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Standards Sizing for Clothing based on Anthropometry Data

Young-Suk Lee

Department of Clothing Science, Chonnam National University, Gwangju, 500-757

Corresponding Author
Young-Suk Lee
Department of Clothing Science,
Chonnam National University, Gwangju,
500-757
Mobile : +82-10-2894-1597
Email : jaabo1994@naver.com

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Objective: The purpose of this study was to examine the various sizing systems and specified anthropometric data as well as the fit issues used today.

Background: A standard sizing system for clothes is a system that is developed based on body shape and size classifications method. To develop an efficient sizing system, we have to classify the database from the majority of the samples.

Method: The method of this paper deals with the secular trend of height spanning from 1997 to 2010 along with the morphological feature patterns for Koreans. It also investigates the comparison of the growth pattern between male and female and the body shape classification according to the drop values based on the anthropometric data samples of KATS taken from the 2010 surveys in order to develop and define the new guidelines for the size designation systems of clothes.

Results: The results are classified with body size and shape categories according to the drop values by age and sex in order to develop the new guidelines for the size designation systems based on these body dimensions from the analyzed anthropometric database.

Conclusion: These new guidelines for the size designation system will eliminate the confusion that currently exists among countries and individual apparel designers.

Application: The adopted standards could be used to compare the sizing systems worldwide.

Keywords: Standard, Anthropometry, Drop values, Clothing, Morphology, Sizing system, Growth

1. Introduction

There are great variations in the anthropometric measurements and body proportions of the world populations. Increasing international economic independence, however, makes it necessary to go beyond national frontiers and to establish international anthropometric standards for consumer goods and the design of workplace (Jurgens, 1990).

As a means to further improved quality and production efficiency, standardization plays with the improved systems in business and its simplification. However, with simplicity and harmonization, standardization now means better human relations between and inside manufacturing and commercial units. In fact, everyone benefits

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from it on all levels, from the producing units to the accounting sections and then the marketing ones, the national and international carriers, the delivery man and finally the consumer (McMahon, 1973).

Thus, in Korea, the first national anthropometry survey was conducted in 1979 by a Korean Government division, the Korean Agency for Technology and Standard (KATS report, 1979). At the time, data were collected on 17,000 sample individuals residing in various parts of the country, aged between six and fifty. A total number of 117 measurement dimensions were taken using calipers and tape measures. Thanks to these data, the KATS established 46 items defining the Korean standard concerning clothing, furniture, desks and chairs. Forty-one of them (KSK 0035 to KSK 0096) were associated with the size designations of men's wear, women's wear, brassieres, socks, etc. Following this survey, the Korean government has been presenting a national anthropometric survey every 5 or 6 years. The surveys of 1986, 1992, 1997, 2003 and 2010 were performed according to the following sequence: the surveys were performed with the traditional measurement method (2D) using an anthropometer, somatometer, caliper and tape measure. The 3-D body scan data collection (Body Line Scanner, Hamamatsu Co.) method (3D) was also adopted for the 2003 and 2010 surveys. All body dimensions were measured with the method defined by the ISO (ISO 8559, 1989; ISO 7250, 1997).

The purpose of this study was to compare the various sizing systems and specified anthropometric data as well as the fit issues used today. The method of this paper deals with the secular trend of height spanning from 1997 to 2010 along with the morphological feature patterns for Koreans. It also investigates the comparison of the growth pattern between male and female and the body shape classification according to the drop values based on the anthropometric data samples of KATS taken from the 2000 and 2010 surveys in order to develop and define the new guidelines for the size designation systems of clothes.

2. Methods

2.1 Samples

The anthropometric data set of the Korea surveys measured during 1997-2010 (KATS, 1997-2010 data set) were analyzed in this paper in order to obtain the information on Koreans' physical features and the KS size standard table for clothes.

2.2 Measures

The 1D Dimension were measured using the anthropometer, calipers and tape measure and 3D shape measurement were measured using cyberware and Hamamatsu 3D body scanner. All measurement methods were performed according to the definitions of ISO 8559 and 7250.

2.3 Procedures

The anthropometric data included Height, 3 girth dimensions (bust/chest girth, waist girth and hip girth) were analyzed to obtain the size chart development, also the five breadth dimensions (inter-bust point breadth, chest breadth, waist breadth, hip breadth and acromion to acromion breadth), four depth dimensions (chest depth, waist depth, abdominal depth and hip depth), four height dimensions (waist height, crotch height, hip height and knee height) and cervicale to wrist length which were analyzed to indicate body shape and body proportion.

Data on size and annual growth changes of measurements of subjects aged from 6 to 20 years were used to clarify the tendency of maturation in body size.

Drop values between the three key dimensions and the distributions between key dimensions were analyzed to define the size categories for the size designation systems.

3D modeling data, body silhouette data of the mid-sagittal plane, front median line, form front and form side views measured by the sliding gauge, and data plotting from the height and breadth measurements, were used as elements for body shape and proportion comparison.

The 3D standard body shape of men and women in their twenties obtained from the 2010 KATS photos (KATS report, 2010) and the 1999 Lee data (LEE, 1999) are presented to define Korean's morphological standard features.

KS sizing of clothes and the sizing variations among country standards were compared to establish the new guidelines for the size designation systems.

3. Results

3.1 Size and shape

3.1.1 Size changes and growth rate in key dimensions

The size changes of height, bust girth, waist girth and hip girth measurements, which present the body development features and annual growth patterns of measurements in Koreans aged 6-20, are shown in Figure 1 and Figures 2 (a), (b), (c).

At age 6, the values of height, bust girth, waist girth and hip girth are 118.9cm, 60.2cm, 52.4cm and 62.4cm. The growth rates of these dimensions are respectively 74.3%, 72.0%, 74.9% and 67.6% of the adult size. Each year, height increases by 4-6cm between the ages of 6 and 12 years, and 2-4cm per year in other girth dimensions (bust and hip) for subjects aged from 12 to 15 years.

