

## Analysis of Body Measurement and Type using 3D Body Scan Data

– Adult men and women in their 20's~30's  
in the 6th Size Korea project –

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### Abstract

The objective of this study was to analyze body measurements, BMI and body type according to age in the male and female groups based on 3D scan body measurement data of adult men and women in their 20's~30's and to provide basic information usable in the clothing and fashion industry. For this purpose, we analyzed 3D scan body measurement data of 848 adults measured in the 6th Size Korea project and the results were as follows. First, there were differences in 3D scan body measurements according to age in the male and female groups, and in general the measurements of the height items were larger in younger adults and the measurements of the circumference, breadth and depth items were larger in older ones. Second, there were differences in 3D scan body measurements according to BMI in the male and female groups, and in general body measurements were largest in the obesity group and lowest in the underweight group. Third, BMI was different according to gender and in general BMI was higher in men and obesity and overweight were more frequent in men than in women. Moreover, BMI was significantly different according to age and was higher in the 30's than in the 20's. Fourth, the mean difference in the drop and lower drop values according to age in the male and female groups was significant, and the drop and lower drop values were lower in the 30's than in the 20's. These results are considered meaningful as data for the development of clothing size systems, patterns and grading in the areas of clothing and fashion targeting consumers in their 20's~30's.

**Key Words** : 3D body scan, Digital human, BMI, Body somatotype

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## I. Introduction

Today's IT revolution has extensive impacts not only on industries but also on every area of human life including economy, culture and daily life. Human engineering and clothing and fashion are also utilizing IT technologies and representative examples are 3D body scanner, apparel CAD, production software, 3D digital avatar and clothing, 3D digital fitting, 3D virtual try-on simulation, etc.<sup>1),2),3),4)</sup> In measuring body sizes to make clothes, conventional body measuring using a tape measure is replaced with 3D body scan that measures the body surface using high-sensitivity optical devices and optical technologies without contacting the body<sup>5),6)</sup>. Representative 3D body scan measuring methods developed so far include those using laser light source, white light source, moiré phenomenon and microware. In addition to 3D body scanners for non-contact body measuring, various types of software have been developed for body measuring. There are 3D body scanner and software including WB4 and DigiSize S/W of Cyberware, 2T4 and Body Scanning S/W of [TC]<sup>2)</sup>, BLS(C6648) and BL Manager S/W of Hamamatsu, and Vitus Pro/Smart and Scan WorX S/W of Tecmath<sup>8),9)</sup>.

Throughout the world research is being made actively on the efficient use of 3D body scan data in industries. Developed countries already started research on the development and standardization of body measuring methods from the early 20th century, and most of recent world-scale body measuring projects measure body sizes automatically using 3D anthropometric data obtained with 3D body scanners<sup>10),11)</sup>.

The U.S. and Europe conducted the joint CAESAR project from 2000 and collected 3D

body measurement data, and 3D scanners were also used in Size USA in 2002~2003, Size UK in 2001~2002, Size Japan in 2004~2006, and the 5th Size Korea in 2003~2004 and the 6th Size Korea project in 2010<sup>12),13),14),15)</sup>. Anthropometric data obtained through 3D scan body measuring are expected to be used to propose new standards and to develop pattern design and pattern grading by size in manufacturing clothing and fashion products fit for body size and shape<sup>16),17)</sup>. Moreover, in order for 3D scan body measurement data to be utilized to develop products in various industries in addition to the clothing and fashion industry, 3D body measurement data according to age and body type in the male and female groups are needed to analyze<sup>18)</sup>.

Thus, this study purposed to analyze body measurements and body types based on 3D scan body measurement data of adult men and women in their 20's~30's and to provide basic information useful to develop patterns and grading in the clothing and fashion industry.

## II. Methods

### 1. Subjects

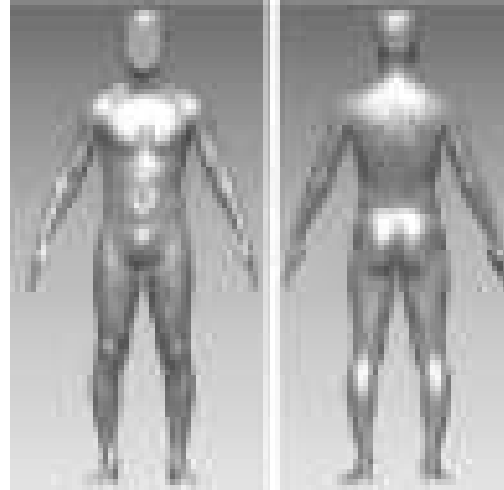
For this study, we used 3D scan body measurements obtained by the 6th Size Korea project. The subjects were 848 people made up 438 adult men and 410 adult women from 20 to 39 years.

### 2. Measuring Method

In the 6th Size Korea project, the subjects who reside in Seoul and Gyeonggi province in Korea were measured by 3D body scanner from June through December, 2010. For 3D body

measuring equipment, Bodyline Scanner (BLS) of Hamamatsu was used and the measured data were processed with 'BodySizer' automatic measuring program<sup>19)</sup>.

