Analysis of Three-Dimensional Torso Shape and Bodice Pattern of Elderly Japanese Women

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Abstract

The population of individuals over 65 years old is growing rapidly. To provide well-fitting clothes for this population, it is important to clarify the difference in body shape between elderly and young women, and the quantitative relationships between flat patterns and body shapes. In this study, our aim was to clarify the factors that explain the diversity among young and elderly Japanese women's body shapes. The subjects were 107 elderly and 230 young healthy Japanese women. Six VIVID 910 non-contact 3D digitizers were used to measure their torsos. In each subject, from the 3-dimensional torso surface, two-dimensional diagrams of the body surface were made using the 3D CAD software and would be the basic pattern for making clothes for that subject. To enable statistical analysis, the 3D data of each individual were transformed to a homologous model and analyzed. The average shapes of the two age groups were calculated and an age difference was observed. Upon principal component analysis of the homologous models, nine factors were extracted. Most of these factors could be effective input variables for pattern making in addition to ordinary size variables. The shapes of the body surfaces were observed in association with the principal component scores of the models.

Keywords: clothing design, dress dummy, principal component analysis, classification

1. Introduction

Apparel fit is important not only in terms of comfort, but also aesthetically. Therefore, the apparel industry tends to design clothing for younger consumers and overlook consumers who are over 65 years old (Alexander, Cornell, & Presley, 2005 [1]; Thomas & Peters, 2009 [2]). In Japan, there is a similar situation. It is said that there are few clothes that satisfy the elderly population. In Japan, the aging society is growing and the percentage of individuals over 65 years old out of the total population exceeded 24.1% in 2012. The projected proportion of the older population out of the total population in 2025 is 30.3%, as the older population is expected to grow by 36,570,000 individuals (Cabinet Office, Government of Japan, 2013 [3]). The apparel industry cannot overlook the segment of the population that is increasing disproportionately at a greater rate than any other segment. In addition, Japanese elderly women are much more interested in clothing fashion than previous generations. Also, their savings are higher than those of other age groups. However, there are few comfortable and fashionable clothes that fit the body shape of elderly people (Watanabe et al. 1997 [4]), because of the lack of information that would be the basis for apparel design. In Japan, a national size survey called "Size Japan" was carried out in 2004 and more than 790 people aged over 60 were measured. However, the problems have not been resolved yet. We need not only size information but also body shape information to make a well-fitted pattern. An effective way of designing well-fitting products is to analyze human body forms and to classify them into several groups. There are few studies analyzing Japanese elderly women's body shape using three-dimensional data. In a previous study, we analyzed the changes in Japanese women's silhouette according to age which was calculated from 3D body measurement data (Watanabe et al. (1999) [5], Matsuyama & Watanabe, 2002 [6]), and from the angles, width, depth and height of the torso (Watanabe et al. [7]) or lower torso (Takabu et al., 2012 [8]), which were two-dimensional data although they were calculated from 3D body measurement data. The aims of the present study were to clarify the difference in the three-dimensional body shape between elderly and young women, and to elucidate factors that explain the diversity among young and elderly Japanese women's body shapes to make dress forms. Also, the body surfaces were calculated for each subject to obtain well-fitting basic patterns.

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2. Methods

2.1. Subjects and measurement

The subjects were 107 healthy elderly women aged 60 to 71 years and 236 healthy young women aged between 18 and 24 years. Their major body measurements are shown in Table 1.

Table 1. The body measurements of the subjects.

Item	Elderly women		Young women	
	Mean	S.D.	Mean	S.D.
	cm	cm	cm	cm
Height	152.1	4.9	157.6	5.2
Shoulder length	37.5	2.1	37.3	1.8
Waist length	39.0	2.4	37.5	1.8
Bust girth	87.2	7.9	81.1	5.0
Waist girth	74.0	8.6	65.7	4.7
Hip girth	89.7	5.7	91.3	4.4
	kg	kg	kg	kg
Weight	52.9	8.1	51.0	6.0

They were asked to put on a sports bra because we intended to design outerwear and a close-fitting elastic camisole on it. Eighteen landmarks were pasted on the body surface. The base lines, such as neck base line, armhole line and shoulder seam line, were drawn on the skin with eyeliner and the waist line was marked with 3mm wide tape.

