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A Study on the Body Shape Analysis for an Avatar Generation of the Virtual Fitting System -Focusing on Korean Women in their 20's-

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Abstract

In the virtual fitting system, the use of a 3D avatar is not a simple garment model, but it should be able to reproduce the size and shape of the customer using a fitting system. Although various virtual fitting systems have their own 3D avatar sizing systems and provide 3D avatars that match the size of the customer, there are limitations in realizing the actual body shape in actual use by the consumer. The purpose of this study is to realize a 3D avatar with excellent size and conformity for customer use. Therefore, this study aims to provide basic data for the formation of a 3D standard avatar of Korean women aged in their 20's, by comparing and analyzing the degree of the consumer user friendly system change of a body type, and the consumer's ability in selecting a consumer representative body type. Based on the survey data of 'Size Korea' conducted from 2004 to 2015 at three times, we examined the change of body shape over 10 years. Then, based on the results of 6th and 7th data, 4 factors of the concurrent body shape change of women of the consumer demographic studied were selected through the use of a factor analysis. Following this analysis, the 4 extracted factors were clustered again and finally released 7 representative body types, which were obtained based on height and weight. The size of each representative figure is derived by the use of a regression analysis, and it is used as a basic data for 3D avatar formation of the virtual fitting system.

I. Introduction

Presently, virtual fitting systems are being widely used as a method for evaluation of clothing fit. The simulation technology of the virtual fitting system has already reached a considerable level, and it is possible to express various forms of clothes and physical properties. However, it is difficult to represent the various body measurements by the 3D virtual body when it comes to a large number of consumers. In order to evaluate fit through the virtual fitting system, it is necessary to grasp the body shape and dimension of the consumer and implement the 3D virtual body based on the actual body shape and measurements.

The 3D virtual body is a tool for clothing design and try-on in the virtual fitting system. It can replace the different body characteristics as the standard of fitting. The 3D virtual body must be designed on the basis of statistical processing and body shape analysis of a certain sample of anthropometric data, and is highly representative of the specific human population characteristics. Therefore, the body shape is classified, and the coverage of the 3D virtual body is refined and expanded.

We would like to review some previous research for formation of 3D virtual body through human measurement information. Qi, Li, and Zhang, (2008) analyzed Chinese men's body based on 3D anthropometric data. Pan, Wang, Sha, & Yu(2013) measured bodies of 18-25 years old women in northeastern provinces of China using both contact and non-contact measurement methods and analyzed the body shape based on statistical analysis and the Chinese clothing standard system. Na (2007) analyzed the shape of the trunk part based on the slope of the body shape and the vertical distance based on 3D human body scan images of American women. Shim (2002) conducted statistical analysis of anthropometric data to understand the body shape of middle-aged Korean women. Based on the difference of bust and hip circumference, she classified them into 3 body types and used them as basic data for a size system customized to middle-aged women. Kim,S.R. and Jo,J.S.(2001) classified body type and standard of body type classification by statistical analysis of anthropometric data on 279 middle-aged women. Most of these studies form a 3D human body with data obtained through 3D human body scan, and conduct body shape analysis. 3D human body scan technology has been developed and used in the apparel industry since 2000. A 3D human body scanner can acquire the 3D shape of the human body in a short time and obtain body dimensions and information immediately. However, there are problems such as selection of the measurement site, high-cost facilities and technical problems, and limitations to the programs for forming an avatar. Therefore, in this study, body shape analysis is going to be conducted on the basis of traditional measurement data.

Age is an important factor in determining changes to the body shape; as age increases, the values related to size and weight increase. A study of body changes in adults aged 20-59 (Dong, 2008) showed that as age increased, height decreased and body weight increased. As age increases, the height measurements decrease, waist, abdomen, and hip increase, and the flexion of the waist becomes unclear. The neck and upper arms become thicker and the bust and hips droop. Thus there are many changes in body shape. The developmental process of adult women decreases the change of body weight at about 20 years of age. Therefore, in order to establish the standard for the size of the representative figure, this study intends to define the age range of the subject as a 20-year-old adult woman.

The purpose of this study was to investigate the following:

1. Based on the data of the Korea Anthropometric Survey conducted three times from 2004 to 2015, it examined the change of body shape among 20-year-old Korean women.

2. This study selected factors related to changes in body shape by factor analysis.

3. The study performed clustered analysis with selected factors. Classification was made by body type.

4. The study derived each representative body size by

regression equation.

5. The representative body size is provided as basic data of the follow-up avatar formation study.

Ⅱ. Methods and Procedures

1. Research Subjects and Materials

This study used data from the Korea Anthropometric Survey (Size Korea) conducted three times from 2004 to 2015. The subjects of the study were Korean women in their 20's, viz. those in the 19-29 age group. The following Table 1 shows the number of measurement items, number of subjects, and the number of women in their 20's.

2. Measurement Items

The measurement items of this study to analyze the body shape characteristics of women in their 20's are shown in Table 2 below. These items were selected by referring to 'Standard sizing system for clothe (1991)', 'Sizing systems for female adult's garments (2009)', and 'Location and method of anthropometric surveys for garments (2008)'. A total 81 items were selected and subdivided as 14 items of height, 22 items of circumference, 30 items of length, 6 items of breadth, 6 items of depth, 2 items of angle and 1 item of weight.

3. Research Method

The data of this study were statistically processed using SPSS program, and the research problems to be revealed in this study are as follows.

(1) Human body measurement data was analyzed as an essential element for forming a representative body type avatar. After eliminating the missing cases from the total measurements, the data are summarized and the statistical parts defined.

(2) F-test and T-test were conducted on the differences in measurements each year. The degree of body change over 10 years was compared and analyzed.

(3) Body type classification was performed based on the 6th and 7th data sets. The purpose of the body type classification was to form a 3D avatar that accurately reflects the characteristics of a specific body type and to obtain accurate parameters of human body parts required for forming a 3D avatar. The more the measurement items are, the more accurate the avatar expression will be. However, it is difficult to make an accurate conclusion because of many plural collinearities among various measurement items. In order to express the classification result more objectively and clearly, we combined many measurement items through factor analysis and extracted some factors independent of each other. These factors sufficiently reflect the characteristics of the human body and are free of the problem of

Table 1. Korea Anthropometric Survey (Size Korea)

Times	Period	Number of Measurement Items	Number of Subjects	Number of Women (19~29 years old)
5th	March 2003 ~ November 2004	359 items	14200 (0~9 years old)	942
6th	March 2010 ~ November 2010	139 items	14016 (7~69 years old)	1027
7th	May 2015 ~ December 2015	133 items	6413 (16~69 years old)	897

Table 2. Measurement Items

Measurement Items		Measurement Items	
Height (14)	Stature	Length (30)	Waist Front Length
	Cervical Height(straight)		Waist Front-Omphalion Length
	Acromion Height		Interscye Front Length
	Shoulder Height		Interscye Fold Front Length
	Axilla Height		B.P to B.P
	Elbow Height		Shoulder Length
	Hip Height		Scye Depth
	Waist Height		Back Waist Length
	Waist-Omphalion Height		Back Waist-Omphalion Length
	Anterior-Superior Iliac Spine Height		Cervical to Knee Hollow Length
	Knee Height		Total Length
	Crotch Height		Vertical Trunk Length
	Lateral Malleolus Height		Body Rise
	Bust Height		Thigh Vertical Length
Circumference (22)	Head Circumference		Biacromion Length
	Neck Circumference		Interscye Back Length
	Neck Base Circumference		Interscye Fold Back Length
	Chest Circumference		Cervical to B.P
	Bust Circumference		Cervical to Waist Line
	Under Bust Circumference		S.N.P to B.P
	Waist Circumference		S.N.P to B.P to Waist Line
	Waist-Omphalion Circumference		S.N.P to Inferior Scapula Point to Wasit Line
	Abdominal Circumference		Upper Arm Length
	Hip Circumference		Arm Length
	Armscye Circumference		Lower Arm Length
	Truck Circumference		Cervical to Wrist
	Thigh Circumference		Waist to Hip
	Midthigh Circumference		Outside Leg Length
	Knee Circumference		Total Crotch Length
	Low Knee Circumference		Total Crotch-Omphalion Length
	Calf Circumference	Breadth (6)	Chest Breadth
	Minimum Leg Circumference		Bust Breadth
	Ankle Circumference		Waist Breadth
	Upper Arm Circumference		Waist-Omphalion Breadth
	Elbow Circumference		Hip Breadth
	Wrist Circumference		Biacrominal Breadth
Depth (6)	Armscye Depth	Angle (2)	Right Shoulder Angle
	Chest Depth		Left shoulder Angle
	Bust Depth	Weight (1)	Weight
	Waist Depth		
	Waist-Omphalion Depth		
	Hip Depth		
Total	81		

collinearity between the measurement items. In order to better express human body characteristics, groups of similar body types were classified through cluster analysis. In this study, cluster analysis was performed on factors derived from factor analysis.