In 3D scan body measuring, the circumference, length, breadth and depth items were measured in the basic standing position with the feet of the left and right feet 18cm apart from each other and the wrists 17cm~19cm apart from the trunk<sup>20)</sup>. <Figure 1>



<Figure 1> Basic Standing Position of the Measured Subjects

– Korean Agency for Technology and Standard, p.41.

### 3. Analysis Measurement Items

This study compared a total of 34 items of body measurements as in <Table 1> including 8 height items, 5 length items, 11 circumference items, 4 breadth items and 5 depth items as well as weight item.

### 4. Analysis Methods

This study compared the body measurements

of male and female groups according to age and analyze BMI according to gender and age

<Table 1> Body Measurement Items

Body Measurement Lists					
Height (8)	Stature	Cervical Height	Shoulder Height	Bust Height	Waist Height
	Abdominal Height	Hip Height	Crotch Height		
Length (5)	Bishoulder Length	Waist Front Length	Neck Point to Breast Point to Waistline	Waist Back Length	Arm Length
Girth (11)	Neck Base Circumference	Chest Circumference	Bust Circumference	Underbust Circumference	Waist Circumference
	Abdominal Circumference	Hip Circumference	Knee Circumference	Calf Circumference	Ankle Circumference
	Wrist Circumference				
Breadth (4)	Chest Breadth	Bust Breadth	Waist Breadth	Hip Breadth	
Depth (5)	Chest Depth	Bust Depth	Waist Depth	Abdominal Depth	Hip Depth
Weight (1)	Weight				

using 3D scan body measurements obtained from 848 adult men and women in the 6th Size Korea. In addition, this study aimed at comparative analysis of body measurements between drop/lower-drop groups classified in KS K 0051 according to gender and age.

In this study, data were analyzed with SPSS 12.0 and the contents of analysis were as follows.

First, the subjects were divided into the male and female groups and the difference in body measurement items according to age in each of the male and female groups was also analyzed through t-test. By age, the subjects were divided into two groups the 20's (20~29 years) and the 30's (30~39 years).

Second, in each of the male and female groups, the difference in the body measurement items according to BMI (body mass index) was analyzed through one-way ANOVA and Duncan's post-hoc test.

Third, difference in BMI according to gender and age was analyzed through t-test, and frequency analysis was performed on BMI according to gender and age. By BMI, the subjects of this study were divided into 4 groups: underweight (under 18.5 kg/m<sup>2</sup>), average weight (18.5~24.9 kg/m<sup>2</sup>), overweight (25.0~29.9 kg/m<sup>2</sup>) and obesity (over 30.0 kg/m<sup>2</sup>). This BMI group division was based on BMI intervals set by the World Health Organization (WHO) for Asian people.

Fourth, difference in drop and lower drop according to gender and age was analyzed through t-test, and frequency analysis was performed on drop and lower drop according to gender and age. Drop and lower drop were classified based on KS K 0050 (size for adult men's wear) and KS K 0051 (size for adult women's wear). For men's measurements, drop

was classified by the difference between bust circumference and waist circumference and lower drop by the difference between hip circumference and waist circumference. By drop, men were divided into 4 groups: BB type (-8.2~6.9cm), B type (7.0~12.9cm), A type (13.0~18.3cm), Y type (18.4~32.0cm). By lower drop, men were divided into 2 groups: B type (-12.0~11.6cm), A type (11.7~30.0cm). For women's measurements, drop was classified by the difference between hip circumference and bust circumference and lower drop by the difference between hip circumference and waist circumference. By drop, women were divided into 3 groups: N type (3~9cm), A type (9~21cm), H type (-14~3cm). By lower drop, women were divided into 3 groups: Ordinary body type (14~22cm), Body type with slim waist (22~38cm), Body type with thick waist (-4~14cm).

Fifth, the subjects were divided by gender (male and female) and age (20's and 30's), and difference in drop and lower drop according to BMI was analyzed through one-way ANOVA and frequency analysis was performed on drop and lower drop according to gender and age.

### III. Results and Discussion

#### 1. Comparison of Body Measurements according to Age in the Male and Female Group

<Table 2> shows the results of t-test on difference in body measurement items according to age in adult men and women groups. We calculated the means of the 20's and the 30's for the male and female groups, respectively and compared the mean values (MD) between men and women through t-test.

According to the results in <Table 2>, the results of analyzing difference in body measurements according to age in each of the male and female groups were as follows. For the male group, significant difference was observed between the 20's and the 30's in the height items such as stature, cervical height, shoulder height, cervical height, bust height, waist height, abdominal height, hip height, and crotch height. In general body measurements were larger in the 20's than in the 30's. Among the length items, arm length was significantly different between the 20's and the 30's, that is, it was larger in the 20's than in the 30's.

Among the circumference items, neck base circumference, chest circumference, bust circumference, bust circumference, underbust circumference, waist circumference, abdominal circumference and hip circumference were significantly different according to age. In general body measurements were smaller in the 20's than in the 30's. Among the breadth items, chest breadth, bust breadth, waist breadth and hip breadth were significantly different according to age and in general the 30's showed larger sizes than the 20's. Among the depth items, chest depth, bust depth, waist depth, abdominal depth and hip depth were significantly different according to age and in general the 30's showed larger sizes than the 20's.