The subject was asked to maintain the natural standing position, with their feet 20cm apart from each other and their arms abducing approximately 20 degrees. After they stood in the correct position, the tips of two horizontal bars were adjusted to touch the subject's back in the occipital region and sacral region, respectively. The subject was asked to maintain contact with the tips of the bars to avoid a swaying motion during the measurement. VIVID 910 non-contact 3D digitizers (Konica Minolta Sensing, Inc., Tokyo, Japan) were used in this study. The height and angle of the VIVID digitizers could be freely moved, and the digitizers were arranged in such a way that there was no loss of data at the side of the torso and the shoulders. The data from the six digitizers were consolidated using software that we had designed.

The origin was unified based on the landmarks; the back neck point was the origin of the X-axis (transversal direction), the trochanter point was the origin of the Y-axis (vertical direction) and the right side neck point was the origin of the Z-axis (sagittal direction). The models were not rotated around any axis. The areas outside of the armhole line, above the neckline and below the hipline were cut off.

2.2. Analysis of 3D body shape

The torsos were expressed by more than 180,000 points. To enable statistical analysis, the data for an individual were transformed to a homologous model (Fig.1) by the HBM (Homologous Body Modeling) software (Digital Human Research Center, Tokyo, Japan). Homologous modeling is a reconstruction of data points in such a way that the data for each subject will consist of the same number of data points of the same topology, and each data point will have the same anatomical position across subjects. Homologous models were not rotated at all to make them uniform, because gravity, which garments hang down parallel to, is very important in clothing design. Gravity causes the center and side seam to hang perpendicular to the floor. These models were then analyzed with principal component analysis using HBS-PCA (Human Body Statistica, Digital Human Research Center, Tokyo, Japan) [9] [10] to clarify which body parts showed major differences among the individuals.

Fig. 1. The polygon data of a subject after cutting off the unnecessary area for analysis (left) and Homologous model of the same subject (right.)

2.3. Development of body surface

We tried to observe how the principal components showing variation of the torso among individuals made a difference in the flat pattern shape. The body surface of each subject, which will be the basis of the clothing pattern, was calculated by 3D CAD software named “LookStailorX” (Digital fashion Co., Osaka, Japan). The procedure was as follows: the number of data points for each three-dimensionally measured data was redacted to approximately 1500 points, converted to OBJ data format, and entered into the 3D CAD software as a digital virtual dress dummy (Fig. 2). A tight fitting cloth was automatically generated on it. Then, the neck line, armhole line, center front line, center back median line, waist line, hip line, shoulder seam line and side seam line, the last of which is defined as the perpendicular line from the shoulder point, were drawn on it as a cutting line. Darts were defined referring to Bunka’s basic pattern and drawn as shown in Fig. 3. The pieces inside of these lines were cut out and transformed into a surface with 2D coordinates (Fig. 4). The distortions of the developed surfaces were within 2%.The surface data were entered into the apparel CAD system named CREACOMPO (Toray Advanced Computer Solution, Inc., Tokyo, Japan).

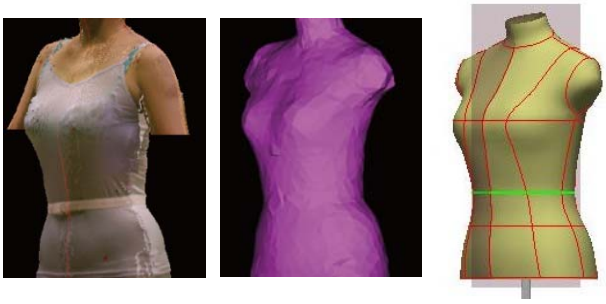

Fig. 2. The procedure of getting a subject’s three-dimensional measured data as the digital virtual dress dummy of “lookStailor X”.

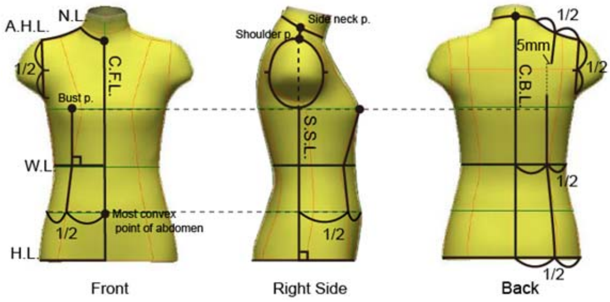

Fig. 3. The base lines and darts used as cutting line to develop the surface of the torso.