On average, maturity of growth in height is reached at the age of 17-18 years for males and 15-16 years for females. For girls at age 10, the values of height, bust girth, waist girth and hip girth are 140.7cm, 72.0cm, 62.0cm and 76.2cm, respectively (Figures 1, 2).

For boys at age 10, the values of height, chest girth, waist girth and hip girth are, 141.4cm, 72.0cm, 64.9cm and 75.2cm, respectively (Figures 1, 2). Each year, height increases by 4-6cm between the ages of 6 and 12 years in both sexes. Then, height

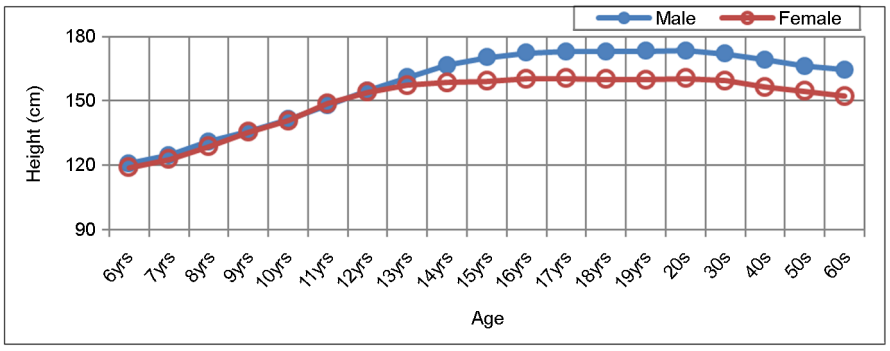


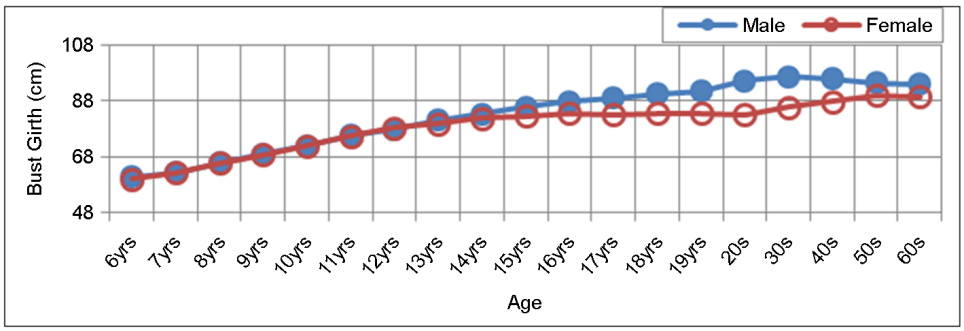
Figure 1. Size and Growth pattern of Height in Korean male and female groups from the 2010 data set

increases 2-3cm per year in the girls group and 4-5cm in the boys group aged from 12 to 15 years.

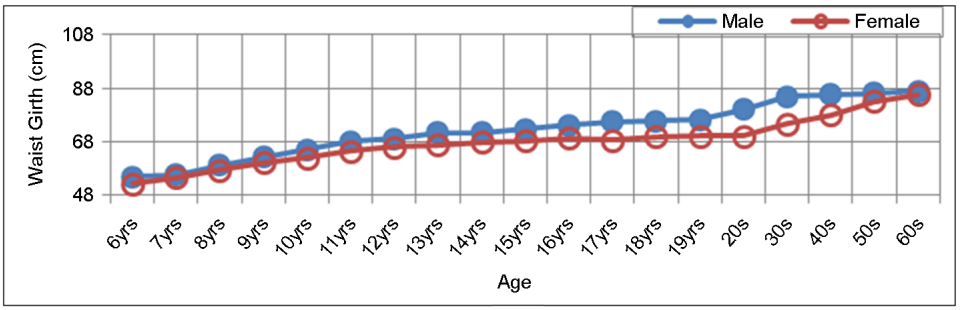
3.1.2 Growth comparison between sexes

The data on chest/bust, waist and hip girth of male and female from the 2010 samples were compared according to age in both sexes (see Figure 2).

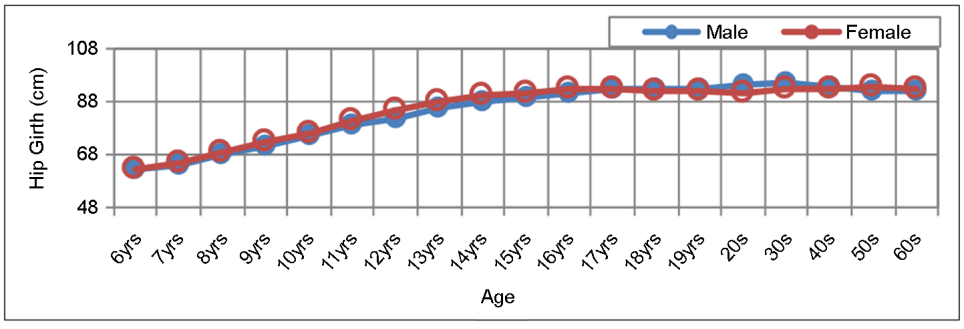
As shown in Figure 2(a), the mean bust girth value of 18-years-old women is 83.6cm and the mean chest value of the 18 years- old men is 90.6cm with showing the differences of 7cm. Around the age of 14, the gaps between sexes start to appear in bust/chest girth.



(a) Bust girth



(b) Waist girth



(c) Hip girth

Figure 2. Growth pattern of girth dimensions in Korean male and female groups

Waist girth of males from the 2010 data has been found to be 54.7cm at the age of 6, and was found in female with size 52.4cm. Starting from the age of 8, differences between male and female already start to show in waist shape and size (Figure 2-b).