(4) The size of the representative body representing each cluster (each body type) was derived based on the above method. The stature, bust, and waist circumference were specified as the average size of each cluster, and the measures of the other items were derived through multiple regression equations based on the average size.

(5) Find out if the size of the representative body type obtained from the research is well expressed in the body of a women in their 20's. It is provided as basic data of avatar formation research.

III. Results and Discussion

1. Analysis of 5th, 6th, and 7th anthropometric measurements

The total descriptive statistics for 83 items related to Korean women in their 20's are shown in Table 3 Missing values were removed in a total of 2,814 cases.

The average size of 5th, 6th, and 7th set is 160.25cm in stature, 114.26cm in bust height, 98.2cm in waist height, and 79.14cm in hip height. On the circumference side, the bust circumference is 83.53 cm, the waist circumference is 70.06 cm, and the hip circumference is 92 cm. The font waist length is 41.18cm, and the back waist length is 42.14cm , the back is a bit long. The bust breadth is 26.65cm, waist breadth is 24.55cm, and hip breadth is 32.38cm. In the depth item, the chest is 20.81cm, the waist is 17.35cm, and the hip is 21.11cm. The shoulder angle is about 1 degree difference between right and left, and the right side is more tilted. The Rohrer's Index was 1.32 and the BMI was 21.14, the obesity index shows normal.

2. Comparative analysis results of measurement data by year

The results of the F-test for measurement differences by year are shown in the following Table 4, Table 5, Table 6,Table 7, Table 8, and Table 9.

Table 3. The Total Descriptive Statistics Body Measurement of Korean Women in Their 20's (Unit:cm)

Measurement Items		Total (N=2814)						
		Range	Min.	Max	Mean	St Dev.	Median	Frequency
Height	Stature	37.40	140.80	178.20	160.25	5.17	26.761	160.20
	Cervical Height(straight)	34.00	120.20	154.20	135.91	4.84	23.428	135.90
	Acromion Height	32.60	112.70	145.30	129.07	4.72	22.296	129.00
	Shoulder Height	34.20	113.50	147.70	130.31	4.71	22.176	130.20
	Axilla Height	31.50	104.00	135.50	118.89	4.51	20.346	118.80
	Elbow Height	26.80	85.50	112.30	97.70	3.76	14.152	97.70
	Hip Height	27.70	65.50	93.20	79.14	3.80	14.444	79.00
	Waist Height	31.40	84.60	116.00	98.02	4.17	17.377	97.90
	Waist-Omphalion Height	28.50	80.70	109.20	93.98	3.91	15.324	93.90
	Anterior-Superior Iliac Spine Height	27.70	73.10	100.80	86.89	3.92	15.373	86.90
	Knee Height	15.50	34.00	49.50	41.29	2.22	4.940	41.30
	Crotch Height	24.60	61.00	85.60	72.96	3.48	12.105	73.00
	Lateral Malleolus Height	3.70	4.80	8.50	6.29	0.46	0.210	6.30
	Bust Height	32.20	98.20	130.40	114.26	4.61	21.249	114.20

Table 3. Continued

Measurement Items		Total (N=2814)						
		Range	Min.	Max	Mean	St Dev.	Median	Frequency
Circumference	Head Circumference	10.50	50.00	60.50	55.42	1.48	2.203	55.40
	Neck Circumference	15.50	28.00	43.50	31.84	1.78	3.186	31.50
	Neck Base Circumference	18.20	30.00	48.20	37.30	2.24	5.010	37.30
	Chest Circumference	51.80	69.70	121.50	83.54	5.47	29.968	83.00
	Bust Circumference	57.00	67.10	124.10	83.53	6.48	42.050	82.70
	Under Bust Circumference	45.50	60.00	105.50	72.59	5.28	27.903	72.00
	Waist Circumference	57.50	53.50	111.00	70.06	6.84	46.763	69.00
	Waist-Omphalion Circumference	69.20	59.80	129.00	75.42	7.03	49.396	74.50
	Abdominal Circumference	68.30	62.70	131.00	80.86	7.15	51.156	80.30
	Hip Circumference	53.50	77.70	131.20	92.00	5.38	28.903	91.50
	Armscye Circumference	24.50	29.00	53.50	37.18	2.93	8.559	37.00
	Truck Circumference	51.70	130.20	181.90	148.20	6.40	40.982	147.80
	Thigh Circumference	37.20	42.50	79.70	54.60	4.22	17.784	54.30
	Midthigh Circumference	38.70	37.70	76.40	48.65	4.35	18.915	48.20
	Knee Circumference	19.90	28.60	48.50	35.09	2.21	4.899	35.00
	Low Knee Circumference	17.20	26.30	43.50	32.52	2.07	4.290	32.40
	Calf Circumference	21.00	28.10	49.10	34.48	2.54	6.451	34.20
	Minimum Leg Circumference	8.80	16.70	25.50	20.68	1.22	1.478	20.60
	Ankle Circumference	9.50	19.20	28.70	23.23	1.14	1.293	23.20
	Upper Arm Circumference	22.40	18.80	41.20	25.37	2.52	6.369	25.10
	Elbow Circumference	15.30	20.00	35.30	24.40	1.73	2.998	24.20
	Wrist Circumference	5.70	12.30	18.00	14.50	0.76	0.571	14.50
Length	Waist Front Length	19.60	26.40	46.00	33.94	2.35	5.512	33.90
	Waist Front- Omphalion Length	16.90	31.30	48.20	38.03	2.16	4.676	37.90
	Interscye Front Length	25.00	20.50	45.50	31.96	1.94	3.761	32.00
	Interscye Fold Front Length	23.40	20.60	44.00	32.08	2.42	5.876	32.00
	B.P to B.P	19.30	11.70	31.00	17.37	1.65	2.718	17.30
	Shoulder Length	8.70	8.50	17.20	12.14	1.24	1.535	12.05
	Scye Depth	14.70	10.20	24.90	16.83	1.67	2.785	16.80
	Back Waist Length	18.10	30.30	48.40	39.22	2.26	5.109	39.20
	Back Waist-Omphalion Length	18.10	35.40	53.50	43.30	2.37	5.615	43.20
	Cervical to Knee Hollow Length	28.10	84.90	113.00	96.88	3.61	13.061	96.80
	Total Length	39.90	121.40	161.30	138.57	4.95	24.526	138.40
	Vertical Trunk Length	19.00	54.80	73.80	63.25	2.70	7.308	63.10
	Body Rise	19.30	16.60	35.90	25.57	2.51	6.288	25.60
	Thigh Vertical Length	16.90	19.80	36.70	28.18	2.09	4.372	28.20
	Biacromion Length	16.50	31.00	47.50	39.27	2.21	4.867	39.20
	Interscye Back Length	18.50	27.50	46.00	36.50	2.26	5.120	36.50
	Interscye Fold Back Length	22.00	26.00	48.00	34.80	2.59	6.706	34.70
	Cervical to B.P	22.60	26.00	48.60	33.22	2.25	5.047	33.00
	Cervical to Waist Line	21.50	40.50	62.00	49.44	2.76	7.594	49.30
	S.N.P to B.P	19.90	18.50	38.40	24.94	2.08	4.311	24.70
	S.N.P to B.P to Waist Line	19.00	34.00	53.00	41.18	2.40	5.765	41.10
	S.N.P to Inferior Scapula Point to Wasit Line	16.10	35.20	51.30	42.14	2.05	4.203	42.00
	Upper Arm Length	16.90	25.70	42.60	31.46	1.63	2.657	31.40
	Arm Length	16.70	46.50	63.20	54.21	2.52	6.365	54.10
	Lower Arm Length	16.90	36.10	53.00	44.26	2.77	7.649	44.15
	Cervical to Wrist	23.80	64.00	87.80	76.18	3.30	10.871	76.10
	Waist to Hip	28.50	10.50	39.00	20.20	2.79	7.770	20.00
	Outside Leg Length	30.60	87.10	117.70	99.52	4.16	17.323	99.30
	Total Crotch Length	42.40	56.00	98.40	69.38	4.74	22.502	69.00
	Total Crotch- Omphalion Length	35.70	47.50	83.20	61.18	3.91	15.254	61.00

