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Lower-body figure analysis of Chinese adult women

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Abstract

To determine the parameters to be considered when designing lower-body apparel, we analyzed the lower-body figures of adult women in their early 20s from Shanghai, China, using 3-dimensional whole body scanner. Thirty-nine lower-body-related measurements were used to analyze the figures of 210 Chinese women. Obesity and height of the lower body, length from waist to crotch, shape of abdomen, and leg bone length were analyzed. Factor analysis was performed and the results were classified into three clusters. The first cluster describes the obesity of the lower body, the second denotes small hip measurement, and the third describes slim and long legs. This is the first study to quantify figure analysis of the lower body of Chinese women using 3-dimensional body measurements. The findings of this study will provide concrete information regarding crotch width, crotch length, inseam, outseam, waist slope, etc., for designing trouser patterns for Chinese adult women.

Keywords: Chinese women, lower body, body figure, 3D body scan, measurement characteristics

I. Introduction

In the 21st century, the world has been exposed to global markets without boundaries. For an apparel industry to be competitive in such an environment, studies and data on the figure type and size of various human races are required.

A number of domestic and overseas projects, such as the launch of a spaceship in 2003, distributive liberalization in 2005, and the Beijing Olympics in 2008, have seen China gain the attention of the world as a large consumer market. The inflow of varied information, rise in fashion standards, and intellectual elevation of socioeconomic activity on the development of mass media and high educational backgrounds mean that Chinese consumers are increasingly interested in imperial products and improved quality in their fashion surroundings (Cha, 2008). A preference for fashion products, the actual condition of wearing and purchasing, and information about Chinese body types have become necessary to develop clothing goods that cater to such consumer requests.

Human body measurements are important for an exact analysis of body figure type, and obviously lead to advances in quality of fit. In the past, the length of the human body and its circumference were obtained using a measuring tape, yielding 2D data from 3D measurements. These data provide information on body size in a static situation, but do not provide 3D data on body shape. Two-dimensional methods are inaccurate because the 3D data differ for each

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person and circumstance. We have thus come to use a 3D whole body scanner for body measurements. Such scanners obtain a 3D figure, providing measurements for the body size and appearance without direct body measurements. In addition, highly authentic sampling information can be used repeatedly. This removes some of the obstacles to human body measurement (Adriana & Ashdown, 2008; Cha, 2012; Choi, 2008; Choi & Ashdown, 2011). In this study, we analyzed the figure type and lower-body size of Chinese adult females in their early twenties using data obtained from 3D whole body scanners. We also provide concrete information related to Chinese women's lower bodies in terms of crotch width, crotch length, inseam, outseam, slope of waist, etc. that may be useful to the Chinese apparel industry when designing trouser pants for adult women.

II. Background

1. Special features and types of 3D body scanner

Depending on their measurement method, 3D body scanners can be classified as laser, phase shift, infra-red, or structured light projection scanners. The laser and infra-red methods gather data of the human body shape in the x-, y-, and z-planes after taking a photograph of the human body surface. These approaches allow a whole body scan, but the equipment is generally very large. The method of structured light projecting obtains the surface shape using cross stripes. This can cause some difficulties in obtaining an image because of the need to adjust the angle at each point. The phase shift technique reflects a separated pattern at the surface. This image is fed to a computer by a camera, and the phase shift method then calculates each pixel and provides the size. Although phase shift techniques can view the human body as several pieces, it is not easy to change a pixel into a surface. Various types of 3D body scanners are used around the world. The most widely used are the Whole Body Scanner WB4 (Cyberware Corporation), Vitus 3D Body Scanner (Techmath Corporation), Body Scanner (TC^2 Corporation), and Triform Body Scan (Wicks & Wilson Corporation). The software employed in these machines includes DigiSize (Cyberware Corporation), Scanworx and Polyworx (Techmath Corporation), and 3D Body Measurement Soft System (TC^2 Corporation) (Cha, 2012; Choi, 2008; Kim, 2006).

3D body measurements give exact data within a short time, and can continue to perform measurements over a given period (Lee et al., 2012; Song & Ashdown, 2011). However, it is difficult to obtain data for parts of the body that are covered or overlap, such as the armpit and crotch. In the case of direct body measurements, data will differ according to the measurer, environment, frequency, and so on. It also requires a lot of time for the measurement, but has the merit of providing data for covered areas, such as the crotch and armpit. 3D body scanners can obtain data on the whole body within a minute, including data on body size, shape, and posture.

2. Classification of the lower body figure

Body measurement is a basic method for obtaining characteristics of body size and shape. Most of all, an understanding of body figure is important for making ergonomic apparel that has a good fit (Adriana & Ashdown, 2008). The body measurements must analyze and systematize the body figure in connection with clothes. That is, they should classify body figures in terms of their relationship with relevant items of clothing.

Park (1998) studied the body measurements of 364 women in their twenties. This study performed a factor analysis and cluster analysis on the measurements. The factor analysis found a total of 10 distinct factors. Three clusters were categorized: cluster 1 had a flat and fat shape, cluster 2 had a big curved silhouette at the front, and cluster 3 had a normal figure.