For the female group, significant difference was observed in the same items as those for the men's group among the height, length, circumference and depth items. Among the breadth items, on the other hand, bust breadth and waist breadth were significantly different according to age in the female group. In addition, the height items were generally larger in the 20's than in the 30's, and the circumference, breadth and depth items were

generally larger in the 30's than in the 20's.

Overall, there were differences in 3D scan body measurements according to age in the male and female groups. In general the measurements of the height items were larger in younger adults and the measurements of the circumference, breadth and depth items were larger in older ones.

## 2. Comparison of Body Measurements according to BMI

### 1) Analysis of Body Measurements among BMI Groups according to Male and Female

<Table 3> shows the results of one-way ANOVA and Duncan's post-hoc test to see difference in body measurement items according to BMI in each of the male and female groups.

We calculated the means of the 4 groups divided by BMI for each of the male and female groups, and analyzed difference in body measurements among the 4 groups (underweight, average weight, overweight, obesity) according to BMI.

For men, abdominal height showed significant difference according to BMI among the height items, and the measurement was largest in the obesity group (MD=102.3) and smallest in the underweight group (MD=98.8). All of the length items, bishoulder length, waist front length, neck point to breast point to waistline, waist back length and arm length were significantly different among the BMI groups, and among the circumference items neck base circumference, chest circumference, bust circumference, underbust circumference, waist circumference, abdominal circumference, hip circumference, knee circumference, calf circumference, ankle circumference and wrist circumference were significantly different according to BMI. Among

**<Table 2> Body Measurements according to Age in the Male and Female Group**

Unit: cm

	Men (n=438)				Women (n=410)				t-value
	20's (n=235)		30's (n=203)		20's (n=208)		30's (n=202)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Stature	174.5	5.4	172.4	5.9	161.7	5.2	160.4	4.9	2.64**
Cervical Height	148.5	5.1	146.8	5.4	136.8	4.8	135.8	4.5	2.37**
Shoulder Height	141.8	5.2	140.1	5.3	131.1	4.6	130.2	4.5	2.16*
Bust Height	125.4	4.6	123.3	4.8	115.6	4.5	113.6	4.4	4.48***
Waist Height	105.6	4.3	103.8	4.4	100.5	3.8	99.2	3.8	3.39***
Abdominal Height	99.8	4.4	98.5	4.3	91.6	3.8	90.1	4.1	3.85***
Hip Height	86.6	3.8	84.7	3.9	79.3	3.5	78.2	3.5	3.38***
Crotch Height	78.3	3.6	75.9	4.0	73.7	3.3	72.1	3.2	5.10***
Bisshoulder Length	42.4	2.4	42.5	2.3	37.5	1.9	37.5	1.9	-0.38
Waist Front Length	37.9	2.2	37.9	2.2	32.9	1.9	33.1	1.9	-1.01
Neck Point to Breast Point to Waistline	46.1	2.3	46.5	2.6	40.6	2.1	40.9	2.2	-1.27
Waist Back Length	44.3	2.2	44.5	2.3	37.7	1.9	38.0	1.9	-1.76
Arm Length	58.4	2.6	57.3	2.7	53.2	2.3	52.2	2.4	4.46***
Neck Base Circumference	42.4	2.2	43.5	2.4	36.9	1.8	37.5	2.1	-3.47***
Chest Circumference	98.5	6.3	101.0	6.7	87.2	5.3	89.1	6.3	-3.35***
Bust Circumference	92.8	6.9	95.7	7.3	85.5	6.2	87.8	7.8	-3.37***
Underbust Circumference	86.2	6.4	89.0	6.8	73.3	5.0	76.5	6.3	-5.64***
Waist Circumference	79.4	8.4	84.2	8.9	69.0	5.8	73.0	8.1	-5.85***
Abdominal Circumference	82.7	7.8	86.4	8.0	79.6	6.2	83.7	7.4	-6.09***
Hip Circumference	94.1	5.8	95.2	5.4	91.8	4.8	92.9	5.7	-2.20*
Knee Circumference	36.3	2.3	36.4	2.2	34.8	2.1	34.8	2.3	0.22
Calf Circumference	36.8	2.8	37.3	2.7	34.1	2.4	34.5	2.5	-1.74
Ankle Circumference	26.1	1.6	26.1	1.5	24.2	1.5	24.2	1.5	-0.34
Wrist Circumference	17.7	1.1	17.9	1.2	16.0	0.9	15.9	0.9	1.61
Chest Breadth	35.3	2.0	36.0	2.1	31.7	1.6	31.9	1.8	-1.45
Bust Breadth	32.5	2.2	33.3	2.1	28.6	1.7	29.2	2.1	-3.14**
Waist Breadth	29.0	2.5	30.1	2.6	25.0	1.9	26.2	2.4	-5.57***
Hip Breadth	34.1	1.7	34.4	1.6	34.0	1.5	34.2	1.7	-1.57
Chest Depth	22.0	1.8	22.8	2.1	19.5	1.9	20.4	2.0	-4.62***
Bust Depth	22.3	2.1	23.3	2.2	21.8	2.2	22.7	2.7	-3.75***
Waist Depth	20.6	2.8	22.6	2.9	18.3	2.1	19.6	2.8	-5.43***
Abdominal Depth	21.3	2.6	23.0	2.7	20.5	2.1	21.9	2.6	-5.86***
Hip Depth	24.3	2.2	25.1	2.0	22.2	1.8	23.0	2.3	-3.89***
Weight (kg)	68.9	10.4	71.3	10.7	54.3	7.1	56.4	8.4	-2.64**