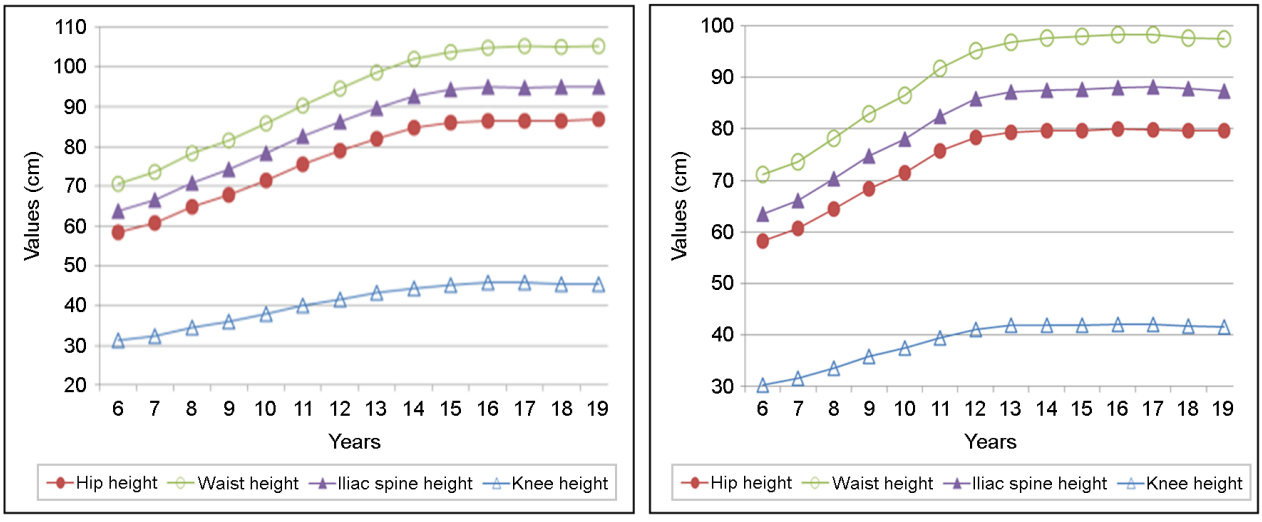
Hip girth of males and females from the 2010 data has been found to be 62.5cm and 62.4cm at the age of 6 respectively, and show almost the same size values over the whole age period with the same growing tendency (Figure 2-c).

3.2 Body proportion

3.2.1 Height dimensions

Figures 3(a) and (b) show the size changes of height dimension in knee height, waist height, hip height and iliac spine height based on the 2010 Korean male and female data set. The proportions of knee height, waist height, hip height and iliac spine height of female group in their twenties from the 2010 data are 0.26, 0.61, 0.38, 0.49 and 0.54 times to the height, respectively. These values can be used to make pattern grading, work space and accessories design in order to predict the body length of each part (A. Gleiss et al., 2013).

Body proportion is critical for manufacture body fitting clothes. The proportion ratio index of body height dimension corresponding to height should be taken into consideration when designing good product construction systems. Five body dimensions, namely, total body height, waist height, hip height, crotch height and knee height, are considered to be very important parameters for well-fitted balanced design and functionality.



(a) Data of males (b) Data of females

Figure 3. Height measurements of Koreans from the 2010 data

3.2.2 Cervicale to wrist length

The size of cervicale to wrist length is a key factor in designing the formal shirts for men.

Table 1 and Figure 4 suggest the distribution range of cervicale to wrist length size in men. Cervicale to wrist length values are concentrated in the range from 80 to 85cm, which approximately represent a 40% cover rate of men.

Table 1. Distribution range of the cervicale to wrist length size in men

Cervicale to wrist length (cm)	70~71	71~72	72~73	73~74	74~75	75~76	76~77	77~78	78~79	79~80	80~81	81~82	82~83	83~84	84~85
N	2	3	10	17	41	63	85	117	151	213	259	319	362	344	292
%	0.1	0.1	0.3	0.5	1.3	1.9	2.6	3.6	4.6	6.5	7.9	9.7	11.0	10.5	8.9
Cervicale to wrist length (cm)	85~86	86~87	87~88	88~89	89~90	90~91	91~92	92~93	93~94	94~95	95~96	96~97	≥97	Total	
N	257	226	170	140	83	58	28	18	6	4	5	2	2	3,277	
%	7.8	6.9	5.2	4.3	2.5	1.8	0.9	0.5	0.2	0.1	0.2	0.1	0.1	100.0	