Hong and Park (2003) measured 195 female students, aged from 18 to 23 years old. They also carried out a factor analysis and cluster analysis for a total of 38 items. Six factors and three discrete clusters were found.

Ha and Sung (2005) measured 138 females aged from their twenties to sixties. Each female satisfied three conditions: a 90 cm bust circumference, Rohrer index of 1.5, and relative weight of over 110%. The authors analyzed factors and clusters for a total of 28 items, and determined seven factors and four clusters.

Park (2006) measured 341 females, aged from 19 to 24 years old, in Shanghai and Beijing, China, and analyzed factors and clusters for a total of six items. The factor analysis found six factors, and the cluster analysis determined three distinct clusters.

Choi (2008) analyzed the factors and clusters given by a total of 45 items from the measurements of 1036 Korean females aged in their twenties and thirties. The factor analysis classified seven elements, and the cluster analysis determined one cluster with a thick figure with short legs, one with long legs and a thick waist, and a third cluster was thin and tall with long legs.

Song and Ashdown's (2011) lower body shape categorization method was a multidimensional body shape analysis using a large anthropometric data set (SizeUSA) and statistical methods. This body shape analysis used measurement data of 2,981 women aged 18－35 years from the SizeUSA data set. A total of 15 drop values calculated as differences between measurements and 1 angle were used for the principal component analysis, including drop values for girth, back arc, front arc, width, depth, backs depth, and front depth. The factor analysis classified five elements. From cluster analysis, they identified three body shape groups curvy shape (curviest silhouette between waist level and hip level and the most prominent abdomen silhouette), hip tilt shape (most prominent buttocks and lower body that is tilted toward the back), and straight shape (noncurvy silhouette and less prominent buttocks).

3. Preceding studies about Chinese adult women's body figure

Kim (2005) compared and analyzed partial proportion of body shape of Korean adult women with that of Chinese 19-50 aged adult women who live in Shanghai and Beijing, China, which the data of Chinese were from self-measurement. The result showed that Chinese women have longer lower body, higher hips, and more narrow width of waist compared to Korean women. Also, hips thickness of Chinese women is similar with that of Korean women, but Chinese women have thick breast, greatly grown around breast, small waist size, and small hip circumference.

Choi (2002) compared body shape of women of Korea and China using measurement data of 410 women, 210 Korean female college students and 200 Chinese female college students. Chinese female college students have big tilt of the shoulders and hips, and Korean female college students have healthy lower body, long legs and arms for the height, and large hips, compared to each country.

According to the study of Korean Apparel Industry Association (2004), Chinese adult women are taller than Korean adult women, but weight of those two are alike. So, it shows that Korean adult women are fat relatively. Chinese adult women have western body shape which has large breast and hips, small gourd-shaped waist, and very high waist height.

In the research of Samsung Fashion Institute (2003), it shows that the value of circumference and thickness are high in Chinese women, but the value of width is high in Korean women. So, it can be known that Chinese women show round shape with high flatness ratio relative to Korean women. Also, Chinese women have large breast and long upper body, but size of mammilla was small. In case of lower body, Korean women were thick especially in hip parts. In brief, Chinese women compared to Korean women have grown upper body especially in breast, but their shoulder were narrow, and in lower body, it is flat and total crotch length and hip length are long.

To summarize the above, in lower body, the body shape Chinese adult women are that circumference of waist and hips are small but tilt of hips is large, and total crotch length and hip height are long. In addition, difference in size of waist and hips is large and they have high waist height like western body shape. However, most pre-researches were through self-measurement and almost no studies were done with 3D measurement. Also, since most researches were concentrated in the upper body and overall proportion, there is not enough information on lower body shape of Chinese women. So, it needs to be studied deeply. Thus, this research tried to help in design of pants for Chinese adult women by analyzing lower body shape of Chinese adult women using data from 3D measurement.

III. Methodology

1. Subjects

A total of 210 women from University in China, were selected by simple random sampling. The women were aged from 18 to 24 years old. Informed consent was obtained from participants to report their body shapes and size data.

2. Period and place of measurement

A preliminary measuring test was conducted from 21－24 January, 2008, in the Human Engineering room in University in China. The main measurement was carried out from 20 February to 30 March, 2008.

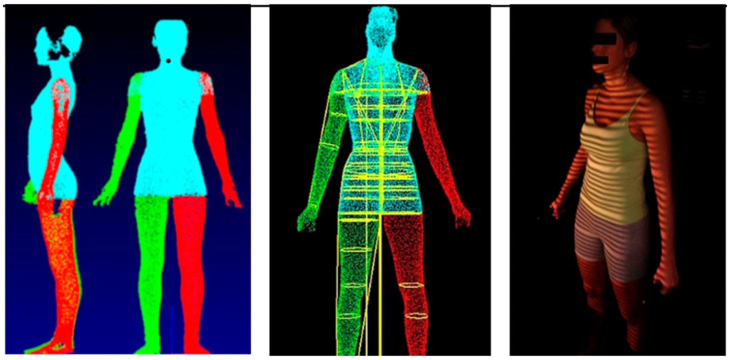
3. Posture of 3D body measurement

The subjects were asked to stand with their feet 30 cm apart and their legs straight. To prevent the loss of data from the crotch and armpit areas, they were also required to hold handles and look forward (Cha, 2008; Choi & Ashdown, 2011) (Fig. 1).