\*p&lt;.05, \*\*p&lt;.01, \*\*\*p&lt;.001

the breadth items, chest breadth, bust breadth, waist breadth and hip breadth were significantly different according to BMI. Among the depth items, chest depth, bust depth, waist depth, abdominal depth and hip depth were significantly different according to BMI. As the result of Duncan's post-hoc test, for example, chest circumference among the circumference items was largest in the obesity group (MD=116.2 D), which was followed by overweight (MD=105.7 C), average weight (MD=97.2 B) and underweight (MD=88.9 A).

In general, the length, circumference, breadth and depth items were largest in the obesity group, which was followed by overweight group, average weight group and underweight group.

For women, all the height items except shoulder height, namely, stature, cervical height, bust height, waist height, abdominal height, hip height and crotch height were significantly different according to BMI, and the sizes were generally largest in the underweight group and smallest in the obesity group.

All of the length items, all the height items except arm length, namely, bishoulder length, waist front length, neck point to breast point to waistline and waist back length were significantly different among the BMI groups, and the sizes were generally largest in the obesity group and smallest in the underweight and average weight group. In all of the circumference, breadth and depth items, significant difference was observed according to BMI, and the measurements were generally largest in the obesity group and smallest in the underweight group.

The results of comparing BMI between the male and female groups are as follows. In the male group, only abdominal height was significantly different and abdominal height was highest in the obesity group, which was followed

by the overweight group, the average weight group and the underweight group. In the female group, all the height items except shoulder height were significantly different, and the height items were largest in the underweight group, which was followed by the overweight group, the average weight group and the obesity group. This suggests the general tendency that heights are generally small in obese women.

In the circumference, breadth and depth items, the body measurements were largest in the obesity group for both men and women, which was followed by the overweight group, the average weight group and the underweight group.

<Figure 2> shows 3D scanned body image who belonged to the average size of each four BMI group including under weight, average weight, over weight, obesity in the men and women. As shown in the digital human image, the body measurements of the circumference, breadth and depth items tend to be largest in the obesity group for both men and women, which is followed by the overweight group, the average weight group and the underweight group.

## 2) Comparison and Frequency Analysis of BMI between the Male and Female Groups

<Table 4> shows the results of analyzing difference in BMI according to gender. BMI was significantly different between the male and female groups and was higher in men than in women.

<Table 5> shows the results of frequency analysis for the 4 BMI groups of men and women. As to the distribution of BMI in all the subjects, the frequency of average weight was highest (73.6%), which was followed by overweight (17.5%), underweight (6.5%) and obesity (2.5%).