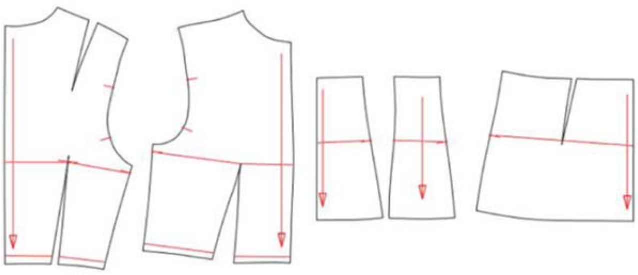

Fig. 4. A set of developed surfaces of the torso and the grain of each piece.

3. Results and discussion

3.1. The average shape of 3D body shape

The models were analyzed with DHRC-HBS human body shape statistics software, using the FFD (Free Form Deformation) technique. The FFD method is a way of deforming the shape of the object smoothly by moving control lattice points set around the object. The reference body form automatically deforms to coincide with the other body forms using the FFD method. Dissimilarity is defined by movements of the control lattice points [11]. Fig. 5 shows the average homologous models in the young and elderly age groups. We can observe the age difference in body shape visually. The elderly women had a wider waist, subcutaneous fat deposition on the iliac crest, rounded upper back, less protruded scapula, flatter buttock, lower breast, protruded abdomen, and a neckline that was inclined more forward. These models were expressed by 3d coordinates, and should be useful and directly applicable for making dress dummies or mannequins. Furthermore, calculations of the average model in subgroups that had been divided according to dress size or body type, which will be analyzed in the next section, should be more useful information for apparel manufacturers.

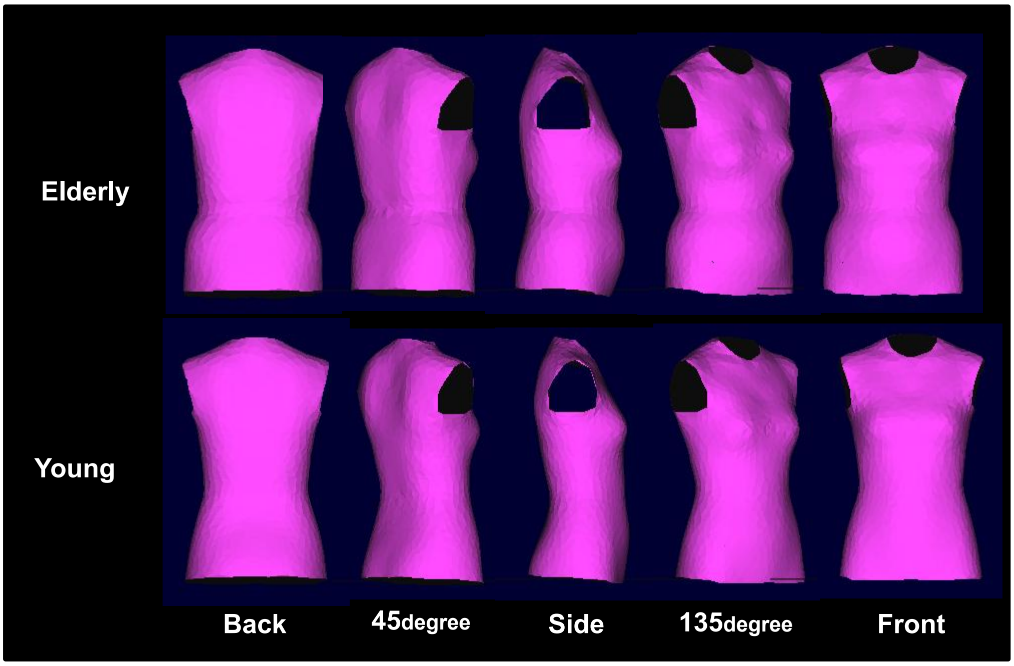

Fig. 5. The average models of each age group calculated by HBS software.

