Analysis of Standing Posture Shapes of Elderly Women for Clothing Design

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Abstract: Essential for aged persons undergoing age-related body structure changes is the design of clothing patterns appropriate to their body shapes. The present study used a bodyline scanner to take three-dimensional (3D) measurements of 30 elderly women and 10 younger women in standing posture. From the 3D scan-derived data and principal component analysis (PCA) of homologous models, comparison and investigation were made of body shape characteristics of the two groups. From the 3D data, it was clarified that, compared with the younger women, the elderly women had larger the back protrusion point-cervicale horizontal distance and the back side angle of inclination, while the elderly women had smaller the back protrusion point-back waist point horizontal distance and the nipple to anterior waist length. Thus the upper body of elderly women inclined and curved forward. From the PCA of the shapes of elderly women, the following factors concerning posture were extracted: the high-low of height items, the extent of spinal curvature, the forward-backward inclination of the spine, the left-right differences of the spinal inclination, the rate of fatness-thinness, and the extent of protrusion of the trunk anterior surface. It was shown that accompanying increased age is the formation of unique body shapes.

Key words: elderly women, body shape, three-dimensional measurement, homologous model, principal component analysis

1. Introduction

In the White Paper on the Aging Society of 2010, the number of aged persons age 65 and older comprised 22.7% of the Japanese population; since then, the population of aged persons has continued to increase rapidly. An ultra-aging society has already formed in Japan, and an important issue is enabling aged persons to enjoy healthy, high-quality lives. Nevertheless, perhaps due to the low market presence of clothing for aged persons, there are few clothing items that take into account body-structure changes and the physical functions of aged persons. Now, with the Baby Boomers entering this aging group, if clothing that is suitable and proper for aged persons can be supplied, then aged persons can experience a better quality of life; plus, this would be a vibrant and expanding market. In order to provide age-appropriate clothing, it is necessary to investigate clothing patterns that fit the dimensions and body shapes of aged persons. Yet insufficient analysis has been made hitherto regarding the body shapes of aged persons specifically for clothing design.

As for prior research on the body shapes and clothing of older persons, research has been performed including an investigation of the three-dimensional (3D) shapes of upper torsos, and concerning dorsal shapes (1-3). No research exists, however, on typifying patterns for full-body 3D shapes, nor on comparisons with younger persons. To improve the appropriateness of clothing for aged persons, it is thought that it will be necessary to grasp not only body dimensions, but also body shapes.

Thus, as fundamental research for ensuring safe and comfortable clothing styles for aged persons, standing posture 3D measurements were made of elderly women and younger women, data was extracted therefrom, and body shape characteristics were ascertained for dimensional data of each group. Also, using the standing posture data for elderly women and younger women (hereafter, “the two groups”), standing posture body shapes were derived. Comparison was made of body shape characteristics of the two groups, and detailed analysis was performed for elderly women characteristics.

2. Materials and Methods

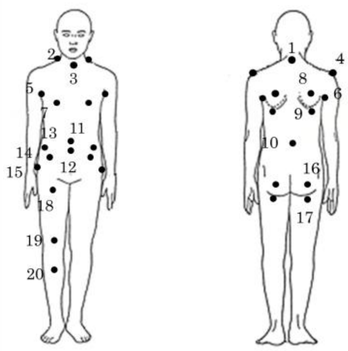
2.1 Subjects

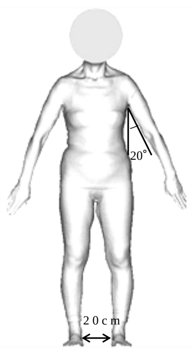
Subjects were 30 healthy women age 65 and older living in the Tokyo metropolitan area. As comparison subjects, data was collected and analyzed for 10 female university students. Average ages were, respectively, age 70 and age 21.

2.2 Measurement device and Measurement posture

For each subject, sticker-type landmarkers were attached at measurement-point locations as determined by the person performing measurements, and these were measured using a non-contact 3D measurement device (a bodyline scanner made by Hamamatsu Photonics Co.). Standard points used for measurement are shown in Fig. 1. To ensure a figure as close as possible to a nude state, subjects wore a flesh-colored tank top and tights, with no ties or other fasteners, with a white cap on their heads. Measurement time was approximately 10 seconds.

Measurement posture was as shown in Fig. 2. Based on ISO 20685, the head was facing in a frontal direction, with the orbitomeatal plane maintained horizontally. Upper limbs hung down naturally, with palms facing backwards, open approximately 20 degrees from the body side. As for feet, left and right foot axes were parallel, open such that the distance between foot axes was approximately 20cm.





1.Cervicale 2.Side neck point 3.Fossa jugularis point 4.Acromiale 5.Axillaris anterior 6.Axillaris posterior
7.Thelion 8.Peak of button 9.Angulus inferior scapulae point 10.Posterior waist point 11.Omphalion
12.Abdominal extension point 13.Iliocristale 14.Iliospinale 15.Trochanterion 16.Peak of buttock
17.Gluteal furrow point 18.Maximum thigh point 19.Patella Center 20.Maximum calf point

Fig. 1 Standard points of measurement

Fig. 2 Posture of measurement

2.3 Measurement items and Analysis

Standing posture measurement categories were 5 height, 4 breadth, 6 length, 7 circumference, and body weight, for a total of 23 measurement categories, and are shown in Fig. 3 and Table 1. In addition measurement results are shown in Table 1.