<Table 3> Body Measurements according to BMI in the Male and Female Groups

Unit: cm

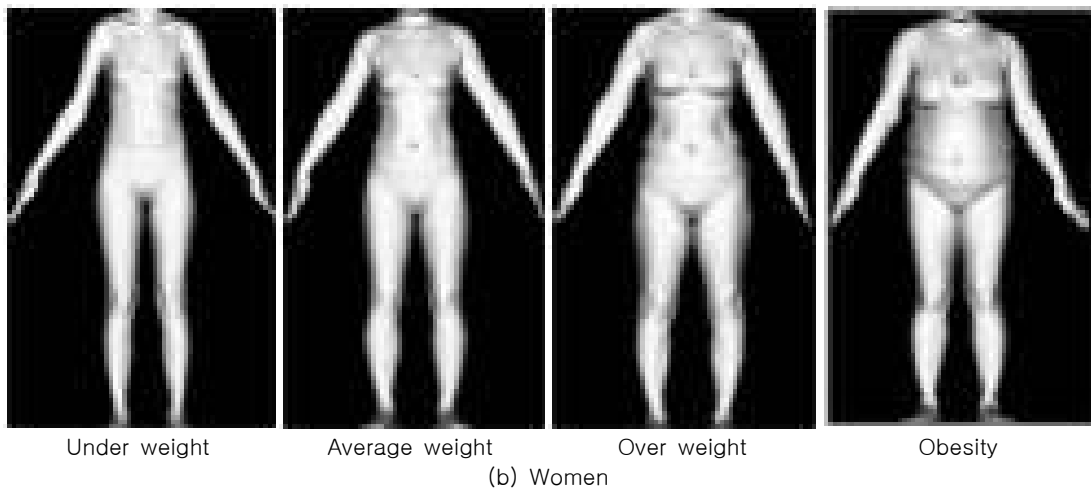
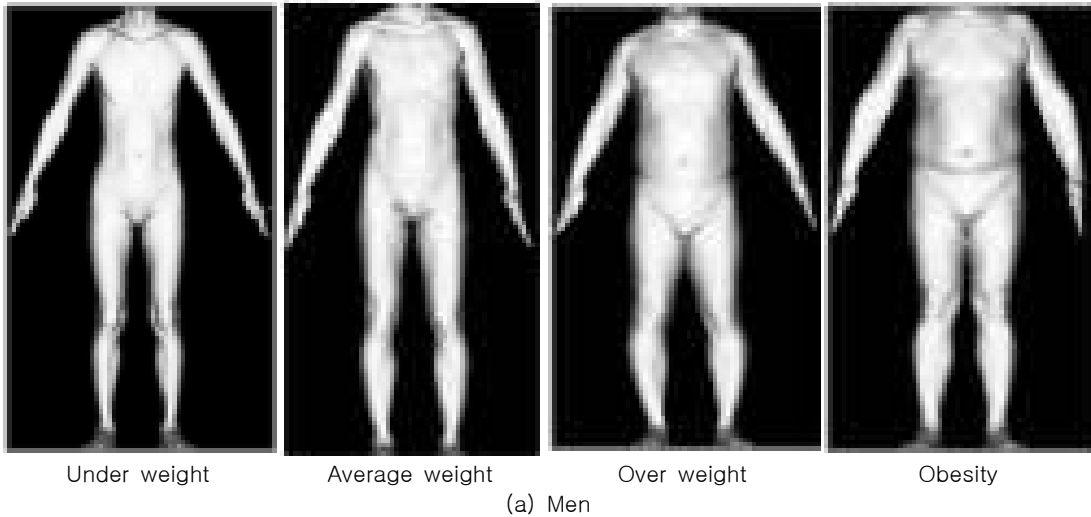
	Men (n=438)					Women (n=410)				
	Under weight (n=14)	Average weight (n=303)	Over weight (n=105)	Obesity (n=16)	F	Under weight (n=41)	Average weight (n=321)	Over weight (n=43)	Obesity (n=5)	F
Stature	174.8	173.3	173.6	175.7	1.18	163.3 B	160.8 AB	161.2 AB	157.9 A	3.56*
Cervical Height	148.5	147.4	148.0	150.4	2.08	138.2 B	136.0 AB	136.9 AB	134.6 A	3.15*
Shoulder Height	142.0	140.7	141.4	143.5	1.71	132.4 B	130.4 AB	130.9 AB	128.9 A	2.59
Bust Height	125.9	124.4	124.2	125.6	0.83	117.3 C	114.5 BC	113.2 B	109.4 A	8.92***
Waist Height	105.1	104.7	104.7	106.0	0.45	101.4 B	99.8 AB	99.3 AB	97.0 A	3.47*
Abdominal Height	98.8 A	98.9 A	99.5 A	102.3 B	3.24*	92.8	90.6	90.7	92.0	3.74*
Hip Height	87.6	85.7	85.4	87.2	2.08	80.5	78.6	78.4	78.5	3.87**
Crotch Height	79.0	77.3	76.5	77.1	2.06	75.1 C	72.9 BC	71.9 AB	70.2 A	8.64***
Bisshoulder Length	40.8 A	42.0 B	43.4 C	46.4 D	32.46***	37.0 A	37.3 A	39.2 B	39.4 B	17.67***
Waist Front Length	37.4 A	37.6 AB	38.7 B	40.1 C	13.33***	33.1 A	32.8 A	34.1 AB	34.6 B	7.56***
Neck Point to Breast Point to Waistline	45.5 A	45.7 A	47.4 B	49.4 C	24.84***	40.2 A	40.5 A	42.7 B	44.4 C	22.67***
Waist Back Length	44.9 A	44.1 A	44.9 A	46.2 B	6.88***	38.2 AB	37.5 A	39.3 BC	40.1 C	15.13***
Arm Length	58.0 AB	57.6 A	58.3 AB	59.4 B	3.58*	53.4	52.7	52.4	51.8	1.46
Neck Base Circumference	41.0 A	42.3 B	44.2 C	47.7 D	61.69***	35.9 A	37.0 A	39.8 B	40.4 B	49.64***
Chest Circumference	88.9 A	97.2 B	105.7 C	116.2 D	226.40***	81.4 A	87.5 B	97.6 C	105.5 D	144.64***
Bust Circumference	81.9 A	91.5 B	100.8 C	112.3 D	234.68***	79.1 A	85.7 B	97.7 C	110.6 D	146.21***
Underbust Circumference	76.6 A	85.0 B	93.7 C	104.6 D	239.75***	68.8 A	74.2 B	83.7 C	95.1 D	133.67***
Waist Circumference	67.5 A	78.1 B	90.5 C	103.2 D	259.86***	63.5 A	69.9 B	82.8 C	97.9 D	175.57***
Abdominal Circumference	73.7 A	81.2 B	92.2 C	104.0 D	223.64***	73.9 A	80.7 B	92.6 C	104.6 D	142.56***
Hip Circumference	85.9 A	92.5 B	99.7 C	107.2 D	180.73***	86.7 A	91.7 B	101.1 C	107.1 D	137.67***
Knee Circumference	33.7 A	35.6 B	38.1 C	40.7 D	99.97***	32.8 A	34.6 B	37.4 C	39.7 D	60.54***
Calf Circumference	31.8 A	36.2 B	39.4 C	42.9 D	164.40***	31.6 A	34.1 B	38.0 C	40.2 D	98.45***
Ankle Circumference	24.5 A	25.7 B	27.0 C	28.7 D	55.79***	23.4 A	24.1 A	25.8 B	25.9 B	27.25***
Wrist Circumference	16.6 A	17.5 B	18.6 C	19.4 D	56.25***	15.4 A	15.8 A	16.9 B	17.9 C	40.20***
Chest Breadth	32.9 A	34.8 B	37.3 C	40.3 D	140.53***	30.2 A	31.6 B	34.0 C	35.5 D	63.92***
Bust Breadth	29.3 A	32.1 B	34.6 C	38.0 D	150.76***	26.9 A	28.7 B	31.7 C	34.5 D	107.37***
Waist Breadth	25.4 A	28.5 B	32.0 C	35.9 D	238.39***	23.5 A	25.3 B	28.9 C	33.2 D	126.80***
Hip Breadth	32.2 A	33.7 B	35.6 C	37.2 D	87.41***	32.7 A	33.9 B	36.3 C	36.7 C	58.73***
Chest Depth	19.5 A	21.7 B	24.1 C	26.6 D	137.23***	18.0 A	19.8 B	22.9 C	25.6 D	106.73***
Bust Depth	19.5 A	22.0 B	24.8 C	27.7 D	172.35***	19.7 A	21.9 B	26.0 C	30.7 D	135.11***
Waist Depth	17.1 A	20.3 B	24.5 C	28.5 D	207.23***	16.4 A	18.6 B	22.9 C	28.2 D	160.39***
Abdominal Depth	18.5 A	21.0 B	24.7 C	28.6 D	201.10***	18.5 A	20.9 B	25.0 C	29.8 D	146.46***
Hip Depth	21.6 A	23.9 B	26.6 C	29.7 D	187.92***	20.2 A	22.3 B	26.0 C	30.5 D	199.52***
Weight (kg)	53.2 A	65.9 B	80.0 C	97.6 D	265.64***	46.8 B	54.2 AB	69.0 AB	79.6 A	186.60***