4. Measurement instruments and garments

The 3D Whole Body Scanner (TC^2 Corporation) was used for measurements (Fig. 2). The subjects wore

<Fig. 2> 3D whole body scanner



<Fig. 1> Posture of 3D body scanning

only a thin pair of briefs. To prevent the loss of data from the crotch and armpit areas, they were also required to hold handles and look forward briefs without upper wear to ensure they were physically comfortable for the test, and wore a hat on their head after tying their hair.

5. Measurement items and analysis of 3D data

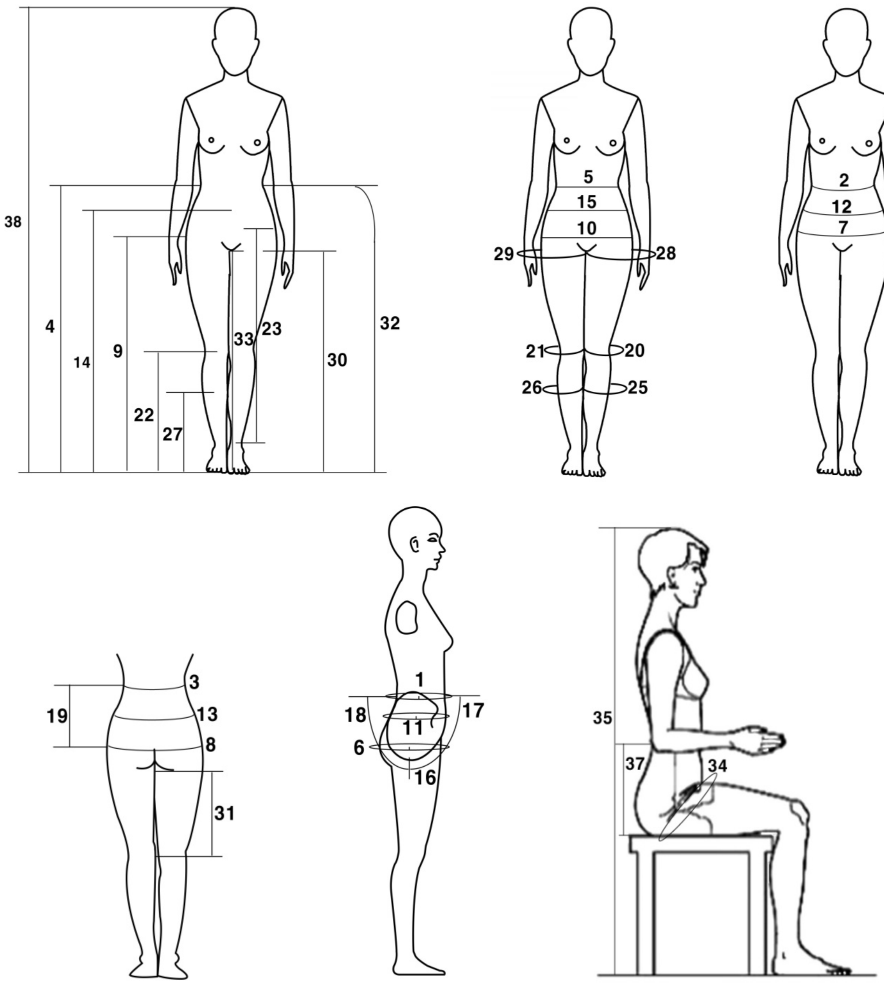
These data were analyzed using TC^2 Corporation's analysis program at the Hong Kong Polytechnic University. A total of 39 items were determined using the underbody auto-extract program. These opened and analyzed an Excel program after conversion from ORD files. The 39 items were as 〈Table 1〉 and 〈Fig. 3〉. The DC Suite program of the Digital Clothing Center at Seoul National University was used to make 3D forms.

