40	53.78	3.77	42.09	64.21	2.04*	8.66	0.00
Across back width	33.65	2.17	27.50	40.80	33.92	2.72	25.12	41.91	0.28	1.51	0.13
Across front width	32.07	1.78	27.10	37.40	33.69	4.73	20.40	46.30	1.62*	5.96	0.00
Across shoulder	37.92	1.98	33.00	43.20	34.85	3.65	23.83	43.46	**−3.07***	−13.88	0.00
Shoulder length	12.78	1.08	9.50	16.00	12.57	1.00	9.73	15.41	−0.21*	−2.77	0.00
Shoulder slope (°)	24.53	3.32	15.00	35.00	21.83	4.08	10.10	31.30	**−2.70***	−9.70	0.00
Ratio of back waist length	0.28	0.01	0.24	0.32	0.32	0.02	0.25	0.37	**0.04***	−33.77	0.00

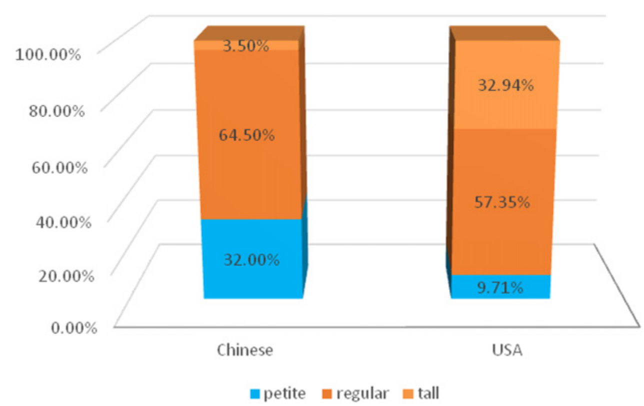


Figure 2. Percent height both Chinese and U.S. subjects.

females indicated that body dimensions of Chinese female women were more concentrated around their mean measurements. In other words, body dimensions of U.S. young Caucasian females were more varied than that of Chinese.

Comparison of height distribution

Figure 2 showed the comparison of height distribution between the two groups. Each group was sorted by height and arranged into the following three height categories used by ASTM sizing standard committee (Table 5).

Figure 2 showed that both Chinese and U.S. females had the largest percentage in the regular height category, but had different height distributions for petite and tall categories. U.S. females had a higher percentage (32.94%) of *Talls* and much less percentage (9.71%) of *Petites*, whereas Chinese females had a higher percentage (32.00%) of *Petites* and much less percentage (3.50%) of *Talls*.

Table 5. Height categories adopted by ASTM sizing standard committee.

Categories of height	Imperial	Metric (cm)
Petite	$h \leq 5'2''$	$h \leq 157.48$
Regular	$5'2.5'' \leq h \leq 5'6.5''$	$158.75 \leq h \leq 168.91$
Tall	$h \geq 5'7$	$h \geq 170.18$

Comparison of distribution of body types

The software FFIT for apparel was used to classify the body shapes of both subject groups. The nine body shapes were effectively identified by the software.

Figure 3 showed the body shape distributions in both of the ethnic groups. It could be seen that the spoon shape was the most predominant shape in Chinese females, with nearly 57% of population falling into this category, and the bottom hourglass shape was the second most popular one, with 26% of Chinese samples belonging to this category. In contrast with Chinese subjects, bottom hourglass shape was the most popular one in U.S. young females, almost 44% of population falling into this category, and spoon shape was the second largest category, 22% of U.S. females belonging to this category. The hourglass shape was the third most popular shape in both of the ethnic groups. Nearly 90% of each of the ethnic groups fell into these three body shapes: spoon, bottom hourglass and hourglass.

Chinese subjects versus national sizing

To examine whether body measurements of the Chinese samples were consistent with the current national sizing standards (GB/T 1335.2-2008), the study compared the Chinese sample data with average size (160/84A) of national standards by t test. The mean values of body size in spoon