3.2. Principal component analysis of 3D body shape

Wide variations in the shape of the torsos were seen. The homologous models were analyzed by principal component analysis. The models of 107 young women were chosen randomly to be balanced with the number of elderly subjects. Nine principal components (PC) were extracted and the principal component scores for each individual were calculated. The results of the analysis are shown in Table 2. For each principal component, the subjects with a low principal component score and those with a high principal component score were compared. Furthermore, average +10 or +20 S.D. models and average -10 or -20 S.D. models for each principal component were generated by the HBS software; they were compared and the principal components were interpreted.

The first principal component (PC1) was interpreted as the factor of aging of body shape between

Table 2. The result of principal component analysis of the torso of 107elderly and 107 young women.

Principal component	eigen value	contribution ratio (%)	acumlate contribution ratio (%)
PC1	1362.2	30.3	30.3
PC2	961.4	21.4	51.6
PC3	713.5	15.9	67.5
PC4	608.8	13.5	81.0
PC5	124.1	2.8	83.8
PC6	103.0	2.3	86.1
PC7	72.9	1.6	87.7
PC8	64.7	1.4	89.1
PC9	54.0	1.2	90.3
total	4500.0	90.3	

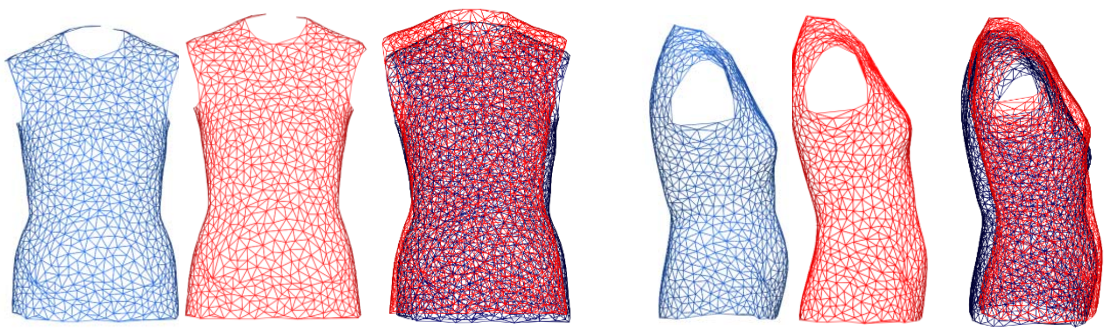

Fig.6 Models showing average -10S.D. and +10S.D.for PC1, which was interpreted as aging of body shape.

young women and elderly women (Fig. 6). In our previous study of young women, the torso of the subjects with a higher PC1 principal score was higher than that of the subjects with a lower principal score. It was interpreted as the height of the torso from the hip line level to the cervical point level because the side silhouettes were similar to each other [12]. In this study, the torso of the subjects with a higher PC1 principal score was higher than that of the subjects with a lower principal score. Therefore, the silhouettes are clearly different from each other in this study. The subjects with a low principal component score had a rounded back and flatter and lower bust, and those with a high principal component score had a straight back and higher bust. These features are similar to those of the average model of women described in section 3.1. Fig. 7 shows a scatter diagram, in which the 1st principal component score was plotted against the 2nd principal component score of the young and elderly subjects. As to the 1st principal component score, the two age groups overlap between minus 60 and plus 60. However, the elderly women tended to have lower scores and the young women tended to have higher scores. There were elderly subjects who had a score lower than minus 60 and there were young subjects who had a score higher than 60. We concluded that PC1 shows aging of body shape, including the height of the torso. The contribution ratio of this factor was 30.3%, and we can say that it is a factor that has a large contribution to the diversity in torso shape. However, the elderly women's body shape could not be sharply distinguished from young women's body shape. It was supposed that the appearance ratio changes with aging.