Table 3. Continued

Measurement Items		Total (N=2814)						
		Range	Min.	Max	Mean	St Dev.	Median	Frequency
Breadth	Chest Breadth	16.30	20.50	36.80	27.37	1.69	2.858	27.20
	Bust Breadth	16.80	21.90	38.70	26.65	1.82	3.298	26.40
	Waist Breadth	18.90	19.30	38.20	24.55	2.26	5.109	24.30
	Waist-Omphalion Breadth	22.50	21.10	43.60	27.05	2.33	5.452	26.90
	Hip Breadth	19.40	25.70	45.10	32.38	1.77	3.128	32.30
	Biacrominal Breadth	11.90	29.80	41.70	35.59	1.70	2.887	35.60
Depth	Armscye Depth	10.10	5.90	16.00	9.54	1.21	1.460	9.40
	Chest Depth	15.00	13.00	28.00	18.05	1.67	2.795	17.90
	Bust Depth	21.50	14.60	36.10	20.81	2.25	5.063	20.60
	Waist Depth	23.50	12.80	36.30	17.35	2.21	4.866	17.00
	Waist-Omphalion Depth	21.70	13.20	34.90	17.97	2.25	5.081	17.60
	Hip Depth	17.10	15.30	32.40	21.11	1.92	3.682	20.90
Angle	Right Shoulder Angle	28.00	5.00	33.00	20.23	4.26	18.124	20.00
	Left shoulder Angle	30.00	5.00	35.00	19.14	4.26	18.179	20.00
Weight	Weight	72.40	38.00	110.40	54.33	7.81	61.043	53.10
Index	Rohrer's index	1.82	0.89	2.71	1.32	0.18	0.032	1.29
	BMI	28.60	14.70	43.30	21.14	2.74	7.512	20.70

Table 4. Height Item Comparison Result (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test	Duncan Test
		M	SD	M	SD	M	SD		
Height	Stature	160.09	5.20	160.11	5.32	160.57	4.96	2.514	
	Cervical Height	136.13	4.76	135.53	5.03	136.12	4.67	4.967**	a b a
	Acromion Height	129.20	4.67	128.56	4.82	129.53	4.60	10.468***	a b a
	Shoulder Height	130.24	4.70	130.15	4.83	130.57	4.58	2.121	
	Axilla Height	119.46	4.46	118.36	4.61	118.93	4.38	14.499***	a c b
	Elbow Height	97.94	3.74	97.33	3.82	97.87	3.69	7.672***	a b a
	Hip Height	78.20	3.69	79.68	3.79	79.47	3.74	42.882***	b a a
	Waist Height	99.78	4.05	97.35	3.97	96.98	3.93	133.064***	a b c
	Waist-Omphalion Ht.	94.09	3.91	94.07	3.97	93.78	3.86	1.742	
	ASIS Height	86.28	3.83	87.33	4.06	87.01	3.77	18.235***	b a a
	Knee Height	40.93	2.12	41.48	2.24	41.46	2.27	18.496***	b a a
	Crotch Height	72.43	3.48	72.85	3.55	73.64	3.28	28.228***	c b a
	Lateral Malleolus Ht.	6.24	0.48	6.27	0.45	6.35	0.44	13.692***	b b a
	Bust Height	114.53	4.65	113.85	4.66	114.47	4.48	6.536***	a b a
Calculation Items	Shoulder Ht.-Waist Ht.	30.46	2.01	32.80	1.99	33.60	2.08	585.826***	c b a
	Shoulder Ht.-Bust Ht.	15.71	2.32	16.30	2.07	16.11	2.01	18.590***	b a a
	Bust Ht.-Waist Ht.	14.75	2.06	16.50	1.93	17.49	1.94	443.533***	c b a
	Waist Ht.-Hip Ht.	21.58	2.13	17.66	1.98	17.51	1.67	1298.274***	a b b
	Cervical Ht./Stature	0.85	0.01	0.85	0.01	0.85	0.01	67.752***	a c b
	Shoulder Ht./Stature	0.81	0.01	0.81	0.01	0.81	0.01	2.554	
	Axilla Ht./Stature	0.75	0.01	0.74	0.01	0.74	0.01	133.031***	a c b
	Bust Ht./Stature	0.72	0.01	0.71	0.01	0.71	0.01	27.290***	a c b
	Waist Ht./Stature	0.62	0.01	0.61	0.01	0.60	0.01	777.915***	a b c
	Hip Ht. /Stature	.0.49	0.01	0.50	0.01	0.49	0.01	110.932***	c b a
	(Shoulder Ht-Bust Ht.)/ (Shoulder Ht.-Waist Ht.)	0.52	0.06	0.50	0.05	0.48	0.05	92.456***	a b c
	(Bust Ht.-Waist Ht.) / (Shoulder Ht.-Waist Ht.)	0.48	0.06	0.50	0.05	0.52	0.05	92.310***	c b a
	(Waist Ht.-Hip Ht.) / (Shoulder Ht.-Waist Ht.)	0.71	0.09	0.54	0.07	0.52	0.06	1758.121***	a b c

*p<.05, **p<.01, ***p<0.01

Table 5. Circumference Item Comparison Results (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test	Duncan Test
		M	SD	M	SD	M	SD		
Circumference	Head Circum.	54.93	1.42	55.48	1.43	55.84	1.47	91.929***	c b a
	Neck Circum.	.	.	31.31	1.48	32.45	1.91	-14.406***	
	Neck Base Circum.	36.60	2.09	38.00	2.04	37.19	2.36	101.842***	c a b
	Chest Circum.	82.29	5.22	83.32	5.09	85.11	5.79	63.191***	c b a
	Bust Circum.	82.79	6.12	83.36	6.19	84.49	7.06	15.980***	b b a
	Under Bust Circum.	72.05	4.99	72.41	5.03	73.35	5.77	14.640***	b b a
	Waist Circum.	68.20	6.27	70.10	6.30	71.94	7.46	70.275***	c b a
	Waist-Omphalion Circum.	74.77	6.68	74.77	6.52	76.85	7.71	26.915***	b b a
	Abdominal Circum.	.	.	80.36	6.67	81.44	7.64	-3.262**	
	Hip Circum.	91.34	4.92	91.68	5.00	93.07	6.06	26.603***	b b a
	Armscye Circum.	36.46	2.84	36.82	2.48	38.33	3.14	110.898***	c b a
	Truck Circum.	148.08	6.21	148.99	6.23	147.41	6.69	14.897***	b a c
	Thigh Circum.	53.91	4.21	54.82	3.88	55.05	4.50	18.658***	b a a
	Midthigh Circum.	47.47	4.02	48.61	4.03	49.90	4.68	72.968***	c b a
	Knee Circum.	34.80	2.28	35.09	2.10	35.40	2.24	16.651***	c b a
	Low Knee Circum.	32.19	2.06	32.49	1.99	32.91	2.12	27.796***	c b a
	Calf Circum.	34.11	2.45	34.61	2.44	34.71	2.70	14.537***	b a a
	Minimum Leg Circum.	20.60	1.26	20.73	1.21	20.71	1.18	3.313*	b a a
	Ankle Circum.	23.33	1.17	23.19	1.10	23.17	1.15	5.050*	a b b
	Upper Arm Circum.	25.61	2.56	25.09	2.26	25.44	2.74	10.662***	a b a
	Elbow Circum	24.53	1.87	24.49	1.55	24.16	1.76	12.436***	b b a
	Wrist Circum.	14.59	0.79	14.64	0.71	14.26	0.71	72.106***	a a b
Calculation Items	Chest Circum. -Waist Circum.	-0.50	2.77	-0.04	2.64	0.62	2.79	38.098***	c b a
	Bust Circum. -Waist Circum.	14.59	3.17	13.26	3.48	12.54	3.69	81.486***	a b c
	Hip Circum. -Waist Circum.	23.14	4.40	21.57	4.01	21.13	4.42	55.573***	a b c
	Chest Circum. -Under Bust Circum.	10.74	3.19	10.96	2.73	11.14	3.08	3.882*	b b a

*p<.05, **p<.01, ***p<0.01

F-test results of the yearly measurements showed significant differences in 11 items among 14 items. There was no significant difference in stature, but the 7th data set showed the largest values for the hip, knee and crotch heights, and the 5th data set showed the largest value for the waist height. Coming to the 7th data set, it shows generally high values in the height items.