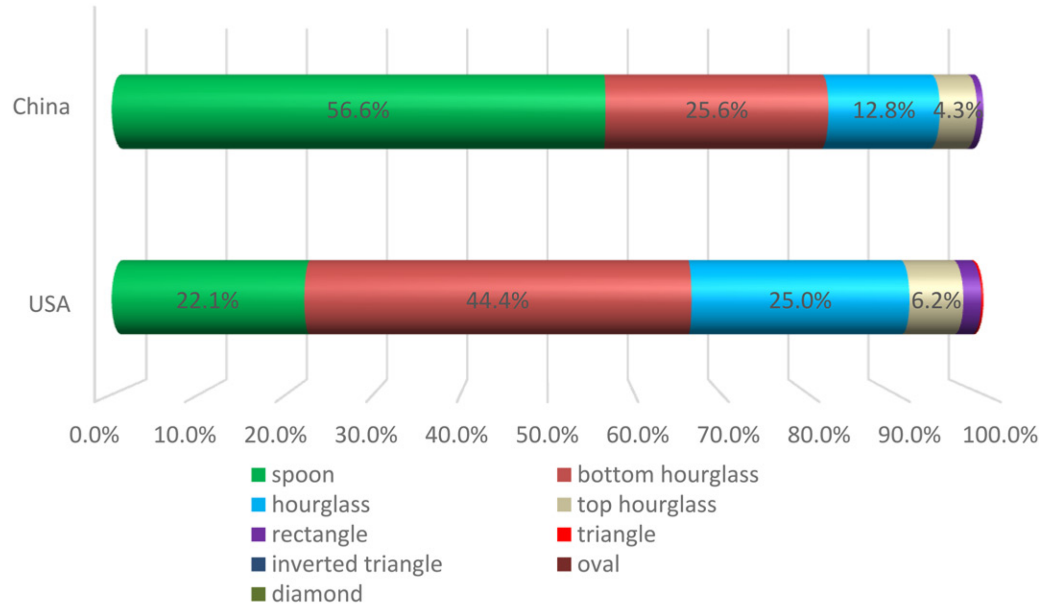


Figure 3. Percentage of body shapes both Chinese and U.S. subjects.

Table 6. Comparison of mean values between Chinese and national standards.

Body measurement	Mean value of: Average of samples	Predominant spoon body shape	Average size of GB/T1335	t Test ($a < 0.05$): t Value	Sig. (2-tailed)
Height	159.99	160.50	160.00	−0.033	0.974
Bust girth	82.66*	80.80	84.00	−5.122	0.000
Waist girth	68.03	65.90	68.00	0.086	0.931
Hip girth	89.31*	89.10	90.00	−3.421	0.001
Back neck height	133.97*	134.40	136.00	−7.92	0.000
Back waist height	97.82	98.50	98.00	−0.861	0.390
Arm length	51.74*	51.70	50.50	10.663	0.000
Across shoulder	37.92*	37.80	39.40	−14.992	0.000

body shape category were also listed for comparison (Table 6).

The results showed that Chinese subjects had the same height, Back Waist Height and Waist Girth with average size of the national standards, but the Bust Girth and Hip Girth were slightly less. The main reason for this was that the subjects were aged from 18 to 35 years old, whereas average body size of national standard was based on all adult women with all ages. As a common physical principle, adult women's measurements, especially Bust Girth, Waist Girth and Hip Girth, tend to be bigger with increased ages (Hui & Hong, 2009). The average Arm Length of subjects was longer and the Across Shoulder was narrower than average size of national sizing standard, this showed that Chinese young females had longer arms and narrower shoulder, compared with average size of national sizing standards.

As had been shown, most of the Chinese young females had the body shape of spoon, however, the average Bust Girth, Waist Girth of Chinese young females with spoon body shapes were much less than the average body size of national sizing standards. Therefore, in order to make the ready-to-wear apparel have a better fit for the human body, it should be considered by the Committee of the National Standard that different body size and body type exist among different age groups for Chinese adult females.

U.S. subjects vs. ASTM sizing

To examine the effectiveness of current ASTM size standards in accommodating the current U.S. young females, this part compared the U.S. subjects with size 10 of ASTM Missy sizing standards by t test. Size 10 is the average size of the 00-20 size range in the ASTM missy sizing standards. Bottom hourglass, body shape that predominated in U.S. subjects was listed for comparison as well (Table 7).

As could be seen from Table 7, most of body dimensions had significant differences from ASTM Missy size 10, which were marked in bold text. All girth was less than that of size 10 of Missy sizing, except waist girth. The reason for this might be that the subjects were aged from 18 to 35 years old, whereas ASTM Missy size 10 was based on all the missy figures aging no more than 55 years old. With increasing age, adult women change shape through the torso. The possible reasons for the noticeably larger Waist Girth of U.S. subjects than that of Missy Size 10 might be explained from two aspects. First, the Waist Girth was automatically extracted, according to the definition specified by [TC]^2,

Table 7. Comparison of mean values between U.S. subjects and ASTM size 10.