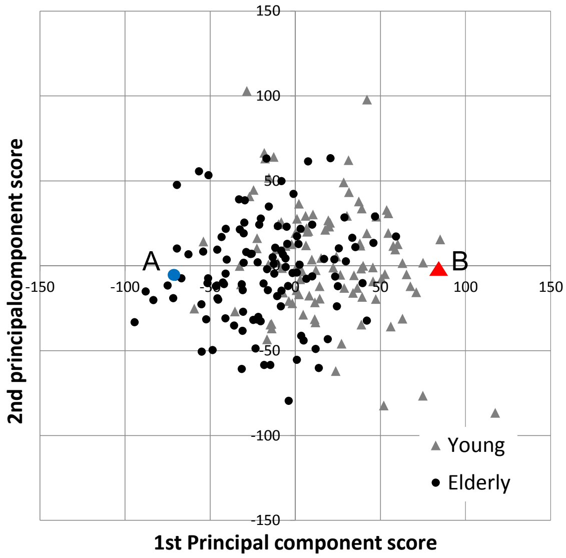

Fig.7 The distribution of the 1st and 2nd principal component scores of the subjects.

Figure 8 shows the other factors. The second principal component (PC2) was interpreted as the inclination of the torso above the waistline level forward or backward. The neckline of the subjects with a higher PC2 principal component score was located more backward than those with a lower score.

The third (PC3) and fourth (PC4) principal components were interpreted as thickness of the front or back side of the torso, respectively. For PC3, the subjects with a higher principal component score had a thick torso and erect back. On the other hand, the subjects with a lower principal component score had a thin torso and curved back. When they were superimposed, as the right-side neck point was the origin of the Z-axis (sagittal direction), a difference was seen in the thickness of the bust and abdomen area. For PC4, the subjects with a lower principal component score had a thick torso and rounded back. On the other hand, the subjects with a higher principal component score had a thin torso and erect back. When they were superimposed, as the right-side neck point was the origin of the Z-axis (sagittal direction), a difference was seen in the thickness of the lumbar and buttock area. The factor of posture and the factor of being fat or thin were combined in those principal components. The subjects with a higher PC3 principal component score and those with a lower PC4 principal component score had a thick torso, but the latter group had a rounded back. In pattern making of apparel, the center of gravity is important for deciding the grain. These facts suggest that the posture of subjects varies widely regardless of thickness or age.

The fifth principal component (PC5) was a concave lumbar area or flatter lumbar area. The subjects with a higher PC5 principal component score had a higher waistline and thick torso as well as a flatter lumbar area. The sixth principal component (PC6) was interpreted as inclination of the whole torso above the hip line level. The subjects with a higher PC6 principal component score had an erect posture and those with a lower PC6 principal component score had a curved back and swayed backward for balance to maintain an upright posture. The seventh principal component (PC7) was protrusion of the abdomen. The eighth principal component (PC8) was considered as distortion of the whole torso relative to the feet. Although both feet were carefully located perpendicular to the X-axis (transversal direction), the torso was rotated to the right or left side. This kind of distortion was seen among the young women. The ninth principal component (PC9) was forward or backward shoulder. The shoulder point and armhole of subjects with a higher PC9 principal component score were located forward.