Looking at the proportion of vertical items to the stature, there was no significant difference in shoulder height; however, there were significant differences in axilla height, bust height and hip height. The proportions of the height difference in each part are as follows: the 5th data set has low hip position, the 6th data set has an ideal ratio, and the 7th data set has high hip position.

The circumference items showed significant differences in all data sets. The 7th data had the largest values for almost all circumference items, and the 7th data had the smallest values for only the ankle and wrist circumferences. It was analyzed that major parts such as bust, waist, and hip circumference were larger than before. Looking at the drop dimensions to see the silhouette of the bust and hip based on the waist, the 5th data had the largest dimensions, followed by the 6th and 7th, respectively. Although the bust circumference became thicker in the order of 5th, 6th and 7th data

sets, the waist and hip circumference gradually become thicker compared to the bust circumference. Thus it is understood that the curvature of the body became smaller with year.

Table 6. Length Item Comparison Result (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test/ T-test	Duncan Test
		M	SD	M	SD	M	SD		
Length	Waist Front Lgth.	32.36	2.09	34.19	1.91	35.26	2.12	466.845***	c b a
	Waist Front-Omphalion Lgth.	38.05	1.99	37.53	2.08	38.60	2.29	60.217***	b c a
	Interscye Front Lgth.	32.24	2.03	31.51	1.94	32.18	1.74	44.075***	a b a
	Interscye Fold Front Lgth.	31.51	2.30	32.90	2.43	31.73	2.29	98.687***	c a b
	B.P to B.P Lgth.	17.33	1.77	17.65	1.40	17.08	1.73	28.911***	b a c
	Shoulder Lgth.	12.80	1.14	12.07	1.27	11.52	.93	291.512***	a b c
	Scye Depth	17.02	1.54	16.53	1.71	16.99	1.70	26.810***	a b a
	Back Waist Lgth.	38.23	2.20	39.13	2.12	40.35	1.96	230.513***	c b a
	Back Waist-Omphalion Lgth.	43.69	2.22	42.48	2.34	43.87	2.29	106.670***	a b a
	Cervical to Knee Hollow Lgth.	96.86	3.57	97.31	3.66	96.41	3.54	14.805***	b a c
	Total Lgth.	138.20	4.97	138.54	5.17	138.98	4.64	5.598***	b ba a
	Vertical Trunk Lgth.	63.70	2.63	63.51	2.71	62.47	2.60	55.604***	a a b
	Body Rise	27.34	2.10	25.91	1.79	23.34	1.87	1001.950***	a b c
	Thigh Vertical Lgth.	27.72	2.16	28.36	2.10	28.47	1.92	35.090***	a a b
	Biacromion Lgth.	39.66	2.35	38.89	2.22	39.31	1.94	30.306***	a c b
	Interscye Back Lgth.	36.40	2.34	36.40	2.40	36.73	1.99	6.460**	b b a
	Interscye Fold Back Lgth.	34.45	2.53	34.94	2.66	35.01	2.53	12.497***	b a a
	Cervical to B.P	32.82	2.16	33.61	2.19	33.17	2.32	30.295***	c a b
	Cervical to Waist Line	47.47	2.38	50.12	2.36	50.68	2.43	466.399***	c b a
	S.N.P to B.P	25.20	2.15	25.06	1.95	24.53	2.08	26.343***	a a b
	S.N.P to B.P to Waist Line	39.95	2.25	41.56	2.26	42.02	2.20	214.378***	c b a
	S.N.P to Inferior Scapula Point to Waist Line	.	.	41.92	2.07	42.39	2.00	-5.032***	
	Upper Arm Lgth.	30.85	1.50	31.56	1.74	31.96	1.42	115.181***	c b a
	Arm Lgth.	53.41	2.40	54.25	2.56	54.99	2.35	94.038***	c b a
	Lower Arm Lgth.	43.80	2.45	43.98	2.67	45.07	3.00	57.718***	b b a
	Cervical to Wrist	75.89	3.39	76.38	3.29	76.23	3.19	5.547**	b a a
	Waist to Hip	22.88	2.45	18.77	2.01	19.09	1.71	1124.412***	a c b
	Outside Leg Lgth.	100.69	4.25	99.41	4.09	98.44	3.82	69.344***	a b c
	Total Crotch Lgth.	72.45	4.47	69.22	3.78	66.39	4.01	493.014***	a b c
	Total Crotch-Omphalion Lgth.	61.23	3.88	62.59	3.53	59.48	3.68	168.239***	a b c
Calculation Items	Back Waist Lgth. - Waist Front Lgth.	5.87	1.88	4.94	1.75	5.09	1.95	67.203***	a b b
	Interscye Back Lgth. -Interscye Fron tLgth.	4.16	2.62	4.89	2.25	4.55	1.98	23.936***	c a b
	S.N.P to Inferior Scapula Point to Waist Line-S.N.P to B.P to Waist Line	.	.	0.36	1.96	0.37	1.94	-0.176	

*p<.05, **p<.01, ***p<0.01

The length items showed a dimensional difference over the years in all parts. The 7th data set showed the largest value in the waist front length and the waist back length. The shoulder length became shorter with the years in the order of 5th, 6th, and 7th data sets. The 7th data had the shortest value in the S.N.P to B.P length and, the B.P to B.P length. For the arm and related items, the upper arm to the lower arm length increased with year in all data sets, showing the largest value in the 7th data set. The total crotch length became shorter with year in the order of 5th, 6th, and 7th data sets.This shows that the length between the waist and hip became shorter as seen from the height item.

The 5th data set was statistically recognized as the largest in terms of difference in the items related to waist front and waist back, and values in the 6th and 7th data sets were similar. In the difference between the length of interscye back and interscye front, the 6th data showed the largest value, and the 5th data showed the smallest value. In other words, length of the back center became gradually shorter than the front center, and length of the interscye front widened. Therefore, the body shape can be seen to be somewhat deteriorated.

All breadth items showed dimensional differences over the years. The 5th data set had the largest value in bust breadth, and the 7th data set had the largest value in hip breadth. Looking at the ratio of body breadth to waist breadth, all items were the largest in the 5th data set, and the ratio became smaller in the order of 6th and 7th data sets. In other words, the bust breadth and hip breadth become relatively smaller as the waist breadth increases gradually. It is analyzed that the curvature of body decreases gradually as seen from the results of the circumference items.

All of the depth items showed dimensional differences over the years. The 7th data set showed the largest value in all items related to bust, waist, and hip. The body depth ratio based on waist depth showed the largest value in the 5th data set, followed by the 7th and the 6th in order. However, the difference between the actual measurements is insignificant and the visual difference is not significant.

In the flatness items, the 7th data set shows the largest values of bust flatness. This is considered to show the largest value of bust protrusion compared to bust breadth. Waist flatness showed the largest value in the 5th data set, followed by the 6th and 7th in order. That is, it was analyzed that the waist area gradually changed into a flat body shape. In other words, it is analyzed that it takes a round shape from the upper body toward the lower body.

Table 7. Breadth Item Comparison Result (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test	Duncan Test
		M	SD	M	SD	M	SD		
Breadth	Chest Breadth	27.33	1.73	27.15	1.74	27.68	1.53	24.128***	b c a
	Bust Breadth	27.02	1.86	26.20	1.67	26.79	1.83	54.602***	a c b
	Waist Breadth	23.89	1.99	24.39	2.11	25.42	2.42	114.761***	a b c
	Waist-Omphalion Breadth	27.13	2.21	26.48	2.20	27.65	2.45	63.600***	b c a
	Hip Breadth	32.39	1.64	32.21	1.70	32.58	1.94	10.180***	b c a
	Biacrominal Breadth	35.95	1.72	35.19	1.76	35.70	1.50	52.702***	a c b
Calculation	Chest Breadth / Waist Breadth	1.15	0.07	1.12	0.07	1.09	0.07	129.264***	a b c
	Bust Breadth / Waist Breadth	1.13	0.05	1.08	0.06	1.06	0.06	448.689***	a b c
	Hip Breadth / Waist Breadth	1.36	0.09	1.33	0.09	1.29	0.08	161.490***	a b c