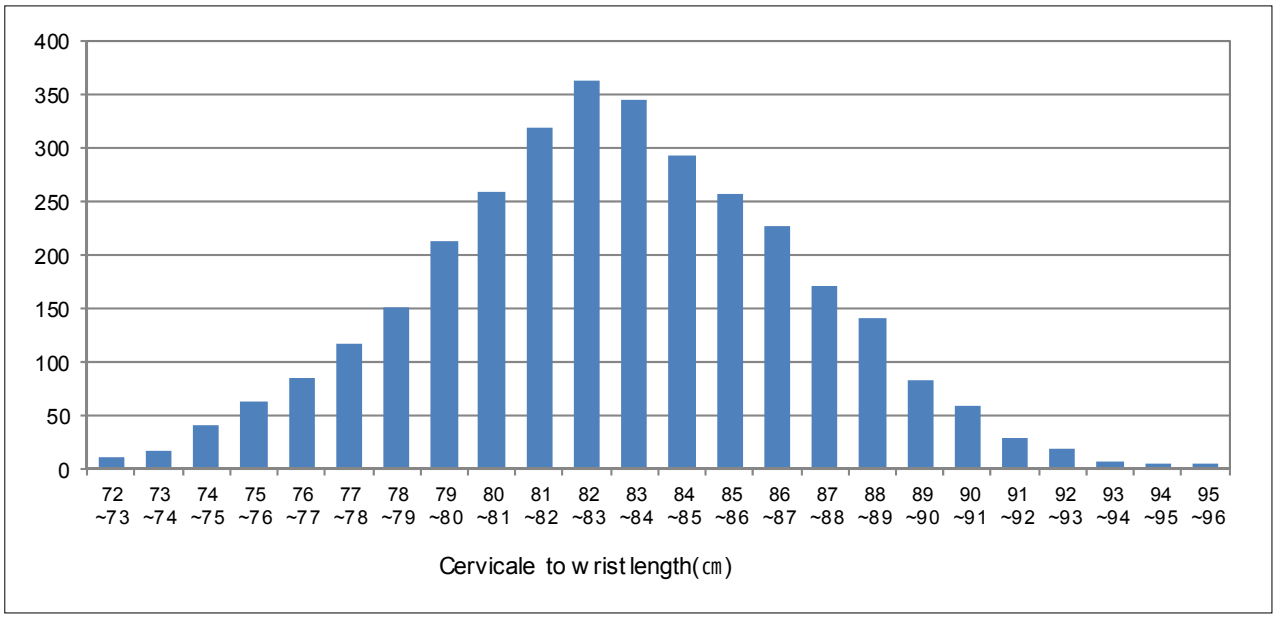


Figure 4. Distribution of the cervicale to wrist length size in men

3.3 The distribution of drop values in Koreans

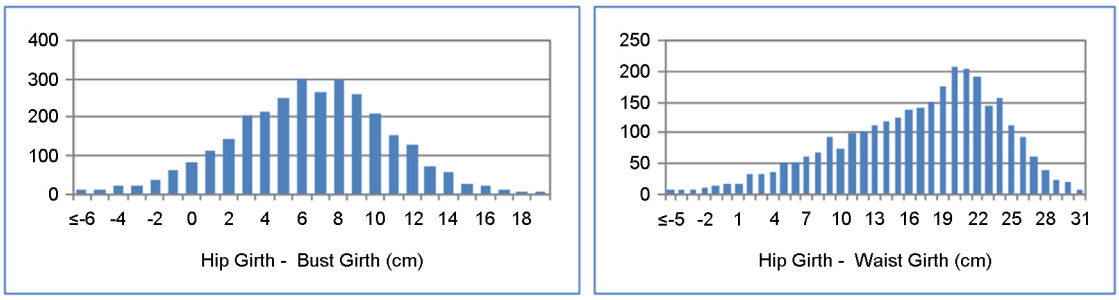
3.3.1 Drop value distribution in Koreans

Figure 5 suggests the drop value between bust girth and hip girth, hip and waist girth based on the data of female body dimension taken in 2010 (N=2,978). As shown in Figure 5(a), the drop values between bust and hip are concentrated in the range from 6 to 9cm, which approximately represent a 40% cover rate of females.

The drop values between hip and waist are concentrated in the range from 19 to 22cm, which approximately represent a 40% cover rate of females (Figure 5-b). Data are divided into three zones corresponding to different body types of Korean women.

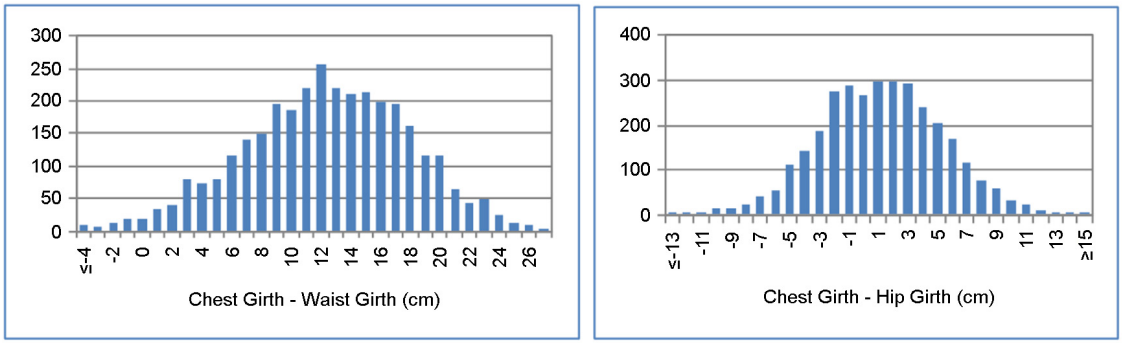
The three body shapes range in descriptive titles from N (regular), H (slim hips) and A (broad hips), as follows: Type N, whose drop value ranges from 6cm to 10cm, can be defined as the standard type for Korean women. Women who have a drop value between 10cm and 16cm belong to type A. This type indicates that a woman has a well-developed hip compared to that of Type H (drop value of -1cm ~ 6cm reflects a woman with a well-developed bust and slim hips).

Figures 6(a) and (b) suggest the drop value between chest girth and waist girth, chest girth and hip girth based on the 2010 data set of men from 19 to 60 years. The drop values are concentrated in the range from 10 to 18cm, which approximately represent a 50% cover rate of men.



(a) Drop values between hip and bust in women (b) Drop values between hip and waist in women

Figure 5. Drop values between Key dimensions in Korean women



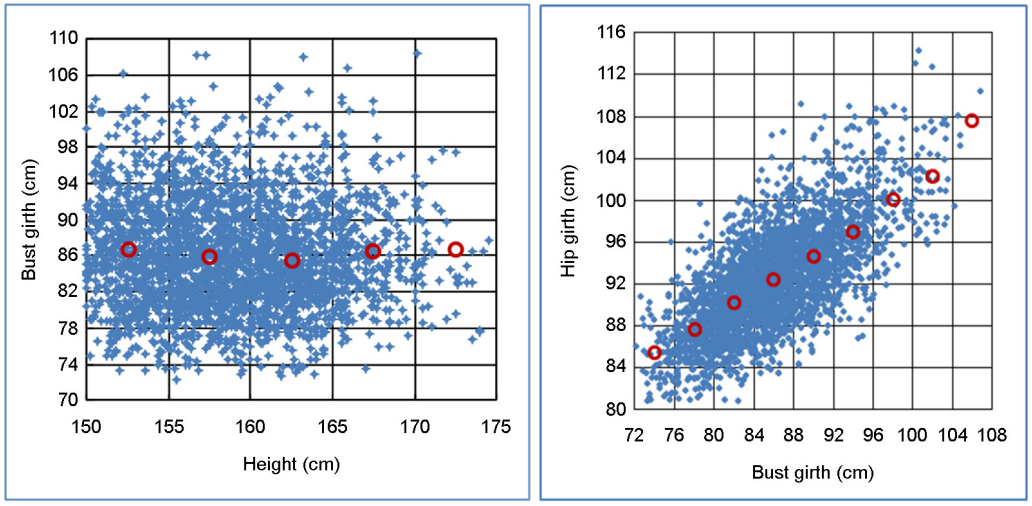
(a) Drop values between chest and waist in men (b) Drop values between chest and hip in men