\*p<.05, \*\*p<.01, \*\*\*p<.001, Duncan test: A<B<C<D



Among men, average weight (69.2%) was most frequent, which was followed by overweight (24.0%), obesity (3.7%) and under

weight (3.2%). Among women, average weight (78.3%) was most frequent, which was followed by overweight (10.5%), underweight (10.0%) and



<Figure 2> 3D Scanned Body Image according to BMI Group in the Men and Women

<Table 4> Comparison of BMI according to Gender

	Men (n=438)		Women (n=410)		t-value
	Mean	SD	Mean	SD	
BMI	23.5	3.2	21.7	2.9	8.94***

\*\*\*p<.001

obesity (1.2%). In comparison between the male and female groups, overweight and obesity were more frequent and underweight was less frequent in the male group than in the female group.

3) Comparison and Frequency Analysis of BMI between the 20's and 30's Groups

<Table 6> shows the results of analyzing BMI according to age in the male and female groups. As a whole, BMI was significantly different according to age, and in both the male and female groups as well, it was significantly different according to age. That is, BMI was significantly higher in the 30's than in the 20's in both men and women.

<Table 7> shows the results of frequency analysis for the 4 BMI groups according to age in the male and female groups.

For the male group, frequency was high in

order of average weight (75.7%), overweight (17.0%), underweight (3.8%) and obesity (3.4%) in the 20's, and in order of average weight (61.6%), overweight (32.0%), obesity (3.9%) and underweight (2.5%) in the 30's, showing that obesity was more frequent and underweight was less frequent in the 30's than in the 20's. For the female group, frequency was high in order of average weight (78.8%), underweight (14.4%), overweight (6.7%) and obesity (0.0%) in the 20's, and in order of average weight (77.7%), overweight (14.4%), underweight (5.4%) and obesity (2.5%) in the 30's. As in the male group, obesity was more frequent and underweight was less frequent in the 30's than in the 20's among women.

3. Comparison and Frequency Analysis of Drop and Lower Drop according to Age

In the results of analyzing difference in the

<Table 5> Frequency Analysis on BMI according to Gender

	Men (n=438)	Women (n=410)	Total
Underweight	14 (3.2%)	41 (10.0%)	55 (6.5%)
Average weight	303 (69.2%)	321 (78.3%)	624 (73.6%)
Overweight	105 (24.0%)	43 (10.5%)	148 (17.5%)
Obesity	16 (3.7%)	5 (1.2%)	21 (2.5%)
Total	438 (100.0%)	410 (100.0%)	848 (100.0%)

<Table 6> Comparison of BMI according to Age

	Men (n=438)					Women (n=410)				
	20's		30's		t-value	20's		30's		t-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
BMI	22.9	3.1	24.3	3.1	-4.8***	21.1	2.5	22.2	3.2	-3.7***

\*\*\*p<.001

drop and lower drop values according to age in each of the male and female groups, the values were significantly different between the 20's and the 30's in both of the male and female groups as in <Table 8>.