〈Table 1〉 Measurement parts

No.	Parts	Explanation
1	Waist full	Anterior waist to posterior waist horizontal circumference
2	Waist front	Waist side point to waist side point front horizontal circumference
3	Waist back	Waist side point to waist side point back horizontal circumference
4	Waist height	Ground to anterior waist length
5	Waist width	Straight length between waist side point to waist side point
6	Hips full	Horizontal circumference through the buttock protrusion
7	Hips front	Buttock side point to buttock side point front horizontal circumference
8	Hips back	Buttock side point to buttock side point back horizontal circumference
9	Hips height	Ground to buttock protrusion length
10	Hips width	Straight length between side buttock protrusion to side buttock protrusion
11	Abdomen full	Horizontal circumference through abdominal protrusion
12	Abdomen front	Front horizontal circumference between side abdominal point to side abdominal point
13	Abdomen back	Back horizontal circumference between side abdominal point to side abdominal point
14	Abdomen height	Ground to abdominal protrusion length
15	Abdomen width	Straight length between side abdominal point to side abdominal point
16	Crotch length full	Anterior waist to posterior waist length through crotch
17	Crotch length front	Anterior waist to crotch length
18	Crotch length back	Posterior waist to crotch length
19	Waist to hips	Waist side point to buttock protrusion length
20	Knee left	Horizontal circumference through left midpatella
21	Knee right	Horizontal circumference through right midpatella
22	Knee height	Ground to tibiale length
23	Knee knock left	Left bone length from pelvis to ankle
24	Knee knock right	Right bone length from pelvis to ankle
25	Calf left	Horizontal circumference of left calf part
26	Calf right	Horizontal circumference of right calf part
27	Calf height	Ground to calf protrusion length
28	Thigh left	Left horizontal circumference through gluteal fold
29	Thigh right	Right horizontal circumference through gluteal fold

〈Table 1〉 Continued

No.	Parts	Explanation
30	Thigh height	Ground to gluteal fold length
31	Thigh length	Gluteal fold to posterior juncture of calf and thigh length
32	Outseam	Waist side point to ground length
33	Inseam	Ground to crotch length
34	Seat full	Circumference of widest part, sitting
35	Seat height	Vertex to ground straight length, sitting
36	Seat width	Straight length of widest part, sitting
37	Waist to seat	Waist point to seat ground straight length, sitting
38	Stature	Ground to vertex straight length
39	Weight	Total body's weight



〈Fig. 3〉 Measurement parts

6. Analysis program and methods

The data obtained were processed using the SPSSWIN 15.0 software. The average and standard deviation of the measurements were calculated to determine the lower body characteristics of Chinese adult women, and an exploratory factor analysis was used to draw measurement item factors of the lower body. A non-hierarchical K-means cluster analysis was performed on the basis of the factor loadings for lower-body grouping. A one-way ANOVA test was then used to verify the difference between lower-body measurement's items derived from the clusters of lower-body measurements. Post-verification was completed using Duncan's multiple range tests. The statistical significance was examined at a level of α=0.05.

IV. Results

We obtained somatometric results by analyzing the size and shape of the lower half of the body using the 3D full body scanner. The minimum, maximum, mean, and standard deviation of 39 metrics are

〈Table 2〉 Lower body size of Chinese women (Units: cm and kg)

Part	Minimum	Maximum	Average	SD
Waist full	59.7	94.6	74.0	6.5
Waist front	28.7	46.1	35.7	3.3
Waist back	31.0	48.5	38.3	3.2
Waist height	86.1	115.0	96.7	4.9
Waist width	21.8	33.9	26.6	2.3
Hips full	82.8	108.4	94.2	4.9
Hips front	41.1	57.2	46.5	2.5
Hips back	31.1	56.3	47.7	3.4
Hips height	65.0	90.0	75.9	4.2
Hips width	31.0	40.0	34.8	1.8
Abdomen full	63.5	102.5	83.4	6.8
Abdomen front	31.0	50.0	40.7	3.4
Abdomen back	32.6	52.2	42.7	3.6
Abdomen height	79.5	108.9	90.6	5.2
Abdomen width	23.1	36.4	30.3	2.4
Crotch length full	46.5	88.1	65.4	5.8
Crotch length front	23.1	43.8	32.4	2.9
Crotch length back	23.4	44.2	33.0	3.2
Waist to hips	11.6	41.0	21.6	3.3
Knee left	32.9	44.7	37.9	2.3
Knee right	32.7	45.3	37.8	2.3
Knee height	38.0	51.0	43.3	2.2
Knee knock left	97.1	101.9	99.7	0.9
Knee knock right	97.1	101.8	99.5	0.8
Calf left	32.2	46.6	37.3	2.5
Calf right	31.7	43.8	37.0	2.2

〈Table 2〉 Continued

Part	Minimum	Maximum	Average	SD
Calf height	27.0	42.0	31.1	2.2
Thigh left	44.2	63.2	52.6	3.6
Thigh right	44.5	63.4	52.9	3.6
Thigh height	56.0	77.0	66.6	3.9
Thigh length	21.1	38.8	28.9	2.4
Outseam	86.9	115.4	97.4	5.0
Inseam	61.0	82.0	71.6	3.9
Seat full	81.3	106.7	92.7	4.7
Seat height	68.0	93.0	80.2	4.0
Seat width	29.5	39.2	33.7	1.7
Waist to seat	8.8	22.9	17.2	2.5
Stature	146.1	182.7	161.1	5.9
Weight	38.0	76.0	52.4	6.7

shown in 〈Table 2〉.