Body measurement	Average of samples	Mean value of bottom hourglass	D5585 missy 10 (curvy/straight)	t Test ($a < 0.05$)	
				t Value	Sig. (2-tailed)
Height	166.61	166.58	166.37	0.66	0.51
Neck base girth	**35.73***	35.63	37.78	−18.65	0.00
Chest girth	89.99*	89.31	93.35	−11.28	0.00
Bust girth	**91.12***	90.19	94.62	−10.95	0.00
Under bust girth	76.60*	76.05	78.74	−7.92	0.00
Waist girth	**78.51***	78.14	73.66/77.47	14.6/3.13	0.00
High hip girth	89.3*	88.81	90.81/91.44	−4.81/−6.82	0.00
Hip girth	**96.93***	97.11	102.24/100.33	−17.35/−11.11	0.00
Thigh girth	58.33	58.23	58.74/57.79	−1.54/2.01	0.12/0.05
Upper arm girth	28.37*	28.10	29.21	−5.98	0.00
Back neck height	142.35	142.39	142.88	−1.58	0.12
Crotch height	76.67*	76.49	77.47	−3.01	0.00
Back waist height	**100.56***	100.33	102.87	−8.76	0.00
Back waist length	**45.08***	45.55	40.96	23.72	0.00
Front waist length	**39.66***	39.65	36.83	17.21	0.00
Arm length	**53.78***	53.58	58.42	−22.72	0.00
Across shoulder	**34.85***	34.34	39.69	−24.48	0.00
Shoulder length	12.57*	12.53	13.02	−8.28	0.00

which was the smallest circumference between level of small of back and a level 4 cm above small of back, following the pant waist ([TC]^2, 1999) .Whereas ASTM defined the Waist Girth as the smallest circumference around the torso taken at the level of the waist, immediately below the lowest rib in ASTM (ASTM Committee, 2009). It suggested that the Waist Girth from [TC] ^{2} might not be the smallest circumference between the bust and hip, but slightly approach down to the small of back, which meant the Waist Girth from [TC]^2 was a little greater than actual waist girth specified in ASTM. Another possible reason was that the predominant body type of U.S. young females was bottom hourglass, different from the Hourglass shape targeted by Missy standard (Elizabeth, 2005). Some measurements relied on an accurate waist measure for their extraction in [TC]^2, including Back Waist Height, Back Waist Length and Front Waist Length. If the waist level was located lower than standard waist level, just like the above explanation, these three body dimensions might be affected and showed significantly less, compared with ASTM missy size 10.

In addition, the Arm Length of U.S. female was much shorter, compared with Missy size 10, owing to different posture of measuring. In ASTM sizing standards, Arm Length was measured from the top of the shoulder joint along the outside of the arm over the elbow to the prominent wrist bone, taken with the arm bent (90°) and the hand placed on the hip (Figure 4(a)). If the arm was posed in this way, the skin of arm might be stretched longer. But if the arms were hanging in the scan position (Figure 4(b)), the skin of the arm could not be stretched, which roughly approached to traditional measurement method. The length of Across Shoulder was less than size 10 of Missy sizing, which might result from the predominant bottom hourglass body type for U.S. young females, instead of the Hourglass shape targeted by Missy standards (Elizabeth, 2005).

The above results indicated that shape characteristics of U.S. young Caucasian females were different from current sizing standards, and it was found that specification of some body measurements extracted from body scanners was not consistent with standard sizing system.

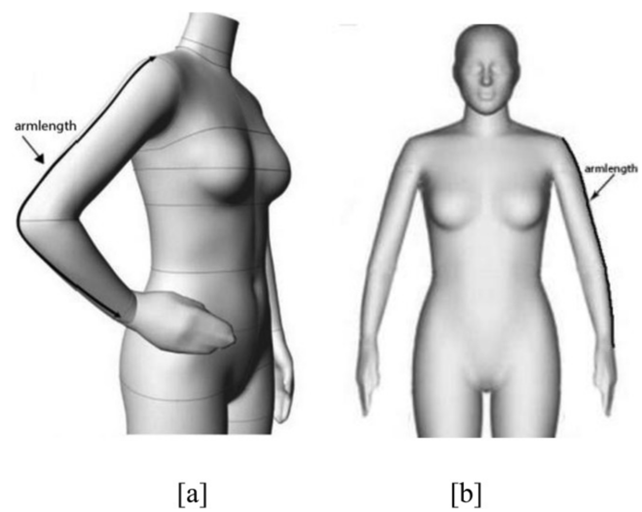


Figure 4. Different posture of measuring the arm length.