*p<.05, **p<.01, ***p<0.01

Table 8. Depth Item Comparison Result (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test	Duncan Test
		M	SD	M	SD	M	SD		
Depth	Armscye Depth	9.30	1.19	9.47	1.20	9.87	1.17	54.422***	c b a
	Chest Depth	17.93	1.57	17.80	1.66	18.45	1.71	40.339***	b b a
	Bust Depth	20.82	2.11	20.54	2.24	21.10	2.36	14.467***	b c a
	Waist Depth	17.64	2.14	16.83	1.95	17.66	2.43	46.697***	a b a
	Waist-Omphalion Depth	18.06	2.10	17.37	1.98	18.57	2.52	71.538***	b c a
	Hip Depth	20.95	1.92	21.03	1.72	21.37	2.10	12.540***	b b a
Calculation Items	Chest Depth/ Waist Depth	1.02	0.09	1.06	0.09	1.05	0.09	50.127***	c a b
	Bust Depth/ Waist Depth	1.19	0.08	1.22	0.09	1.20	0.09	45.857***	c a b
	Hip Depth/ Waist Depth	1.20	0.10	1.26	0.09	1.22	0.09	112.348***	c a b
Flatness	Bust Depth/ Bust Breadth	0.77	0.05	0.78	0.06	0.79	0.06	20.511***	b a a
	Waist Depth/ Waist Breadth	0.74	0.05	0.69	0.05	0.69	0.05	246.840***	a b b
	Hip Depth/ Hip Breadth	0.65	0.05	0.65	0.04	0.66	0.04	8.084***	b a a

*p<.05, **p<.01, ***p<0.01

Table 9. Angle and Other Items Comparison Result (Unit : cm)

Measurement Items		5th (N=907)		6th (N=1027)		7th (N=880)		F-test/T-tes	Duncan Test
		M	SD	M	SD	M	SD		
Angle	Right Shoulder Angle	.	.	20.50	4.25	19.92	4.24	2.974**	
	Left shoulder Angle	.	.	19.03	4.30	19.27	4.22	-1.228	
Other	Weight	54.00	7.15	53.50	7.32	55.65	8.80	19.295***	b b a
	Rohrer'sIndex,	1.32	0.17	1.30	0.16	1.34	0.20	12.384***	b b a
	BMI	21.04	2.57	20.85	2.51	21.56	3.10	16.864***	b b a

*p<.05, **p<.01, ***p<0.01

Angle items were not measured for the 5th data set. Therefore, the 6th and 7th data were compared. The difference in angle is not large, but overall the right shoulder is judged to be dropped than the left shoulder. Obesity-related indexes such as Rohrer's Index and BMI showed the largest values in 7th data set. However, Rohrer's Index values were all in 1.30 range, and BMI values all in 21 range, showing that the degree of obesity is all normal.

3. Changes in Body Shape of Korean Women in Their 20's over the Past 10 Years

Based on the analysis, the body shape of Korean women in their 20's showed little change in stature over 10 years; however, body weight increased and major parts such as bust, waist, and hip circumference became larger than before. In terms of the height and length items, hip height increases gradually, vertical length of hip decreases

gradually, and the vertical length of thigh becomes longer. Among the circumference items, all the circumference values increased, but the differences in circumference between bust and waist and between waist and hip decreased. Thus the curvature of body decreased gradually. The same trend was also observed in the flatness items: bust flatness showed a gradually increasing trend, while flatness of the waist decreased gradually. Length items became generally larger, but shoulder length became shorter. As the length difference between the back center and the front center became shorter and the length difference between the interscye of back and front became longer, the body shape can be seen to have become somewhat backward. On the shoulder angle part, the right shoulder drooped more than the left shoulder. Obesity indices, including Rohrer's Index and BMI

Table 10. The 6th and 7th Descriptive Statistics Body Measurement of Korean Women in their 20's (Unit:cm)

Measurement Items		Total (N=1822)						
		Range	Min.	Max	Mean	St Dev.	Median	Frequency
Height	Stature	32.50	145.20	177.70	160.30	5.07	25.69	160.40
	Cervical Height(straight)	31.70	121.50	153.20	135.76	4.80	23.07	135.80
	Acromion Height	29.60	114.70	144.30	128.95	4.66	21.73	129.00
	Shoulder Height	29.80	116.40	146.20	130.29	4.64	21.51	130.30
	Axilla Height	29.50	104.00	133.50	118.61	4.43	19.63	118.60
	Elbow Height	23.80	86.20	110.00	97.53	3.69	13.64	97.50
	Hip Height	25.70	65.50	91.20	79.57	3.72	13.86	79.50
	Waist Height	25.10	84.60	109.70	97.18	3.90	15.19	97.10
	Waist-Omphalion Height	25.80	81.70	107.50	93.97	3.85	14.82	93.90
	Anterior-Superior Iliac Spine Height	27.70	73.10	100.80	87.21	3.88	15.05	87.20
	Knee Height	15.50	34.00	49.50	41.46	2.22	4.95	41.40
	Crotch Height	22.20	62.30	84.50	73.25	3.40	11.53	73.20
	Lateral Malleolus Height	3.70	4.80	8.50	6.31	0.44	0.20	6.30
	Bust Height	28.60	100.70	129.30	114.16	4.50	20.25	114.10
Circumference	Head Circumference	9.70	50.80	60.50	55.60	1.43	2.05	55.50
	Neck Circumference	15.50	28.00	43.50	31.73	1.64	2.68	31.50
	Neck Base Circumference	15.60	30.00	45.60	37.52	2.15	4.60	37.50
	Chest Circumference	33.30	69.70	103.00	83.70	4.78	22.82	83.30
	Bust Circumference	37.10	67.10	104.20	83.32	5.70	32.51	83.00
	Under Bust Circumference	30.00	60.00	90.00	72.36	4.58	20.97	72.00
	Waist Circumference	37.90	56.50	94.40	70.32	5.78	33.46	69.85
	Waist-Omphalion Circumference	38.10	60.10	98.20	75.08	5.95	35.42	74.60
	Abdominal Circumference	39.90	62.70	102.60	80.27	6.13	37.59	80.10
	Hip Circumference	30.90	79.10	110.00	91.89	4.81	23.14	91.70
	Armscye Circumference	18.30	30.50	48.80	37.32	2.58	6.67	37.10
	Truck Circumference	44.10	131.60	175.70	147.87	6.01	36.17	147.60
	Thigh Circumference	24.70	43.30	68.00	54.61	3.63	13.17	54.50
	Midthigh Circumference	29.30	38.80	68.10	48.87	3.79	14.39	48.60
	Knee Circumference	13.00	29.90	42.90	35.09	1.95	3.80	35.00
	Low Knee Circumference	14.40	26.70	41.10	32.55	1.87	3.50	32.40
	Calf Circumference	15.20	28.10	43.30	34.48	2.28	5.18	34.30
	Minimum Leg Circumference	8.30	17.20	25.50	20.66	1.13	1.28	20.60
	Ankle Circumference	7.10	19.60	26.70	23.14	1.08	1.17	23.10
	Upper Arm Circumference	12.90	19.90	32.80	25.06	2.13	4.56	24.90
	Elbow Circumference	12.00	20.00	32.00	24.23	1.51	2.28	24.20
	Wrist Circumference	4.60	12.40	17.00	14.42	0.70	0.48	14.40