Principal component analysis was used to reduce the number of variables, and an orthogonal rotation technique, Varimax, was used for factor rotation. Only variables with a factor loading of above 0.5 were considered meaningful. This analysis extracted five factors whose eigenvalue was greater than 1, and the total variance explanation power was found to be about 84.5%. The eigenvalue of factor 1 was approximately 16.8, and this factor explains 43.2% of the whole variance. We named this the 'factor of lower-half obesity,' because it consists of the waist circumference, hip circumference, thigh circumference, knee circumference, calf circumference, waist width, and hip width. The eigenvalue of factor 2 was about 8.6, and this factor explains approximately 22.1% of the whole variance. This was named the 'factor of lower-half height,' because it is composed of height, waist height, hip height, thigh height, abdomen height, calf height, outside leg height, inside leg height, and so on. Statistics for the other three factors, as well as a breakdown of the factor loadage, are given in 〈Table 3〉 and 〈Table 4〉.

A cluster analysis was implemented to classify the lower-body types in terms of the factors determined from the factor analysis. A nonhierarchical K-Means clustering was used for cluster analysis, resulting in three appropriate groups to classify the lower-body types. Cluster 1 focuses on the lower-half body shape (n=79), having the highest values of obesity, especially

〈Table 3〉 Factor analysis of the lower body

Factor	Lower body parameters	Eigenvalue	Rate of rest (%)	Rate of accumulated rest (%)
1	Obesity	16.829	43.152	43.152
2	Height	8.598	22.047	65.198
3	Length from waist to crotch	3.966	10.170	75.368
4	Abdomen shape	1.868	4.790	80.158
5	Leg bone	1.685	4.320	84.479

<Table 4> Results of factor analysis

Division	Factor loadage					Commonality (h^2)
	1	2	3	4	5	
Hips full	0.950	0.112	0.164	0.117	−0.009	0.955
Seat full	0.946	0.109	0.147	0.128	0.039	0.946
Thigh left	0.900	0.118	0.146	0.024	0.054	0.849
Seat width	0.896	0.164	0.172	0.103	−0.050	0.872
Thigh right	0.890	0.100	0.135	0.033	0.076	0.828
Hips width	0.886	0.149	0.209	0.085	−0.172	0.887
Weight	0.868	0.273	0.150	0.152	0.163	0.901
Waist back	0.848	0.023	−0.295	0.157	0.174	0.862
Waist full	0.848	0.020	−0.299	0.158	0.177	0.865
Waist front	0.848	0.017	−0.303	0.157	0.181	0.868
Hips back	0.826	0.028	0.143	0.084	0.198	0.750
Calf right	0.814	0.050	0.107	0.189	0.214	0.758
Waist width	0.800	0.095	−0.381	0.206	0.110	0.849
Knee left	0.786	0.100	0.224	0.174	0.247	0.770
Knee right	0.766	0.133	0.228	0.182	0.270	0.763
Hips front	0.749	0.179	0.130	0.117	−0.279	0.701
Calf left	0.669	0.042	0.093	0.164	0.195	0.523
Thigh height	0.026	0.976	−0.008	−0.023	−0.105	0.964
Inseam	0.026	0.976	−0.008	−0.023	−0.105	0.964
Seat height	0.147	0.939	0.107	0.098	0.049	0.926
Hips height	0.111	0.908	0.021	0.125	0.182	0.887
Knee height	0.128	0.890	0.122	0.082	0.118	0.844
Waist height	0.079	0.857	0.493	0.034	0.025	0.986
Outseam	0.072	0.848	0.513	0.030	0.022	0.989
Stature	0.217	0.843	0.155	0.033	−0.059	0.787
Thigh length	−0.085	0.771	−0.140	−0.119	−0.323	0.739
Abdomen height	0.200	0.740	0.274	−0.503	0.059	0.919
Calf height	0.231	0.686	0.159	0021	0.093	0.558
Crotch length full	0.256	0.169	0.885	0.079	0.186	0.917
Waist to seat	−0.096	0.196	0.872	−0.115	−0.047	0.823
Crotch length front	0.209	0.207	0.847	0.084	0.138	0.830
Crotch length back	0.278	0.119	0.844	0.068	0.214	0.854
Waist to hips	−0.057	0.111	0.793	−0.110	−0.249	0.718
Abdomen width	0.484	0.077	−0.017	0.786	0.046	0.968
Abdomen full	0.338	0.024	0.007	0.757	0.099	0.992
Abdomen front	0.313	0.048	−0.048	0.751	0.057	0.947
Abdomen back	0.425	0.000	0.059	0.719	0.134	0.928
Knee knock right	0.228	−0.013	0.034	0.043	0.822	0.731
Knee knock left	0.240	−0.007	0.073	0.076	0.813	0.730

〈Table 5〉 Cluster analysis of lower body types

Division	Cluster			*F*-test
	Cluster 1 (n=79)	Cluster 2 (n=85)	Cluster 3 (n=46)	
Obesity of lower body	0.6831	−0.5888	−0.0851	48.48***
Height of lower body	−0.1057	−0.2258	0.5989	12.00***
Length from waist to crotch	−0.2749	0.0888	0.3080	5.75**
Abdomen shape	0.1472	0.5694	−1.3049	109.81***
Leg bone	−0.5267	0.4179	0.1323	22.68***