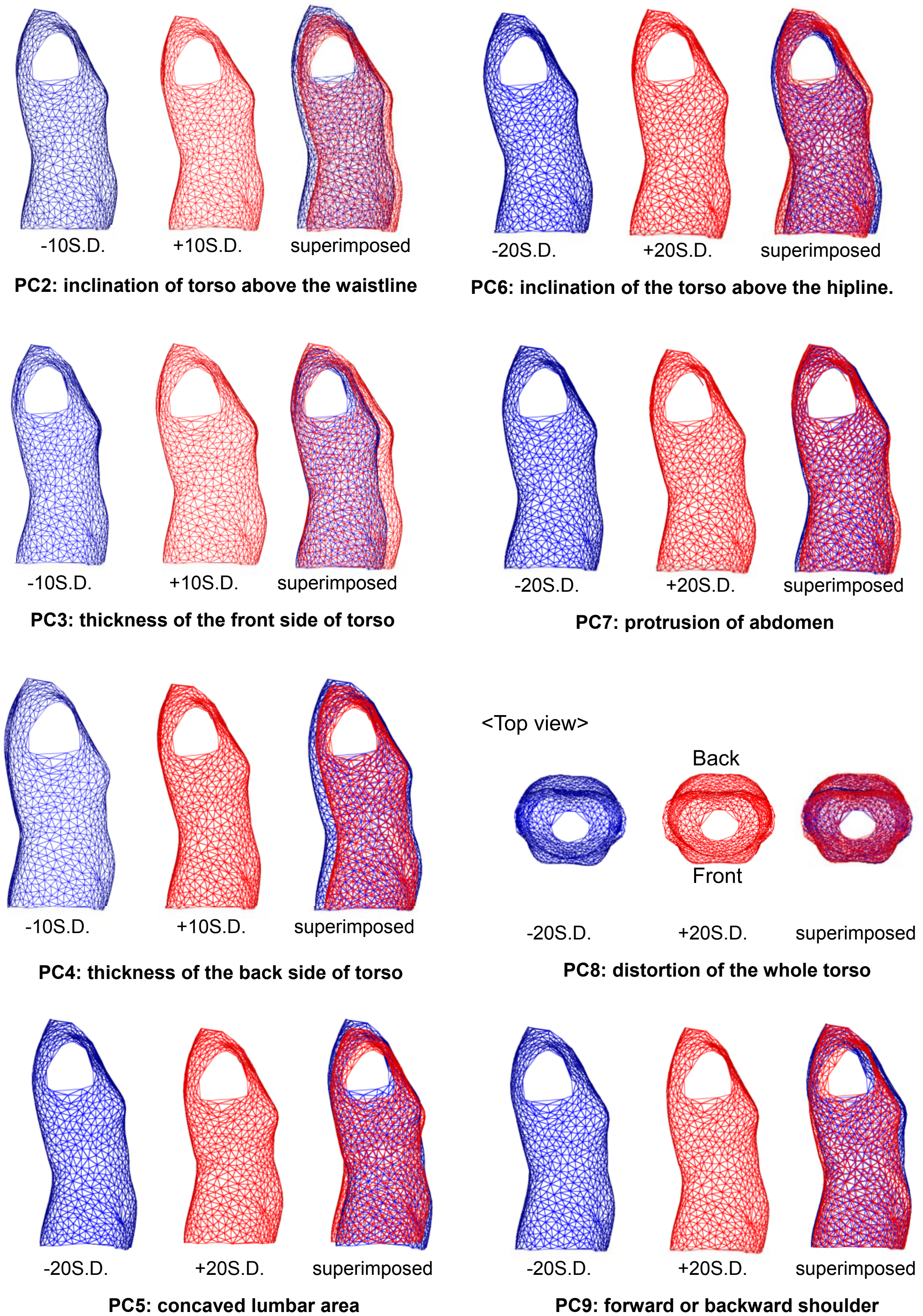

Fig.8 The modes showing average -10 or -20 S.D. and average +10 or +20 S.D. for each principal component, which is generated by HBS. The meanings of the PCs were interpreted respectively.

The contribution ratios of the first four principal components were relatively high and most of them included size like height and girth. As the principal component analysis used the 3D coordinate value of each apex of a polygon, and as the correlation coefficients between the coordinate values located nearby had a tendency to be higher, these results could be said to be natural or appropriate. On the other hand, the principal components with low contribution ratio showed more detailed shape. For example, protrusion of the abdomen (PC7) or forward or backward shoulder (PC9) causes serious fitting problems. Even with the distortions, when we design clothes, we cannot ignore this kind of asymmetry of the body and need to carefully consider which side or which part of the body shape or size should be used. Then, these factors could be effective input variables for pattern making in addition to ordinary size variables.

3.3. Development of body surfaces

The body surfaces of each subject were calculated by the 3D CAD software named “LookStailorX”, and would be the basis of clothing pattern. In Figure 9, the typical body surfaces of a subject who had a higher PC1 score and a subject who had a lower PC1 score, whose positions are shown as “A” and “B” in Fig. 7, were compared. For the subjects with a low PC1 principal component score, the width of the back bodice was wider, the shoulder dart was longer, the front length to back waist length was relatively longer, and the bust dart was shorter. These features suggest their rounded back and lower breast. This kind of information would be useful for designing clothes that correspond with aging or the diversity of body shape. In the next study, the body surfaces developed for each subject will be represented as x-y coordinate values of the apexes or the landmarks and be analyzed statistically, dividing the subjects into subgroups according to the principal component score.

Fig.9 Examples of the body surface development of the subject who has lower score or higher score of PC1 shown on Fig.7.

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