Table 10. Continued

Measurement Items		Total (N=1822)						
		Range	Min.	Max	Mean	St Dev.	Median	Frequency
Length	Waist Front Length	13.40	29.10	42.50	34.60	2.00	4.01	34.50
	Waist Front-Omphalion Length	13.10	31.50	44.60	37.90	2.11	4.44	37.80
	Interscye Front Length	12.50	25.60	38.10	31.73	1.79	3.19	31.80
	Interscye Fold Front Length	14.60	25.30	39.90	32.22	2.31	5.33	32.10
	B.P to B.P	11.90	11.70	23.60	17.31	1.53	2.33	17.30
	Shoulder Length	7.00	8.50	15.50	11.80	1.16	1.34	11.80
	Scye Depth	14.70	10.20	24.90	16.72	1.70	2.88	16.75
	Back Waist Length	15.20	33.20	48.40	39.64	2.11	4.45	39.50
	Back Waist- Omphalion Length	15.10	35.40	50.50	43.03	2.34	5.46	43.00
	Cervical to Knee Hollow Length	24.90	84.90	109.80	96.83	3.59	12.89	96.80
	Total Length	34.60	123.90	158.50	138.67	4.86	23.67	138.70
	Vertical Trunk Length	19.00	54.80	73.80	62.96	2.66	7.07	62.80
	Body Rise	14.50	16.60	31.10	24.70	2.21	4.88	24.70
	Thigh Vertical Length	15.30	21.40	36.70	28.42	2.01	4.04	28.30
	Biacromion Length	16.50	31.00	47.50	39.02	2.07	4.31	39.0
	Interscye Back Length	15.70	28.90	44.60	36.46	2.16	4.67	36.50
	Interscye Fold Back Length	16.70	27.80	44.50	34.83	2.45	6.01	34.80
	Cervical to B.P	14.70	28.00	42.70	33.25	2.02	4.09	33.10
	Cervical to Waist Line	17.00	44.40	61.40	50.25	2.29	5.26	50.10
	S.N.P to B.P	14.40	19.10	33.50	24.68	1.83	3.33	24.50
	S.N.P to B.P to Waist Line	16.60	34.50	51.10	41.66	2.15	4.64	41.50
	S.N.P to Inferior Scapula Point to Wasit Line	16.10	35.20	51.30	42.07	2.00	4.02	42.00
	Upper Arm Length	10.50	27.00	37.50	31.72	1.59	2.53	31.60
	Arm Length	15.40	47.80	63.20	54.56	2.47	6.08	54.50
	Lower Arm Length	16.10	36.90	53.00	44.49	2.85	8.13	44.30
	Cervical to Wrist	23.80	64.00	87.80	76.24	3.22	10.37	76.10
	Waist to Hip	14.10	12.40	26.50	18.92	1.84	3.40	18.95
	Outside Leg Length	24.50	87.50	112.00	98.96	3.94	15.54	98.90
	Total Crotch Length	28.60	56.00	84.60	67.73	3.92	15.38	67.50
	Total Crotch-Omphalion Length	29.60	47.50	77.10	61.03	3.77	14.25	61.00
Bradth	Chest Breadth	10.40	22.80	33.20	27.29	1.53	2.34	27.20
	Bust Breadth	11.50	21.90	33.40	26.33	1.55	2.39	26.30
	Waist Breadth	13.40	19.40	32.80	24.67	1.99	3.96	24.50
	Waist-Omphalion Breadth	13.70	21.10	34.80	26.82	2.07	4.28	26.70
	Hip Breadth	14.80	25.70	40.50	32.27	1.67	2.79	32.20
	Biacrominal Breadth	11.40	29.80	41.20	35.36	1.62	2.64	35.40
Depth	Armscye Depth	7.20	6.30	13.50	9.58	1.09	1.20	9.50
	Chest Depth	10.40	13.00	23.40	17.98	1.54	2.38	17.90
	Bust Depth	13.00	14.60	27.60	20.62	2.04	4.15	20.50
	Waist Depth	10.80	12.80	23.60	17.00	1.80	3.26	16.80
	Waist-Omphalion Depth	11.80	13.20	25.00	17.71	1.91	3.66	17.50
	Hip Depth	11.90	15.30	27.20	21.03	1.64	2.67	21.00
Angle	Right Shoulder Angle	28.00	5.00	33.00	20.30	4.23	17.93	20.00
	Left shoulder Angle	29.00	6.00	35.00	19.17	4.26	18.11	20.00
Weight	Weight	50.60	38.40	89.00	53.77	6.69	44.79	53.20
Index	Rohrer's index	0.68	1.01	1.69	1.31	0.15	0.02	1.29
	BMI	13.20	16.10	29.30	20.91	2.23	4.98	20.70

increased on account of the increase in body weight, but the degree of obesity is considered normal.

4. Extraction of Body Shape Change Factors by Factor Analysis

The analysis is based on the 6th and 7th data sets, which offer comparatively recent information among all the data without the missing measurement items. Based on Rohrer's Index, a total of 1,822 cases were analyzed after removing cases with index values less than 1.0 and more than 1.7. The results of statistical analysis are shown in the following Table 10.

Since it was not feasible to conduct factor analysis for all the measurement items, the analysis was performed on 50 major items indicating human body characteristics. 10 factors were extracted in the first factor analysis, but 4 factors were selected considering the screen-test result, and rotated orthogonally by Varimax method. The results of the factor analysis are shown in Table 11. 4 Factors constituting the body shape were extracted with a cumulative rate of 70.177%.

The characteristics of the 4 extracted factors are as follows.

Factor 1

It can be said to be a factor indicating 'the degree of obesity' by high load in all breadth, depth and circumference items. It has the greatest value among the 4 factors; the total value is 16.69 and the variance explanation power is 33.38.

Factor 2

It can be said to be a factor indicating 'the vertical length of the body' since it is highly loaded on all height items and vertical length items. If the value of this factor is high, it can be seen as a large body vertically. The total value is 11.640 and variance explanation power is 23.279.

Factor 3

This factor represents the total crotch length,waist to hip length, and the body rise etc. It can be said that this factor represents the specifications from the waist to the hip. The total value is 3.798 and variance explanation power is 7.595.

Factor 4

The factor 4 includes items such as shoulder angle, shoulder breadth and length, interscye front and back length etc. This factor explains the degree of tilting of the shoulders, and size and shape of the shoulder and shoulder parts. The total value is 2.961 and variance explanation power is 5.923.

5. Cluster Analysis

In order to better express body characteristics, we grouped them into similar body shapes by cluster analysis. There are various clustering methods, but the K-means Clustering Method was used in this study. This technique aims at partitioning the data into a specific number of clusters, defined a priori by the user, by minimizing the variations within-clusters.

In this study, the 4 factors extracted from the factor analysis were classified into 7 clusters by the K-means Clustering Method. The final modified cluster center table is presented in Table 12 below.

In the analysis of variance in Table 13, The cluster mean square caused by any of the 4 factor scores is much larger than the error mean square within the class. From the probability value, the probability that the 4 factor scores are less than 5%. Regardless of which factor scores, the clustering results are clearer and the classification is clear.

The classified groups were named from tall to short in English alphabets Y, A, B based on height. Based on the degree of obesity, from thin to fat was named by the English alphabets S, M, F. Table 14 shows the number of cases and the share of each cluster.

For the total case (1822), 81 items were subjected to multivariate test and the test results are shown in Table 15 below. From the significance of the F test, it can be seen that no matter which test method, the significance probability is less than 5%, that is, the original hypothesis is rejected (that is, there is no significant difference between the 7 body types), so it is concluded that: there are significant differences among the 7 body types. It proves reasonable to classify the entire case into 7 body types.

Table 11. Factor Analysis Results

Items	Factor1	Factor 2	Factor 3	Factor 4	
Waist Circumference	0.901	0.064	-0.018	0.057	0.819
Bust Circumference	0.891	0.080	0.080	0.041	0.808
Chest Circumference	0.890	0.123	0.026	0.152	0.832
Weight	0.882	0.320	0.266	0.073	0.957
Underbust Circumference	0.870	0.110	0.075	0.027	0.776
Waist Depth	0.853	-0.003	0.028	0.000	0.728
Waist Breadth	0.846	0.127	-0.135	0.086	0.757
Abdominal Circumference	0.840	0.085	0.090	0.037	0.722
Bust Breadth	0.822	0.173	-0.012	0.124	0.721
Upperarm Circumference	0.820	-0.016	0.263	0.007	0.741
Hip Depth	0.818	0.011	0.253	0.053	0.736
Bust Depth	0.817	0.006	0.057	-0.015	0.671
Midthigh Circumference	0.812	0.011	0.249	0.002	0.722
Hip Circumference	0.805	0.184	0.304	0.091	0.782
Armscye Circumference	0.801	0.134	0.028	-0.032	0.661
Thigh Circumference	0.798	0.062	0.366	-0.030	0.776
Armscye Depth	0.754	-0.053	0.032	0.114	0.585
Chest Depth	0.746	0.024	0.013	0.045	0.559
Calf Circumference	0.717	0.120	0.385	0.036	0.678
Chest Breadth	0.672	0.248	-0.024	0.206	0.556
Knee Circumference	0.668	0.256	0.360	0.020	0.641
Neck Circumference	0.668	0.143	-0.049	0.146	0.490
Hip Breadth	0.660	0.268	0.238	0.115	0.577
Elbow Circumference	0.616	0.144	0.407	0.025	0.566
Minimum Leg Circumference	0.501	0.327	0.353	0.106	0.494
Wrist Circumference	0.499	0.179	0.495	0.092	0.535
Crotch Height	0.046	0.944	-0.124	0.053	0.911
Shoulder Height	0.189	0.936	0.192	-0.025	0.949
Axilla Height	0.106	0.934	0.164	-0.004	0.910
Cervical Height(straight)	0.159	0.930	0.214	0.119	0.950
Waist Height	0.077	0.928	0.235	0.072	0.928
Stature	0.149	0.925	0.211	0.116	0.936
Bust Height	0.049	0.921	0.153	0.050	0.877
Hip Height	0.037	0.904	0.020	0.060	0.822
Anterior-Superior Iliac Spine Ht.	0.094	0.899	0.088	0.104	0.836
Outside Leg Length	0.112	0.885	0.291	0.068	0.885
Knee Height	0.022	0.822	0.038	0.081	0.684
Arm Length	0.268	0.792	-0.033	-0.006	0.700
Total Length	0.151	0.744	0.423	0.091	0.764
Body Rise	0.004	0.153	0.802	0.076	0.672
Total Crotch Length	0.381	0.210	0.743	0.018	0.742
Vertical Trunk Length	0.196	0.441	0.641	0.176	0.675
Waist to Hip	0.125	0.215	0.413	0.023	0.232
Biacromion Length	0.357	0.255	0.023	0.734	0.731
Shoulder Length	-0.025	0.165	0.281	0.668	0.553
Biacrominal Breadth	0.371	0.333	-0.017	0.656	0.680
Interscye Back Length	0.415	0.209	0.057	0.615	0.598
Right Shoulder Angle	-0.122	-0.078	0.069	0.563	0.343
Left shoulder Angle	-0.048	-0.112	-0.041	0.556	0.326
Interscye Front Length	0.406	0.293	0.001	0.495	0.497
Total	16.690	11.640	3.798	2.961	
% of Variance	33.380	23.279	7.595	5.923	
Cumulative %	33.380	56.659	64.254	70.177	