Notes: Significance at **p<0.01, and ***p<0.001

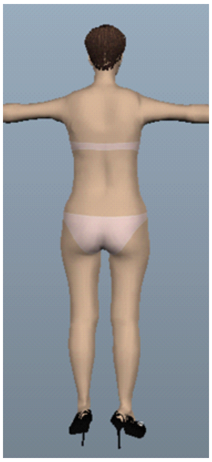
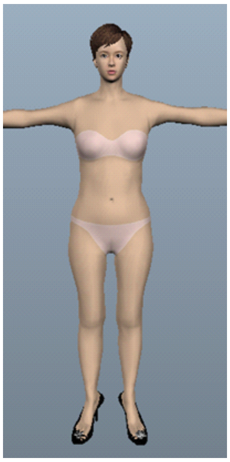
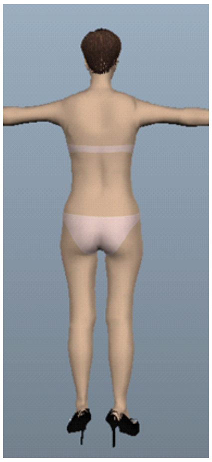
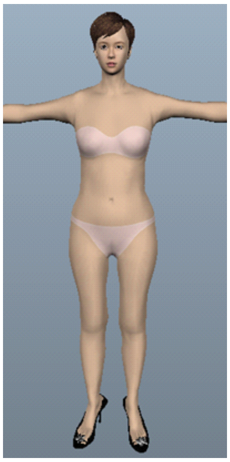
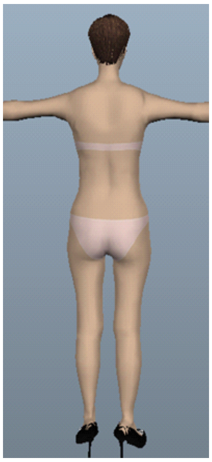
the highest value in most of the circumference, width, and weight measurements and the lowest value of lower-half height. Cluster 2 has a small hip circumference and thin thigh compared to the waist and abdomen circumference, but exhibits the lowest values for hip circumference, hip width, abdomen height, thigh circumference, and weight, and middle values for most other categories. Cluster 3 contains high values of both lower-half height and length from waist to crotch (n=46). Therefore, the clusters were named obesity (cluster 1), small hip (cluster 2), and slim body with long legs (cluster 3) (Table 5).

Statistics for the average measurement size of each cluster are shown in 〈Table 6〉. 〈Fig. 4〉 illustrate each of the three body types. For making avatar, using size is like this. First, 'Obesity' avatar has 77.7cm in waist circumference, waist height 95.9cm, hip circumference 75.5cm, waist to hip length 21cm, and knee height 43.1cm. Second, 'Small hip' has waist circumference 71.7cm, waist height 95.9cm, hip circumference 91.6cm, hip height 75.3cm, waist to hip length 21.4cm, and knee height 43.1cm. Third, 'Slim with long legs' has 71.8cm in waist circumference, waist height 99.7cm, and hip circumference 93.6cm. And it has 77.7cm in hip height, waist to hip length 22.9cm, and knee height 44.3cm.

According to lower body size on cluster, 'Obesity' is bigger than 'Small hip' and 'Slim with long legs' as 77.7cm in waist circumference. Also, 'Obesity' has 97.4cm hip circumference, the largest among the clusters and 'Small hip' has 91.6cm hip circumference, the smallest. In abdomen circumference, 'Obesity' has 86.7cm, the biggest and 'Slim with long legs' has 76.4cm, the smallest, so they have about 10cm differences. In height, waist, hip, abdomen, knee, and crotch are all highest in 'Slim and Long legs', but 'Obesity' and 'Small hip' are almost same. In width, waist width of 'Obesity' is the widest and that of 'Small hip' and 'Slim with long legs' is similar. 'Small hip' has the smallest hip width and 'Obesity' has the largest. Abdomen width is shown the smallest in 'Slim with long legs' as 27.7cm and the largest in 'Obesity' as 31.5cm. In length, 'Slim with long legs' has the longest hip length as 22.9cm and 'Obesity' and 'Small hip' are alike. 'Slim with long legs' has much longer in outside and inside of leg length. 'Slim with long legs' is the tallest as 164.5cm, 'Obesity' is next as 160.9cm, and 'Small hip' is 159.4cm. In case of weight, 'Small hip' is the lightest as 49.6kg, 'Slim with long legs' is next as 52.1kg, and 'Obesity' is 55.4kg.