Conclusions

Through this research, it was learned that U.S. females were generally larger in circumference and taller than Chinese females within the age ranges of 18–35 years old. For specific body parts, U.S. females had greater proportions in the upper body but narrower shoulders. In addition, the body dimensions of U.S. young females showed greater variation than that of Chinese. Different height distributions were found between the two ethnic groups, though both of them fell into the largest percentage in the regular height category. U.S. young women had a higher percentage of *Talls* and lower percentage of Petites, whereas percentages of the same for Chinese young women were the opposite.

For body shape distribution, the spoon shape was the most predominant shape in the Chinese samples, followed by the bottom hourglass shape. Distribution of body shapes of U.S. young women contrasted with that of Chinese subjects. The hourglass shape was the third most popular shapes in both of the ethnic groups. Nearly 90% of both groups fell into these three body shapes: spoon, bottom hourglass and hourglass.

By comparing the average body dimensions with current sizing standards, it was found that the body size of Chinese females was consistent with national sizing standards, except with reference to Arm Length and Across Shoulder. In addition, for those who had predominant spoon body shapes, the bust girth and waist girth might not be well accommodated by sizing standards. The Committee of Chinese Sizing Standard should establish more detailed classification of body type and at the same time add the different age ranges into the new sizing standards. Of the body measurements for U.S. females, nine body dimensions had significant differences from ASTM Missy size 10. The reasons for that were attributed to different targeted body shapes and disputable specification of some body measurements extracted from body scanners.

Limitations and recommendations

This study made a detailed comparison of body size and body type between Chinese and U.S. young females, and achieved some useful conclusions which could be considered by the committee of national sizing standards. But this study still had some limitations. By limiting the sample to females aged 18–35, the sample excluded some other possible body types, for example, triangle and inverted triangle body type. Different measuring systems might have slightly affected the accuracy of body data. This study just examined whether the national clothing sizing standards used for the apparel industry in China and United States meet the current young females, without considering international standards. Further research will increase the age range and measure both with tape or both with body scanner. In addition, international standards, such as ISO 20685, ISO 7250-1 and ISO 8559-1, referring to 'internationally comparable measurements' would be considered.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

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

ASTM Committee. (2009). *Standard Terminology relating to body dimensions for apparel sizing*, New York: American National Standards Institute.

ASTM Committee. (2010). *ASTM D5586/D5586M-10 standard table of body measurements for women aged 55 and older (all figure types)1, 2.* [Online] Retrieved from http://www.astm.org/search/fullsite-search.html?query=D5586&resStart=0&resLength=10& [Accessed 22 7 2018].

ASTM Committee. (2011). *ASTM D5585-11e1: Standard tables of body measurements for adult female misses figure type, size range 00-20.* [Online] Retrieved from http://www.astm.org/search/fullsite-search.html?query=D5585&[Accessed 22 7 2018].

ASTM Committee. (2015). *ASTM D6829-02(2015) Standard tables of body measurements for juniors, size 0–19.* [Online] Retrieved from http://www.astm.org/search/fullsite-search.html?query=D6829&resStart=0&resLength=10& [Accessed 22 7 2018].

China National Standard Committee. (2008). *Location and method of anthropometric surveys for garments (GB/T 16160-2008)/China national standard.* 1st ed. Beijing: China Standard Press.

China National Standard Committee. (2009). *Standard sizing systems for garments Women(GB/T1335.2-2008)/China national standard.* 1st ed. Beijing: China Standard Press.

Chun-Yoon, J., & Jasper, C. R. (1993). Garment sizing: An international comparison. *International Journal of Clothing Science and Technology*, *5*(5), 28–38. doi:10.1108/eb003025

Devarajan, P., & Istook, C. L. (2004). Validation of 'Female figure identification technique (FFIT) for apparel', software. *Journal of Textile and Apparel, Technology and Management*, *4*(1), 1–23.