Table 12. The Final Cluster Centers

	Cluster						
	1	2	3	4	5	6	7
Factor1	43.54	38.42	39.98	38.84	43.52	42.16	40.23
Factor2	104.87	94.03	98.99	98.63	99.79	95.91	102.54
Factor3	46.49	41.51	44.91	41.96	45.03	42.80	43.79
Factor4	28.46	26.67	26.47	27.53	28.70	27.87	27.99

Table 13. ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
F1	1120.786	6	2.130	1815	526.240	0.000
F2	3205.422	6	2.312	1815	1386.240	0.000
F3	759.353	6	2.226	1815	341.180	0.000
F4	163.936	6	2.081	1815	78.765	0.000

Table 14. Number of Case in Each Cluster

Height / Obesity	Y (Tall)				A (Middle)				B(Short)			
	Cluster	Body Type	Case	Share (%)	Cluster	Body type	Case	Share (%)	Cluster	Body Type	Case	Share (%)
S(Thin)	7	YS	313	17.1%	4	AS	325	17.8%				
M(Normal)	1	YM	183	10.4%	3	AM	205	11.2%	2	BM	246	13.5%
F(Fat)					5	AF	263	14.4%	6	BF	287	15.7%

Table 15. Multivariate Test

Effect		Value	F	Hypothesis df	Error df	Sig.
Cluster	Pillai's Trace	2.733	23.181	343.000	12411.000	0.000
	Wilks' Lambda	0.000	184.257	343.000	12270.311	0.000
	Hotelling's Trace	16508.763	84964.090	343.000	12357.000	0.000
	Roy's Largest Root	16502.860	597134.081[b]	49.000	1773.000	0.000

6. Representative Size of Each Body Type

The representative body size of each body type was calculated by referring to the Chinese standards for garments GB /T 1335. 2-2008. According to this standard, upper body items were calculated by applying multiple regression equation to the stature and bust circumference, and the lower body items were calculated by applying multiple regression equation to the stature and waist circumference. First, standard values of the stature, bust, and waist circumference of each body type are presented in Table 16 below. For ease of calculation, numbers after the decimal point were removed.

The multiple regression equation for stature and bust circumference (waist circumference) is as follows.

$y = \beta(h) \times m + \beta(c) \times n + \varepsilon$

Here y is the specific part value, β (h) is the regression coefficient of stature, β (c) is the regression coefficient of the bust circumference (waist circumference), m is the stature value, n is the bust circumference (waist circumference) value, and ε is a constant. Table 17 and Table 18 show the results of the variance analysis of the regression equation for the cervical height among the height items.

Since the correlation coefficient R is close to 1, it can be seen that the linearity is close to the linear relationship between the independent variables (stature, bust circumference) and the dependent variable (cervical height).

Table 16. Reference Body Size by Cluster (Unit:cm)

Item	YM	BM	AM	AS	AF	BF	YS
Stature	168	153	160	159	162	156	165
Bust Circumference	89	79	82	79	89	87	82
Waist Circumference	75	66	68	67	76	74	69

Table 17. Model Summary

Cluster	Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	1	0.930[a]	0.865	0.864	1.0216
2	1	0.879[a]	0.773	0.771	1.1191
3	1	0.874[a]	0.764	0.761	1.0407
4	1	0.855[a]	0.731	0.730	1.0013
5	1	0.854[a]	0.729	0.727	1.0484
6	1	0.879[a]	0.772	0.770	1.0876
7	1	0.800[a]	0.640	0.638	1.1315

a. Prdictors:(Constant), Stature, Bust Circumference

b. Dependent Variable: Cervical Height

Table 18. ANOVA

Cluster No.	Model		Sum of Squares	df	Mean Square	F	Sig.
1	1	Regression	1206.924	2	603.462	578.264	0.000
		Residual	187.843	180	1.044		
		Total	1394.768	182			
2	1	Regression	1038.238	2	519.119	414.494	0.000
		Residual	304.337	243	1.252		
		Total	1342.575	245			
3	1	Regression	707.645	2	353.823	326.669	0.000
		Residual	218.791	202	1.083		
		Total	926.436	204			
4	1	Regression	879.445	2	439.723	438.613	0.000
		Residual	322.815	322	1.003		
		Total	1202.260	324			
5	1	Regression	767.732	2	383.866	349.250	0.000
		Residual	285.770	260	1.099		
		Total	1053.501	262			
6	1	Regression	1137.070	2	568.535	480.636	0.000
		Residual	335.938	284	1.183		
		Total	1473.008	286			
7	1	Regression	706.326	2	353.163	275.853	0.000
		Residual	396.880	310	1.280		
		Total	1103.205	312			

Table 19. Representative Body Size by Body Type (Unit:cm)

Measurement Items		Body Type						
		YM	BM	AM	AS	AF	BF	YS
Height	Stature	168.0	153.0	160.0	159.0	162.0	156.0	165.0
	Cervical Height(straight)	143.2	128.8	135.4	134.6	137.4	131.8	140.2
	Acromion Height	136.1	122.4	128.9	127.6	130.3	125.2	133.2
	Shoulder Height	137.5	123.6	130.4	129.0	131.6	126.4	134.5
	Axilla Height	125.1	112.6	118.6	117.6	119.4	114.9	122.9
	Elbow Height	102.9	92.7	97.8	96.4	98.4	94.7	100.7
	Hip Height	84.3	75.1	79.4	80.9	79.4	76.1	83.5
	Waist Height	103.2	91.9	97.1	96.6	98.1	93.7	100.8
	Waist-Omphalion Height	99.6	88.9	93.6	93.5	94.8	90.4	97.7
	Anterior-Superior Iliac Spine Ht.	92.6	82.2	86.5	86.8	87.9	84.1	90.7
	Knee Height	44.0	39.1	41.0	41.4	41.8	39.7	43.4
	Crotch Height	77.4	69.1	72.1	73.6	73.4	70.3	76.7
	Lateral Malleolus Height	6.6	6.1	6.3	6.2	6.4	6.2	6.5
	Bust Height	120.5	108.3	114.0	113.5	114.9	110.0.	118.6

Based on the AM type, the regression equation of the cervical height is as follows.

$0.784 \times 160 + 0.002 \times 82 + 9.845 = 135.449$

It is relatively close to the original size and displays up to 1 decimal place for convenience of use. The value is 135.4. Regression equation for other items was performed through a similar process, and the sizes are given in Table 19 below.