V. Discussion and Conclusions

This research has attempted to analyze the shape of the lower half of women in their early 20s in Shanghai, China using somatometry with a 3D full body scanner. The results offer a wealth of information to manufacturers who export clothes to China. Kong et al. (2011) analyzed six groups for the ratio

Cluster	Front	Side	Back
Obesity - Waist full: 77.7cm - Waist height: 95.9cm - Hip full: 97.4cm - Hip height: 75.5cm - Waist to hips: 21cm - Knee height: 43.1cm			
Small hip - Waist full: 71.7cm - Waist height: 95.9cm - Hip full: 91.6cm - Hip height: 75.3cm - Waist to hips: 21.4cm - Knee height: 42.9cm			
Slim with long legs - Waist full: 71.8cm - Waist height: 99.7cm - Hip full: 93.6cm - Hip height: 77.7cm - Waist to hips: 22.9cm - Knee height: 44.3cm			

〈Fig. 4〉 Body generation of cluster 1, 2, 3

〈Table 6〉 Lower body size on cluster

Division	Cluster 1 Obesity (n=79)		Cluster 2 Small hip (n=85)		Cluster 3 Slim with long legs (n=46)		*F*-test
	Average	SD	Average	SD	Average	SD	
Waist full	77.7[a]	6.2	71.7[b]	5.3	71.8[b]	6.2	25.90***
Waist front	37.6[a]	3.1	34.6[b]	2.6	34.6[b]	3.1	26.00***
Waist back	40.1[a]	3.1	37.1[b]	2.6	37.2[b]	3.1	25.81***
Waist height	95.9[b]	4.1	95.9[b]	4.6	99.7[a]	5.7	11.92***
Waist width	28.0[a]	2.1	25.7[b]	1.9	25.6[b]	2.2	33.08***
Hips full	97.4[a]	4.4	91.6[c]	3.8	93.6[b]	4.7	39.73***
Hips front	48.1[a]	2.0	45.2[c]	2.1	46.3[b]	2.6	38.56***
Hips back	49.3[a]	2.6	46.4[b]	2.9	47.3[b]	4.2	17.28***
Hips height	75.5[b]	3.2	75.3[b]	4.1	77.7[a]	5.5	5.70**
Hips width	35.9[a]	1.5	33.8[c]	1.4	34.6[b]	1.6	43.83***
Abdomen full	86.7[a]	5.5	84.0[b]	5.2	76.4[c]	6.6	50.29***
Abdomen front	42.5[a]	2.7	41.0[b]	2.5	37.0[c]	3.4	57.96***
Abdomen back	44.2[a]	3.0	43.0[b]	3.0	39.3[c]	3.4	36.84***
Abdomen height	90.0[b]	3.6	87.8[c]	3.9	96.6[a]	4.9	71.17***
Abdomen width	31.5[a]	1.9	30.5[b]	1.8	27.7[c]	2.3	54.12***
Crotch length full	64.5	6.0	65.3	5.3	67.1	6.2	2.98
Crotch length front	31.9	3.1	32.4	2.6	33.1	3.0	2.33
Crotch length back	32.5[a,b]	3.1	32.9[b]	2.9	34.0[a]	3.5	3.18*
Waist to hips	21.0[b]	3.0	21.4[b]	3.6	22.9[a]	2.8	4.85**
Knee left	38.6[a]	2.2	37.4[b]	2.1	37.7[b]	2.5	6.17**
Knee right	38.5[a]	2.2	37.3[b]	2.1	37.7[a,b]	2.6	5.74**
Knee height	43.1[b]	1.9	42.9[b]	2.0	44.3[a]	2.7	6.66**
Knee knock left	99.4[b]	1.0	99.9[a]	0.7	99.6[a,b]	0.9	5.75**
Knee knock right	99.3[b]	0.8	99.7[a]	0.8	99.5[a,b]	0.9	5.49**
Calf left	38.0[a]	2.3	36.7[b]	2.3	37.0[b]	3.1	5.29**
Calf right	37.9[a]	2.0	36.4[b]	1.8	36.6[b]	2.4	12.51***
Calf height	31.0[b]	1.5	30.7[b]	2.2	31.9[a]	2.8	5.14**
Thigh left	54.6[a]	3.6	50.8[c]	2.7	52.6[b]	3.3	28.14***
Thigh right	54.8[a]	3.7	51.2[c]	2.7	52.8[b]	3.3	26.35***
Thigh height	66.5[b]	3.2	65.5[b]	3.6	68.9[a]	4.6	12.56***
Thigh length	29.0[b]	2.0	28.1[c]	2.3	30.2[a]	2.7	11.90***
Outseam	96.5[b]	4.2	96.5[b]	4.6	100.4[a]	5.7	12.33***
Inseam	71.5[b]	3.2	70.5[b]	3.6	73.9[a]	4.6	12.57***
Seat full	95.6[a]	4.2	90.3[c]	3.7	92.0[b]	4.8	33.93***
Seat height	80.1[b]	3.5	79.2[b]	3.7	82.0[a]	4.7	8.08***
Seat width	34.7[a]	1.5	32.8[c]	1.3	33.5[b]	1.6	33.72***
Waist to seat	16.3[c]	2.5	17.3[b]	2.2	18.4[a]	2.2	12.07***
Stature	160.9[b]	4.8	159.4[b]	5.5	164.5[a]	6.8	12.93***
Weight	55.4[a]	6.7	49.6[c]	4.8	52.1[b]	7.5	17.79***