Figure 6. Distribution of drop values between Key dimensions in Korean men

3.3.2 Size plotting between key dimensions

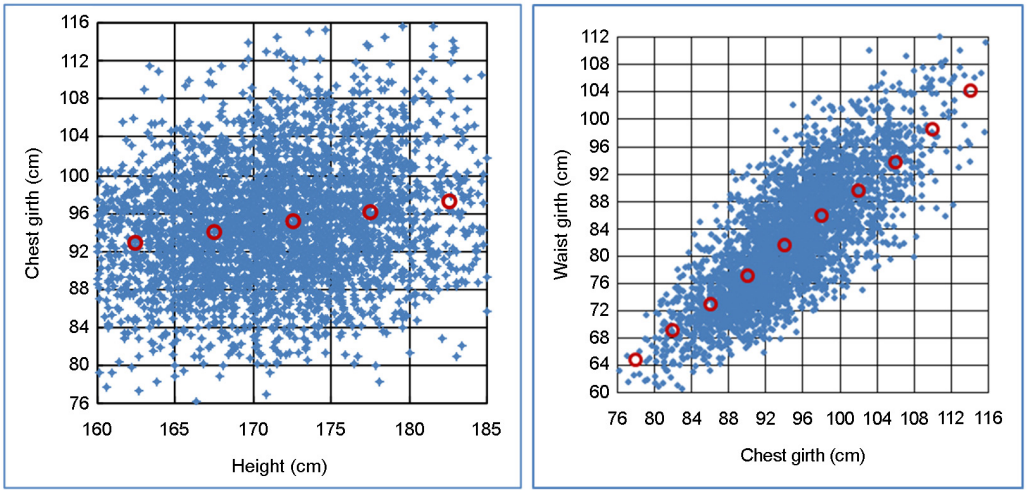
To develop the size range for women's and men's clothing, the size distribution between bust /chest and height and the distribution between bust and hip girth in women, between chest and waist girth in men are analyzed, as shown in Figures 7(a) and (b) and Figures 8(a) and (b).

The size range in the height of women are distributed from 150cm to 175cm, with an 85% cover rate. The size range of bust and hip girth in women are distributed from 76cm to 98cm and, 84-104cm, respectively, with an 85% cover rate. The size range of height, chest and waist in men are distributed from 84-108cm and 64-100cm, respectively, with an 85% cover rate.



(a) (b)

Figure 7. Distribution of the size between bust and height, bust and hip in groups of Korean women



(a) (b)

Figure 8. Distribution of the size between chest and height, chest and waist in groups of Korean men

3.4 3D body modeling in Koreans

Figure 9 shows an example of body shape modeling of Korean women in their twenties using body size data plotting and the form from front and side view using the sliding gauge. This sort of figure realizes a comparison of existing shapes with the desired virtual ones (i.e., a well-proportioned body figure in which height corresponds 8 times to the height of the head) considered as a harmonious body shape by a given or targeted population.

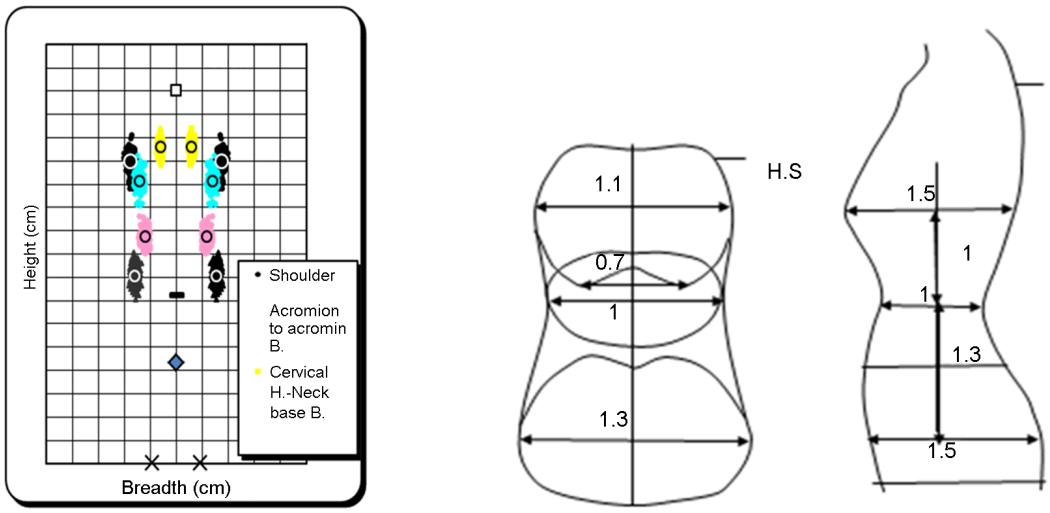


Figure 9. 3D modeling from data plotting and the index from front and side view

3.5 Size designation systems in Korean standards

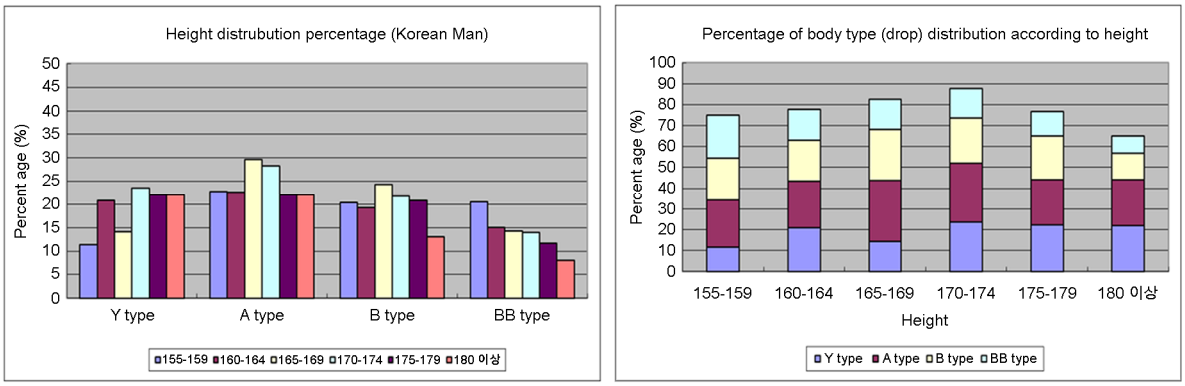
3.5.1 Size designation in men's wear

The size range of the three key dimensions and intervals are determined as follows:

Body type	Drop value (cm)		
	Short	Regular	Tall
Y type (Drop 20)	18	20	22
A type (Drop 16)	14	16	18
B type (Drop 10)	6	10	12
BB type (Drop 2~6)	2	4	6

Height type	Height range (cm)
Short	163 (155~165)
Regular	173 (165~175)
Tall	180 (175~185)

The height distribution and the cover rate according to body shape are shown in Figures 10-a, b.



(a) Height distribution by body type (b) Percentage of body type according to height in men

Figure 10. The cover rates according to body type and height type in Korean men

For men's wear, chest dimension ranges from 73cm to 106 cm, hip dimension from 78cm to 112cm and waist girth from 68cm to 106cm. Chest and hip measurements are established at intervals of 3cm and waist dimension at intervals of 2cm. Height dimension, which ranges from 155cm to 185cm, is divided into three groups, referred to as "short", "regular" and "tall", with an interval of 10cm.

In the case of upper body garments of men in their twenties, the letter code size ranges corresponding to S, M, L and LL are as shown in Figure 11.

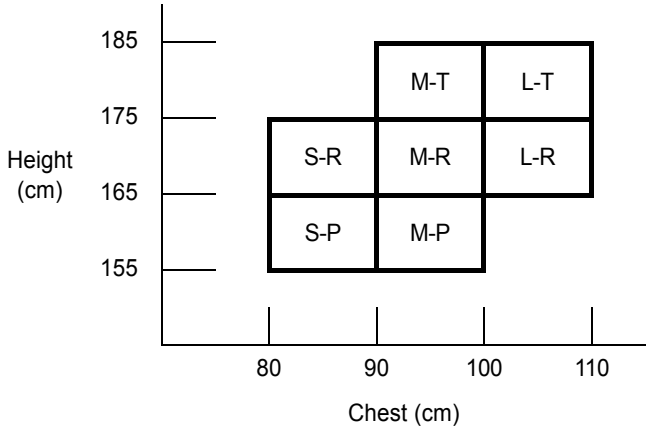


Figure 11. Size range of the letter code in men's wear

3.5.2 Size designation systems in women's wear

In KS K 0051 (2009), bust and hip measurements are established at intervals of 3cm and of 5cm for height dimensions ranging

from 145cm to 175cm. Body type is classified into 3 groups, according to the drop value between bust girth and hip girth. Type N, whose drop value is 6-9cm, can be defined as the standard (regular) Korean women body type.

Type N whose drop value is 6cm, falling under the size range 4-10cm, can be defined as the regular Korean women body type. Women, whose drop value of 12cm ranges between 10cm and 16 cm, belong to type A as follows.

Height type	Height range (cm)
Petite (P)	150 (145-155)
Regular (R)	160 (155-165)
Long (L)	170 (165-175)

Body Type	Mean Drop Value (Hip- Bust, cm)	
A	12	(range of drop value is over 10cm)
M	6	(range of drop values from 4-9cm)
H	0	(bust-hip drop value +3 ~ -4cm)

Letter codes S.M.L. XL representing the size ranges of bust girth and height, in each size code, are shown in Figure 12.

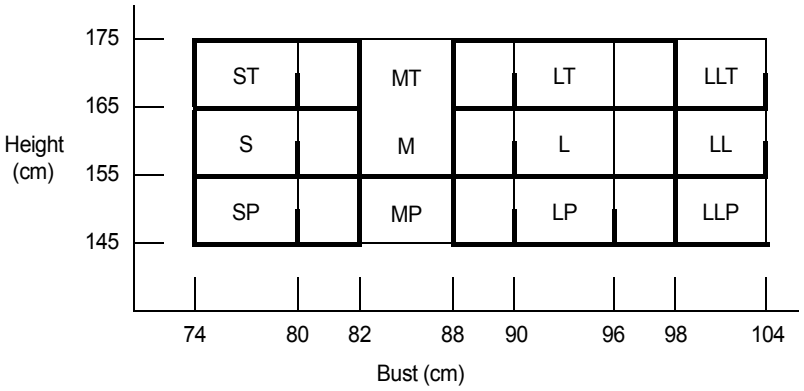


Figure 12. Size designation systems of letter code in women's' wear

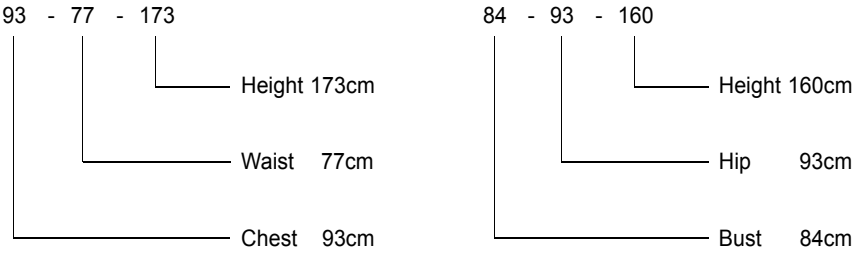
3.6 Standard body type of Koreans in twenties

3.6.1 Standard body type of Korean from the data 2010

According to the 2010 data, the average, height, chest, waist and hip girth of men were 173.3cm, 93.0cm, 77.4cm and 94.3cm, respectively (see Figure 13-a). As for the data of women, the average height, bust, waist and hip girth from the 2010 data were 160.4cm, 83.0cm, 69.3cm and 92.8cm, respectively (see Figure 13-b).