Table 19. Continued

Measurement Items		Body Type						
		YM	BM	AM	AS	AF	BF	YS
Circumference	Neck Circumference	33.1	30.7	31.1	30.8	33.1	32.2	31.7
	Neck Base Circumference	39.3	36.1	37.7	36.8	38.6	37.4	37.7
	Chest Circumference	88.5	79.8	81.9	80.2	88.4	86.6	82.8
	Bust Circumference	89.0	79.0	82.0	79.0	89.0	87.0	82.0
	Under Bust Circumference	77.0	68.6	71.2	69.0	76.6	75.1	71.4
	Waist Circumference	75.0	66.0	68.0	67.0	76.0	74.0	69.0
	Waist-Omphalion Circum.	80.4	70.4	73.2	71.4	81.0	78.4	73.9
	Abdominal Circumference	85.7	75.8	78.6	76.5	86.3	83.4	78.8
	Hip Circumference	97.2	87.4	90.5	88.4	96.8	93.9	91.4
	Armscye Circumference	39.7	35.4	36.6	35.6	39.4	38.7	37.0
	Thigh Circumference	58.2	51.7	54.3	51.4	58.2	56.1	53.5
	Midthigh Circumference	52.1	46.2	48.0	46.4	52.4	50.9	47.7
	Knee Circumference	37.1	33.3	34.6	33.9	36.8	35.5	35.2
	Low Knee Circumference	34.4	30.9	31.9	31.5	34.0	33.1	32.6
	Calf Circumference	36.8	32.6	34.1	33.0	36.5	35.3	34.0
	Ankle Circumference	24.3	22.1	22.8	22.5	23.9	23.1	23.4
	Upper Arm Circumference	26.9	23.6	24.7	23.5	27.0	26.4	24.5
	Elbow Circumference	25.7	23.0	24.2	23.3	25.4	24.7	24.1
	Wrist Circumference	15.1	13.8	14.5	14.1	14.8	14.6	14.4
Length	Waist Front Length	35.8	33.4	34.2	33.8	35.6	34.8	35.0
	Waist Front-Omphalion Length	39.7	36.3	37.9	36.8	39.0	37.8	38.2
	Interscye Front Length	33.1	30.3	30.8	31.1	32.8	31.8	32.1
	Interscye Fold Front Length	34.0	30.9	32.0	31.1	33.6	32.5	32.2
	B.P to B.P Length	18.1	16.8	17.3	16.6	18.1	17.7	17.1
	Shoulder Length	12.2	11.2	11.6	11.9	12.3	11.6	12.1
	Scye Depth	17.7	15.6	16.4	16.5	17.6	16.5	17.1
	Back Waist Length	41.2	38.	39.2	39.0	40.3	39.4	40.4
	Back Waist-Omphalion Length	45.1	41.0	42.9	42.1	43.9	42.6	43.9
	Vertical Trunk Length	66.1	60.1	64.0	61.4	64.5	61.8	63.9
	Body Rise	26.5	23.6	26.2	23.6	25.6	23.8	24.8
	Thigh Vertical Length	30.2	26.6	27.8	28.4	28.5	27.2	29.9
	Biacromion Length	40.6	37.6	37.7	38.4	40.3	39.1	39.4
	Interscye Back Length	38.0	35.0	35.4	35.8	38.0	36.8	36.8
	Interscye Fold Back Length	36.8	33.3	34.2	33.7	36.5	35.5	34.7
	Cervical to B.P Length	35.0	31.8	33.2	32.0	35.0	33.8	32.9
	S.N.P to B.P Length	26.0	23.7	24.7	23.7	26.1	25.1	24.5
	S.N.P to B.P to Waist Line	43.2	40.1	41.6	40.7	42.9	41.5	42.1
	S.N.P to Inferior Scapula Point to Wasit Line Length	43.9	40.3	41.9	41.5	42.8	41.9	42.7
	Upper Arm Length	33.6	30.1	31.6	31.4	32.1	31.0	32.5
	Arm Length	57.7	51.7	53.9	54.2	55.1	53.1	56.4
	Lower Arm Length	46.9	42.0	43.8	44.6	44.8	42.6	46.6
	Waist to Hip	20.5	17.9	19.6	18.1	19.6	18.4	18.9
	Outside Leg Length	105.1	93.7	98.9	98.1	100.0	95.6	102.5
	Total Crotch Length	72.7	64.4	69.6	64.7	70.4	67.3	67.7
	Total Crotch- Omphalion Length	64.9	58.6	62.2	58.5	63.5	60.8	60.7

Table 19. Continued

Measurement Items		Body Type						
		YM	BM	AM	AS	AF	BF	YS
Bradth	Chest Breadth	28.6	26.0	26.9	26.5	28.5	27.6	27.3
	Bust Breadth	27.8	25.0	25.9	25.3	27.8	27.0	26.2
	Waist Breadth	26.3	23.3	23.8	23.5	26.4	25.9	24.5
	Waist-Omphalion Breadth	28.6	25.1	26.2	25.8	28.7	27.9	26.6
	Hip Breadth	33.9	30.7	31.9	31.2	33.7	32.6	32.5
	Biacrominal Breadth	36.6	34.1	34.5	34.9	36.3	35.2	35.8
Depth	Armscye Depth	10.3	9.1	9.1	8.9	10.4	10.3	9.2
	Chest Depth	19.1	17.2	17.6	17.0	19.2	18.9	17.7
	Bust Depth	22.3	19.5	20.3	19.1	22.4	21.8	20.2
	Waist Depth	18.4	15.8	16.6	15.9	18.6	18.1	16.5
	Waist-Omphalion Depth	19.0	16.6	17.2	16.5	19.3	18.9	17.1
	Hip Depth	22.5	19.8	20.8	19.9	22.7	22.0	20.5

Through the above analysis, there are significant differences among the 7 body types. From the morphological point of view, the features of the 7 body types are as follows.

(1) In the Height items, the height ratio of each part to the stature is similar for all 7 body types. In the upper body length, BM is the shortest and YM is the longest. In the length from shoulder to bust, BM is the shortest and YM is the longest.

(2) In the circumference item, YM and AF are similar, YS and AM are similar, and AS and BM are similar. The circumference difference between the bust and waist and between the hip and waist become smaller in the order of M-F-S type. In other words, the M type is relatively curved, and the S type is relatively less curved.

(3) Most vertical items in the length items are proportional to the stature. The hip vertical length becomes shorter in order of YM-AM-AF-YS-AS-BM-BF, and the total crotch length become shorter in order of YM-AF-AM-YS-BF-AS-BM. AM is relatively long in hip length, and AS is relatively short. The length difference between the front waist and the back waist becomes shorter in order of AS-YM-YS-BF-AM-BM-AF.

(4) In the breadth item, YM and AF are similar, YS and AM are similar, and AS and BM are similar. The ratio of the bust to the waist breadth becomes smaller in order of AM-AS-BM-YS-YM-AF-BF. The ratio of the hip to the waist breadth becomes smaller in order of AM-AS-YS-BM-YM-AF-BF. The AM shows a relatively curved shape.

(5) In terms of depth, the ratio of the bust to the waist depth becomes smaller in order of BM-YS-AM-YM-AS-BF-AF. The ratio of the hip to the waist depth becomes smaller in order of BM-AM-AS-YM-AF-BF. The all flatness becomes smaller in order of F-M-S type. In other words, the S type shows relatively flat shape.

IV. Conclusions

This study focuses on developing 3D avatars for fitting evaluation in the virtual fitting system. As a basic step, we analyzed the change of body shape in Korean women in their 20s and selected representative bodies for the 3D avatar.

1. Based on the survey data of Size Korean conducted three times between 2004 and 2015, we examined the change of body shape over 10 years. It was determined that there was little change of stature over 10 years, body weight increased gradually, and major parts such as bust circumference, waist circumference, and hip circumference became larger than before. Among the height and length items, hip height increases gradually, hip vertical length decreases gradually, and the vertical length of thigh becomes larger. Among the circumference

items, all the circumference parts increased, but the difference in circumference between bust and waist and between waist and hip decreased; thus the curvature of body decreased gradually. This trend was also observed in the flatness items; bust flatness showed a gradually increasing trend, and waist and hip flatness showed a gradually decreasing trend. Obesity index increased on account of the increase in body weight, but the degree of obesity is considered normal.

2. The Factor analysis was performed based on the 6th and the 7th anthropometric data sets, and 4 factors representing body characteristics of the target group were extracted. Factor 1 indicates the degree of obesity on account of high load in all breadth, depth, and circumference items. Factor 2 includes all height items and vertical length items, which indicate the vertical length of the body. Factor 3 indicates the characteristics from waist to hip. Factor 4 explains the degree of tilting of the shoulders, the size, and shape of the shoulder and shoulder parts.

3. The selected 4 factors were clustered and classified into 7 body types. The classified groups were named from tall to short in English alphabets Y, A, B based on height. Based on the degree of obesity, from thin to fat were named by English alphabets S, M, F. Accordingly, they were classified and named as YS, YM / AS, AM, AF / BM, BF.

4. The body dimensions of each representative body type were derived by applying regression equations for each part of body, stature, bust circumference, and waist circumference.

5. As a result of the analysis, it is possible to represent the body characteristics of Korean women in their 20's with 7 body types. The 7 body shapes show a numerically morphologically valid difference, which is provided as data for the follow-up avatar formation study.

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