Notes: Significance at: *$p \leq 0.05$, **$p \leq 0.01$, and ***$p \leq$ 0.001, respectively; units: cm, kg; the alphabets [a, b] and [c] indicate measurements that different at significance levels of ≤0.05, ≤0.01, and $p \leq 0.001$, respectively, after the results of Duncan's test were obtained (a>b>c).

of thickness and width of characteristic circumference of the body. Choi (2008) analyzed the height of the lower half, obesity of the lower half, circumference of knee to ankle, shape of hip, length of waist to crotch, shape of abdomen and circumference of thigh of four groups. However, this study analyzed factors relating to whole body size and classified three clusters. A factor analysis for the shape of the lower body found five distinct factors: obesity of the lower half, height of the lower half, height from waist to crotch, shape of the abdomen, and leg bone length. Based on these factor analysis results, three clusters were determined. The first group is an obesity type, which exhibits high values of obesity and has the lowest value for lower-half height. The second group is a small hip type, with average values for most of the factors but the lowest value of hip circumference, hip width, abdomen height, thigh circumference, and weight. The third group has a slim body with long legs, exhibiting high values of lower-half height and length from waist to crotch. The circumferences of the ‘obesity’ type are the largest, and those of ‘small hip’ and ‘slim body with long legs’ types are similar, except for the hip circumference. The ‘small hip’ type has the smallest hip circumference. All of the height measurements for the ‘slim body with long legs’ type are the largest. Compared to Korean women in early 20s, Chinese early 20s women have longer legs, large difference in the size of circumference of waist and hips, and higher hip height, which is western body shape. Korean women have greatly grown lower body and large hips, and Chinese women have relatively flat lower body. So, considering these results, to design the pants for Chinese adult women, it needs to be set differently with Korean women in size of waist, hips, hip height, length of pants, and so on. However, it should be careful to generalize the results of this research since this research was progressed targeting only female college students in Donghua University in Shanghai, China, and anthropometry was in 2008. Therefore, further studies for various ages and regions in China need to be followed.

References

Adriana, P., & Ashdown, S. P.(2008). Three-dimensional body scan data analysis: Body size and shape dependence of ease values for pants’ fit. *Clothing and Textiles Research Journal*, *26*(3), 227-252.

Cha, S. J.(2008). A study for the development of a brassiere pattern for the Chinese adult women: mainly with the women in their early 20s in Shanghai. Unpublished doctoral dissertation, Sookmyung Women’s University, Seoul.

Cha, S. J.(2012). Comparison of direct measurement and 3D body scanning size for Chinese adult women. *The Korean Society of Fashion Business*, *16*, 150-159.

Choi, J.(2008). A study on analysis of lower body type from 3D body scan data and boots cut jeans pattern: Focus on the virtual appearance evaluation. Unpublished master’s thesis, Chonnam National University, Kwangju.

Choi, M. A.(2002). A study on the analysis of Chinese college women’s body types for the establishment of a sizing system. Unpublished master’s thesis, Seoul National University, Seoul.

Choi, S. Y., & Ashdown, S. P.(2010). 3D body scan analysis of dimensional change in lower body measurements for active body positions. *Textile Research Journal*, *81*(1), 81-93.

Ha, J. H., & Sung, O. J.(2005). A study on lower body shapes of plus-sized women to index. *The Research Journal of the Costume Culture*, *13*, 6-17.

Kim, E. H.(2005). The analysis of body type according to the proportion of Chinese women. Unpublished doctoral dissertation, Sookmyung Women’s University, Seoul.

Kim, H. S.(2006). A study on body shapes using 3D measurement and torso pattern of obese women. Unpublished doctoral dissertation, Sungshin Women’s

University, Seoul.

Kong, H. Y., Gu, B. F., Gu, P. Y., Su, J. Q., and Liu, G. L.(2011). Calculation rules research of female lower body torso 3D sizes. *Procedia Engineering*, *15*, 4326-4330.

Korean Apparel Industry Association(2004). Size optimization strategy of Chinese clothing products.

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 attitude toward the use of 3D body scanning. *Clothing and Textiles Research Journal*, *30*(2), 102-118.

Park, J. H., & Hong, J. M.(2003). A figure analysis on lower body of college girls in the twenties. *Fashion & Textile Research Journal*, *5*, 159-166.

Park, J. Y.(2006). A study on the analysis of lower body type and jean pants pattern for early 20s adult women in China: Focused on the residents in Beijing and Shanghai. Unpublished doctoral dissertation, Sookmyung Women's University, Seoul.

Park, S. J.(1998). Clothing-ergonomics study on the development of slacks pattern for the 20s women based on their lower body. Unpublished doctoral dissertation, Yonsei University, Seoul.

Samsung Fashion Institute(2003). Figure research of Chinese adult women.

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.