For the male group, the drop and lower drop values were lower in the 30's than in the 20's and this means that the difference between bust circumference and waist circumference is smaller and the difference between hip circumference and waist circumference is smaller in the 30's than in the 20's. For the female group, the drop and lower drop values were lower in the 30's than in the 20's and this means that the difference between hip circumference and bust circumference is smaller and the difference between hip circumference and waist circumference is smaller in the 30's than in the 20's.

<Table 9> shows the results of frequency analysis on drop and lower drop body types according to age for the male group. In the results, among the drop body types, B type (body type with thick waist) was more frequent in the 30's (19.2%) than in the 20's (7.2%) and Y type (inverted triangle body type) was more frequent in the 20's (58.7%) than in the 30's (36.9%). Among the lower drop body types as well, B type (body type with thick waist) was more frequent in the 30's (52.2%) than in the 20's (21.7%).

<Table 10> shows the results of frequency analysis on drop and lower drop body types according to age for the female group. In the results, among the drop body types, H type (body type with large bust and small hip) was more frequent in the 30's (28.7%) than in the

<Table 7> Frequency Analysis on BMI Groups according to Age

	Men (n=438)		Women (n=410)		Total
	20's	30's	20's	30's	
Underweight	9 (3.8%)	5 (2.5%)	30 (14.4%)	11 (5.4%)	55 (6.5%)
Average weight	178 (75.7%)	125 (61.6%)	164 (78.8%)	157 (77.7%)	624 (73.6%)
Overweight	40 (17.0%)	65 (32.0%)	14 (6.7%)	29 (14.4%)	148 (17.5%)
Obesity	8 (3.4%)	8 (3.9%)	0 (0.0%)	5 (2.5%)	21 (2.5%)
Total	235 (100.0%)	203 (100.0%)	208 (100.0%)	202 (100.0%)	848 (100.0%)

<Table 8> Comparison of Drop and Lower Drop according to Age

Unit: cm

	Men (n=438)					Women (n=410)				
	20's		30's		t-value	20's		30's		t-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Drop	19.1	4.5	16.8	4.9	5.05***	6.3	3.8	5.2	5.4	2.60**
Lower Drop	14.6	4.2	11.0	5.0	8.31***	22.9	3.5	20.0	5.1	6.80***

\*\*p<.01, \*\*\*p<.001

<Table 9> Frequency Analysis on Drop and Lower Drop according to Age in the Male Group

Men (n=438)				
		20's	30's	Total
Drop	BB Body type with protruding abdomen (Drop: -8.2 ~ 6.9cm)	2 (0.9%)	4 (2.0%)	6 (1.4%)
	B Body type with thick waist (Drop: 7.0 ~ 12.9cm)	17 (7.2%)	39 (19.2%)	56 (12.8%)
	A Ordinary body type (Drop: 13.0 ~ 18.3cm)	78 (33.2%)	85 (41.9%)	163 (37.2%)
	Y Inverted triangle body type (Drop: 18.4 ~ 32.0cm)	138 (58.7%)	75 (36.9%)	213 (48.6%)
	Total	235 (100.0%)	203 (100.0%)	438 (100.0%)
Lower Drop	B Body type with thick waist (Lower Drop: -12.0 ~ 11.6cm)	51 (21.7%)	106 (52.2%)	157 (35.8%)
	A Ordinary body type (Lower Drop: 11.7 ~ 30.0cm)	184 (78.3%)	97 (47.8%)	281 (64.2%)
	Total	235 (100.0%)	203 (100.0%)	438 (100.0%)

<Table 10> Frequency Analysis on Drop and Lower Drop according to Age in the Female Group

Women (n=410)				
		20's	30's	Total
Drop	N Ordinary body type (Drop: 3 ~ 9cm)	116 (55.8%)	100 (49.5%)	216 (52.7%)
	A Body type with small bust and large hip (Drop: 9 ~ 21cm)	49 (23.6%)	44 (21.8%)	93 (22.7%)
	H Body type with large bust and small hip (Drop: -14 ~ 3cm)	43 (20.7%)	58 (28.7%)	101 (24.6%)
	Total	185 (100.0%)	174 (100.0%)	309 (100.0%)
Lower Drop	Ordinary body type (Lower Drop: 14 ~ 22cm)	77 (37.0%)	103 (51.0%)	180 (43.9%)
	Body type with slim waist (Lower Drop: 22 ~ 38cm)	128 (61.5%)	76 (37.6%)	204 (49.8%)
	Body type with thick waist (Lower Drop: -4 ~ 14cm)	3 (1.4%)	23 (11.4%)	26 (6.3%)
	Total	390 (100.0%)	353 (100.0%)	693 (100.0%)

20's (20.7%) and N type (ordinary body type) was more frequent in the 20's (55.8%) than in the 30's (49.5%). Among the lower drop body types, the body type with thick waist was more frequent in the 30's (11.4%) than in the 20's (1.4%) and the body type with slim waist was more frequent in the 20's (61.5) than in the 30's (37.6%). These results show that, in the female group, difference in body type according to age is similar to that in drop and lower drop according to age.