The average stature of male from the 2010 data has been found to be 173.3cm with a 95 percentile of 185.9cm for young men

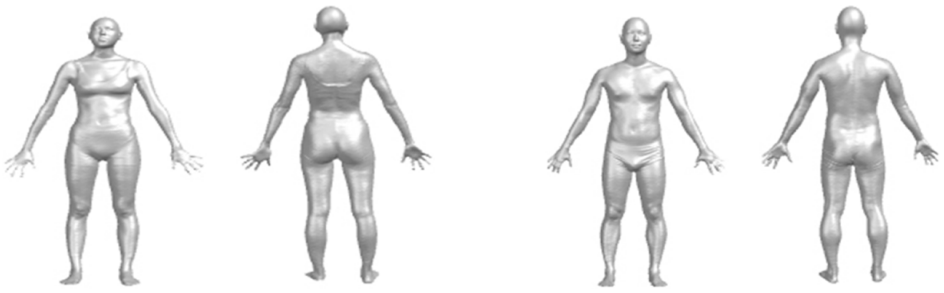
in their twenties. In comparison with the 1997 data, which showed an average stature of 171.8cm, there has been a 2cm increase.



(a) Men's wear (b) Women's wear

Figure 13. Regular size of KS

The means of height, chest/bust, waist and hip girth are 173cm, 93cm, 77.4cm and 94cm, respectively, in 19-year-old men, and respectively 160cm, 84cm, 69.3cm and 93cm in 19-year-old women. These sizes can be regarded as the standard young adult female and male body shape in Korea, as shown below in Figure 14 (Photos from "Size Korea 2010").



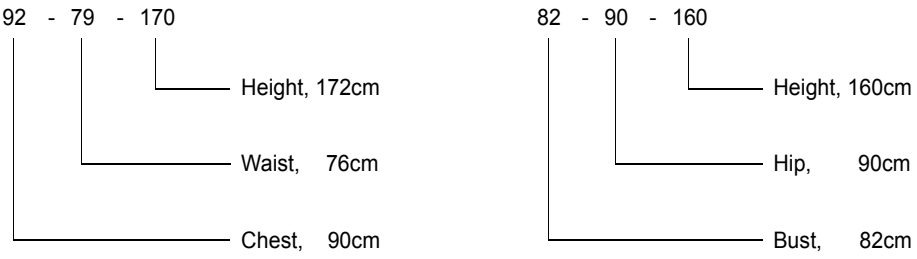
Women (Height 160, B-W-H: 84-70-93) Men (Height 173, C-W-H: 93-77-94)

Figure 14. Standard body shape of Korean women and men from 2010 data

3.6.2 Standard of Koreans from the data 1997

As for the data of women subjects in their twenties, the average height, bust, waist and hip girth from 1997 data were 159.8cm, 82.0cm, 65.8cm and 89.2cm, respectively. In 1997, the results for men in their twenties regarding the means of height, chest, waist and hip are 171.6cm, 89.6cm, 76.4cm and 92.6cm, respectively as shown in Figures 15(a), (b). The average stature of male from the 2010 data has been found to be 173.3cm with a 95 percentile of 185.9cm for young men in their twenties. In comparison with the 1997 data, which showed an average stature of 171.6cm, there has been a 2cm increase.

These sizes can be regarded as the standard young adult body shape in Korea, as indicated in Figure 16 (Photos from Lee data 1997).



(a) Men's wear (b) Women's wear

Figure 15. Regular size of KS

Women (Height 160, B-W-H: 82-66-90) Men (Height 172, C-W-H: 90-76-93)

Figure 16. Standard body shape of Koreans from 1997 data

3.7 Compatibility of the sizing system

3.7.1 Different sizing labeling with same bust measurement

ISO standards include the ISO/TC 133 norm pertaining to clothing that is applied in most European countries. As member states, European countries respect the ISO standards when establishing their clothing size standards and size labeling system. However, despite ISO's efforts, countries could not neglect consumer's preference for national clothing sizing system with which they are familiar with, and thus, they still continue to use the former national sizing system. Therefore, clothing based on the same physical features follows different sizing systems. Even when following the same sizing system, in practice, the corresponding measurements are different and thus bring confusion to consumers who pursue imported products or products from abroad.

For instance, a 92cm bust girth clothing is labeled differently in different countries, as shown below:

Japan	France
15	40
UK	Italy
14	44

3.7.2 Sizing standards of garments according to countries

Garment sizes can be by large divided into three, the European, American and the Asian systems, each having its own characteristics. In Table 2, we have reviewed the Korean, Japanese, French, Italian, German and American sizing norms distinguishing female sizes. We also look at their conformity to the ISO standards and the conformity between themselves (ISO 3637: JIS L 4005: AFNOR: DIN: KS K 0059: ASTM D 5586: UNI).

Table 2. Size chart of each size code by standards ISO, KS, JIS, AFNOR, Italy, DIN and ASTM

	80	84	88	92	96	100	104	108	112
ISO									
Size code	80	84	88	92	96	100	104		
Bust	80	84	88	92	96	100	104		
Waist	63	69	74	79	83	87	92		
Hip	87	92	96	99	103	106	109		
Height	160	160	160	160	160	160	160		
KS									
Size code	79	84	88	91	94	100			
Bust	79	84	88	91	94	100			
Waist	65	67	73	74	76	80			
Hip	88	90	94	96	98	102			
Height	160-164	160-164	160-164	160-164	160-164	160-164			
JIS									
Size code	7YR	9YR	13YR	15Yr	17YR	19YR			
Bust	80	83	89	92	96	100			
Waist	61	64	67	70	73	76			
Hip	85	87	91	93	95	97			
Height	158	158	158	158	158	158			
AFNOR									
Size code	34n	36n	38n	40n	42n	44n	46n	48n	
Bust	80	84	88	92	96	100	104	110	
Waist	58.6	61.8	65.2	68.8	72.6	76.25	79.85	85.3	
Hip	84	88	92	96	100	104	108	112	
Height	160	160	160	160	160	160	160	160	