Elizabeth, A. N. (2005). Body shape analysis of Hispanic women in the United States, Doctor Thesis, North Carolina State University, Raleigh, NC, USA.

Elizabeth, B., Karel, L. L., & Marilyn, R. D. (2006). Analysis of body measurement systems for apparel. *Clothing & Textiles Research Journal*, *24*(2), 66–79.

Fortuny, K., Chaudry, A., & Jargowsky, P. (2010). *Immigration trends in metropolitan American, 1980–2007*. Washington, DC: *Urban Institute*, pp. 1–18.

Gap Inc. (2013). *Annual report.* [Online] Retrieved from http://www.gapinc.com/content/attachments/gapinc/GPS_AR13.pdf [Accessed 22 July 2018].

Goldsberry, E., Shim, S., & Reich, N. (1996). Women 55 years and older: Part I. Current body measurements as contrasted to the PS 42-70 data. *Clothing and Textiles Research Journal*, *14*(2), 108–120. doi:10.1177/0887302X9601400202

Han, H., Nam, Y., & Choi, K. (2010). Comparative analysis of 3D body scan measurements and manual measurements of size Korea adult females. *International Journal of Industrial Ergonomics*, *40*(5), 530–540. doi:10.1016/j.ergon.2010.06.002

Hoeffel, E. M., Rastogi, S., Kim, M. O., & Shahid, H. (2012). *The Asian population:2010.* [Online] Retrieved from http://www.census.gov/prod/cen2010/briefs/c2010br-11.pdf [Accessed 1 12 2014].

Hui, J. W., & Hong, F. W. (2009). Garment sizes for old aged people in the north part of Shanxi. *Journal of Textile Research*, *30*(12), 108–112.

Humes, K. R., Jones, N. A., & Ramirez, R. R. (2011). *Overview of Race and Hispanic origin: 2010.* [Online] Retrieved from http://www.census.gov/prod/cen2010/briefs/c2010br-02.pdf [Accessed 1 December 2014].

Istook, C. L. (2008). Three-dimensional body scanning to improve fit. In: C. Fairhurst, ed. *Advances in apparel production.* Boston: CRC press, pp. 94–116.

Lee, J. Y., & Istook, C. L. (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, Y.-A., Damhorst, M. L., Lee, M.-S., Kozar, J. M., & Martin, P. (2012). Older women's clothing fit and style concerns and their attitudes toward the use of 3D body scanning. *Clothing and Textiles Research Journal*, *30*(2), 102–118. doi:10.1177/0887302X11429741

Makhanya, B. P., Klerk, H. M., Adamski, K., & Mastamet-Mason, A. (2014). Ethnicity, body shape differences and female consumers' apparel fit problems. *International Journal of Consumer Studies*, *38*(2), 183–191. doi:10.1111/ijcs.12079

Newcomb, E., & Istook, C. L. (2011). Confronting stereotypes: apparel fit preferences of Mexican-American women. *Journal of Fashion Marketing and Management: An International Journal*, *15*(4), 389–411. doi:10.1108/13612021111169915

Park, S. (2004). *A basic study for standardization of 3-dimensional body scanning system – The verification of accuracy of 3-dimensional scan data.* Seoul: Seoul National University.

Shin, H. S.-J., & 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. Volume doi:10.1111/j.1470-6431.2006.00581.x

Simmons, K. P. (2002). *Body shape analysis using three-dimensional body scanning technology*, Raleigh, NC: North Carolina State University.

Susan, P. A., & Lucy, D. (2006). A study of automated custom fit: Readiness of the technology for the apparel industry. *Clothing & Textiles Research Journal*, *24*(2), 121–136.

Taylor & Francis group. (2014). *Modern survey sampling*. 1st ed. Boca Raton FL: CRC Press.

[TC]^2. (1999). *Body scanner measurement descriptions.* Raleigh, NC: Internal document.

[TC]^2. (2018). [TC]^2. [Online] Retrieved from http://www.tc2.com [Accessed 21 July 2018].

U.S. Department of Commerce. (1958). *National Bureau of Standards Commercial Standard CS 215-58: Body measurements for the sizing of women's patterns and apparel*, Washington, D.C.: U.S. Government Printing Office.

Worldometers. (2018). *China population.* [Online] Retrieved from http://www.worldometers.info/world-population/china-population/ [Accessed 22 July 2018].