#### 4. Comparison of Drop and Lower Drop according to BMI

<Table 11> shows the results of analyzing difference in the drop and lower drop values according to BMI in each of the male and female groups. In the results, the mean values of drop and lower drop were different among the underweight, average weight, overweight and obesity groups in both of the male and female groups. As the result of Duncan's post-hoc test in both of the male and female groups, in general, the drop and lower drop values were highest in the underweight group, which was followed by the average weight, overweight and obesity groups. This is believed to show the tendency that the higher BMI is the larger waist circumference is.

#### V. Conclusion

This study analyzed difference in 3D scan body measurements, BMI, and drop and lower drop according to gender and age, and the results were as follows.

First, in the results of analyzing difference in 3D scan body measurements according to age in each of the male and female groups, all of the height, circumference, breadth and depth items were significantly different between the 20's and the 30's of the male group. The results showed the tendency that the measurements of the height items were larger in younger ones and the measurements of the circumference, breadth and depth items were larger in older ones. In the female group, all of the height and depth items were different between the 20's and the 30's. In the female group as well, the measurements of the height items were larger in younger ones and the measurements of the circumference, breadth and depth items were larger in older ones. As shown in this results, we may need to consider that clothing pattern for younger people tend to be made longer heights and lengths and that for older people tend to be made longer circumferences and breadths. These results may be usable for apparel and fashion businesses targeting those

<Table 11> Comparison of Drop and Lower Drop according to BMI in the Male and Female Groups

Unit: cm

	Men (n=438)					Women (n=410)				
	Under weight	Average weight	Over weight	Obesity	F	Under weight	Average weight	Over weight	Obesity	F
Drop	21.5 B	19.1 B	15.2 A	13.0 A	29.95***	7.6 C	6.0 BC	3.3 B	-3.5 A	13.84***
Lower Drop	18.4 D	14.4 C	9.2 B	4.0 A	79.24***	23.2 C	21.8 C	18.3 B	9.2 A	25.34***

\*\*\*p<.001, Duncan test: A<B<C<D

in their 20's~30's to classify the size system according to age and develop clothing patterns.

Second, in the results of analyzing difference in 3D scan body measurements according to BMI in each of the male and female groups, almost all of the length, circumference, breadth and depth items were significantly different among the underweight, average weight, overweight and obesity groups in both of the male and female groups. In general, body measurements were largest in the obesity group and smallest in the underweight group. In case of the height items, only abdominal height was significantly different according to BMI in the male group. That is, abdominal height was largest in the obesity group of men and smallest in the underweight group. In the female group, on the contrary, almost all of the height items were significantly different and they were generally largest in the underweight subgroup and smallest in the obesity subgroup. These results are able to be useful for apparel and fashion businesses manufacturing apparels in consideration of obese body type to develop size systems or patterns.

Third, in the results of analyzing difference in BMI according to gender, the mean value of BMI was significantly different between the male and female groups, and was higher in men than in women. In the results of analyzing the frequency of BMI type in the male and female groups, overweight and obesity were more frequent and underweight was less frequent in men than in women.

What is more, when difference in BMI according to age was analyzed for each of the male and female groups, BMI was significantly different according to age in both of the male and female groups and was higher in the 30's than in the 20's. Moreover, in the results of

frequency analysis according to age in each of the male and female groups, obesity was more frequent and underweight was less frequent in the 30's than in the 20's in both of the male and female groups.

Fourth, the mean values of drop and lower drop were significantly different according to age in each of the male and female groups, and in both of the male and female groups the drop and lower drop values were lower in the 30's than in the 20's. In the results of analyzing frequency according to age in each of the male and female groups, for the male group, B type (body type with thick waist) was more frequent and Y type (inverted triangle body type) was less frequent in the 30's than in the 20's among the drop types, and B type (body type with thick waist) was more frequent in the 30's than in the 20's among the lower drop types. For the female group, H type (body type with large bust and small hip) was more frequent and N type (ordinary body type) was less frequent in the 30's than in the 20's among the drop types, and body type with thick waist was more frequent in the 30's than in the 20's among the lower drop types. Waist circumference was generally larger in the 30's than in the 20's. In addition, when the difference between the drop and lower drop values according to BMI was analyzed, the higher BMI was the smaller the difference was in both of the male and female groups.

This study analyzed relations among 3D scan body measurements, BMI, and drop and lower drop body types according to age in adult men and women in their 20's~30's. The results of this study are expected to be used as basic information in research on garment size systems, in standard of body/clothing size and digital human/clothing and in the development of size description systems, patterns and grading in the

clothing and fashion industry targeting consumers in their 20's~30's. Future research needs to expand the subjects to other age groups of adult men and women. Based on the results of this study, moreover, we plan to study apparel manufacturing and pattern design in the clothing and fashion industry.

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