Table 2. Size chart of each size code by standards ISO, KS, JIS, AFNOR, Italy, DIN and ASTM (Continued)

	80	84	88	92	96	100	104	108	112
Italy									
Size code	38	40	42	44	46	48	50	52	
Bust	80	84	88	92	96	100	104	110	
Waist	59	62	65	69	73	77	81	85	
Hip	86	90	94	98	102	106	110	116	
Height	164	164	164	164	164	164	164	164	
DIN									
Size code	17	18	19	20	21	22	23		
Bust	80	84	88	92	96	100	104		
Waist	65	68	72	76	80	84	88		
Hip	90	94	97	100	103	106	109		
Height	160	160	160	160	160	160	160		
ASTM									
Size code	2	4	8	10	12	14	16		
Bust	83,8	86.7	92.1	94.6	98.4	102.5	107.0		
Waist	64.4	66.4	71.1	73.6	78.1	82.6	87.6		
Hip	91.14	94.3	99.7	102.2	106.1	109.8	114.3		
Height	166.3	166.3	166.3	166.4	166.4	166.4	166.4		

4. Discussion

As the basis for the new sizing standards, anthropometric data collection, including three-dimensional information, together with the comparison of these data among countries are becoming necessary tools for the entire manufacturing community (Gupta, 2004).

In Korea, like many other countries, the mean height has been increasing in last several decades. In such countries anthropometric data will be outdated sooner or later. The information on the speed of the secular change in height in last several decades is useful to judge if the database is still representing the intended target population or to judge how long the latest database will serve as the reference data (Ashizawa K, 2002; Kouchi and Mochimaru 2005).

The comparison of the growth in both sexes are plotted in Figure 1 and Figure 2. In women, height increases from birth to maturity 3.2 times (for comparison it is 3.5 times for men) mainly due to rapid growth in leg length. The lines are very similar for both survey data. On average, maturity of growth in height is reached at the age of 17-18 years for males and 15-16 years for females.

The average stature of males from the 2010 data has been found to be 173.3cm with a 95 percentile of 185.9cm for young men in their twenties. In comparison with the 1997 data, which showed an average stature of 171.8 cm, there was a 2cm increase. As can be seen in Figures 1 and 2, the means of height, bust, waist and hip girth are respectively, 173.2cm, 93.0cm, 78.4cm and 94.3cm in men aged 19 years, and respectively 160.2cm, 83.6cm, 69.3cm and 92.8cm in women aged 19 years. These sizes are as large as Europeans in height (EN 13402-3, 2009), and have a narrower hips compared to American data from the ASTM standard (ASTM D 5585, 2011; LEE 2006; LEE 1999).

A number of studies have been carried out on the growth stages of puberty (Duke 1980; Tanner 1978; Tanner 1962). These reports showed that the puberty stages for boys appear at the age 9.1 to 12.5 years, while girls reaches the stages as early as 10.0 years. The growth stages are highly correlated to height growth as shown in Figures 1, 2.

The body proportion data from the 2010 surveys are plotted in Figure 3. Total body height is clearly of primary importance for all growing children for clothes-fitting purposes, and this has been recognized in many national standards (KS K 9402 2009; KS K 9403 2009; ASTM D 6458 2012; LEE 2003). Figure 3 shows the results of height dimension body proportion rate against the height. The results show respectively, 0.93, 0.81, 0.38, 0.99 and 0.26 times the height in eye height, shoulder height, fingertip height, span and maximum shoulder breadth. These values can be used to make work space and accessories design in order to predict the body length of each part (Greiner, 1992).

Figures 5, 6, 7, 8 show the body type of Korean divided by drop value. The values of chest girth according to waist girth are plotted in Figure 8-b. The regular body type N in women has the 6-9 drop value for bust and hip girth. These drop value distributions are quite similar in Japanese body type showing from JIS (JIS L 4005, 2001; LEE, 2006). Body size distribution sector is critical for size designation of body fitting clothes. The distribution ratio index of body height dimension corresponding to the bust/chest should be taken into consideration when designing good product construction systems.

Figure 9 shows the comparison between existing shapes with the desired virtual ones (i.e. a 8 head-tall-well-proportioned body), and with body shapes from 235 women from 20 to 29 years selected as harmonious body shape. According to the 8 head-tall- well proportional body, the waist height position should be at 100cm high for a woman being 160cm high (see the horizontal line).

As shown in Figures 14 and 16, the means of height, chest/bust, waist and hip girth are 173cm, 93cm, 77.4cm and 94cm, respectively, in 19-year-old men, and respectively 160cm, 84cm, 69.3cm and 93cm in 19-year-old women. These sizes can be regarded as the standard young adult female and male body shape in Korea, as shown below in Figure 14 (Photos from "Size Korea 2010"). The range of the Key dimensions at each sizing are reviewed based on Asian and European standards. These comparisons for the size designation system will eliminate the confusion that currently exists among countries and individual apparel designers.

5. Conclusions

The clothing sizing system is a recurrent problem with requires further research and improvement regarding sizing system standards, body measuring system and size labeling system in association with clothing manufacturers, consumers and researchers. The higher level information processing and control of studies on human body growth and developing the compatible sizing system of clothes will eliminate the confusion that currently exists among countries and individual apparel designers. In the present production processes, standardization, by reducing differences and disorder, by guaranteeing quality, by increasing production efficiency and the rapidity of improvements, plays an ever important role in promoting international trade. Further, it makes it easier to expand, and more comfortable to practice.

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Author listings

Young-Suk Lee: jaabo1994@naver.com
Highest degree: Ph.D. Otsuma University, Japan
Position title: Professor, Department of Clothing Science, Chonnam National University
Areas of interest: Anthropometry, Human morphology, Standards, Sizing