The upper body analyses, as shown in Fig. 4, used coordinate values (*x*, *y*, *z*) of 3D data, and comparison was made of four items: (a) back protrusion point-cervicale horizontal distance, (b) back protrusion point-back waist point horizontal distance, (c) cervicale-right side neck point horizontal distance, (d) cervicale-back protrusion point vertical distance. Also (e) back side angle of inclination, with a vertical line having its apex at the cervicale, and from the cervicale to the right back protrusion point connected with a straight line, was calculated. Further (f) front side angle of inclination, with a vertical line having its apex at the fossa jugularis point, and from the fossa jugularis point to the right bust point connected with a straight line, was calculated and investigation was made of the upper body inclination of the two groups. As for the lower body, measurements were made of the transverse diameter and thickness diameter of waist position and abdominal position in the abdominal region, and the body shape characteristics of the two groups were thus ascertained.

For the comparisons of the two groups, using the 3D data, examination were made of differences in mean values and the *t*-test, and body shape characteristics were compared and investigated. Differences of the two groups were ascertained from an overlapping horizontal sectional view and a vertical sectional view, with the back waist point used for the respective shapes of the two groups. In this way, the shape characteristics of elderly women were clarified.

2.4 Homologous models creation and Principal component analysis

Homologous model is shape data set with anatomical correspondence using an identical number of points and identical topological structures. From 3D scan-derived data, selection was made of 64 points among human body anatomical characteristics points; then, using BLM DHAIBA and DHRC-HBS-PCA software developed by the National Institute of Advanced Industrial Science and Technology, Homologous models were created, and the principal component analysis (PCA) was performed. The human body shape analysis was performed while excluding effects on the PCA, distal position from the upper arm maximum position, which was not included. From results of the PCA, analysis was made of body shape characteristics of elderly women in standing posture from comparisons with younger women.

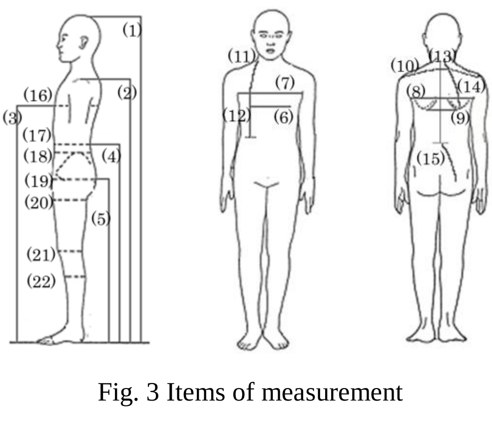


Fig. 3 Items of measurement

Fig. 4 Items of the upper body analysis

Table 1. Measurement results (mean value and standard deviation) in standing position of elderly women and younger women and dimensions change rates of the two groups (unit: cm)

Item	Younger		Elderly		Change rate (%)	*t*-test
	Mean	SD	Mean	SD		
(1) Height	159.5	2.5	153.2	4.3	-3.9	**
(2) Shoulder height	128.3	2.0	124.5	4.7	-2.9	*
(3) Nipple height	113.4	2.8	106.4	3.9	-6.1	**
(4) Back waist height	97.0	1.9	92.7	3.4	-4.5	**
(5) Peak of buttock height	78.6	2.1	75.0	3.7	-4.6	**
(6) Nipple to nipple breadth	16.2	1.4	16.4	1.4	1.1	
(7) Anterior biaxillary breadth	29.4	1.2	29.1	1.5	-1.0	
(8) Posterior biaxillary breadth	29.9	1.4	30.4	1.9	1.5	
(9) Angulus inferior biscapular breadth	16.2	0.5	16.9	1.4	4.2	
(10) Posterior biacromial arc	39.3	1.8	39.1	2.4	-0.5	
(11) Side neck to nipple length	25.9	1.6	27.9	2.5	7.6	*
(12) Nipple to anterior waist length	16.8	2.2	13.5	2.2	-19.4	**
(13) Cervical to posterior waist length	38.7	1.9	39.0	2.6	0.6	
(14) Cervical to angulus inferior scapular length	22.4	3.5	23.8	2.3	6.1	
(15) Back waist to peak of buttock length	20.3	1.0	19.2	1.7	-5.3	
(16) Bust circumference	84.1	3.1	90.1	7.0	7.0	*
(17) Waist circumference	69.0	2.5	80.3	8.5	16.4	**
(18) Abdominal circumference	78.1	4.5	89.7	7.4	14.8	**
(19) Hip circumference	91.1	2.6	92.5	4.9	1.5	**
(20) Thigh circumference	53.9	2.8	51.6	3.9	-4.2	
(21) Knee circumference	36.4	1.3	35.4	2.3	-2.5	
(22) Calf circumference	34.0	1.7	34.0	2.3	-0.1	
(23) Body weight (kg)	50.4	3.7	52.4	7.5	3.94	

*: $p < 0.05$, **: $p < 0.01$

3. Results

3.1 Upper body analysis of elderly women and younger women

To ascertain in detail differences in upper body of the two groups, investigation was made regarding items: (a) back protrusion point-cervicale horizontal distance, (b) back protrusion point-back waist point horizontal distance, (c) cervicale-right side neck point horizontal distance, (d) cervicale-back protrusion point vertical distance, (e) back side angle of inclination and (f) front side angle of inclination. First, for each item, measurement values and dimensions change rates of the two groups based on the younger women are shown in Table 2. As for dimensions change rates, (a) back protrusion point-cervicale horizontal distance was 30.3%, (e) back side angle of inclination was 22.4%, and (b) back protrusion point-back waist point horizontal distance was -20.0%. The item that showed the most remarkable dimensions change between the two groups was (a) back protrusion point-cervicale horizontal distance, which, at a 5% level, was a significant difference. From these results, it was made clear that the posture profiles of the two groups were greatly different, with the neck of elderly women protruding forward more than younger women, and with the upper body of elderly women having a greater forward inclination and forward curvature.

3.2 Abdominal comparison of elderly women and younger women

To investigate details regarding the abdomen of the two groups, comparisons were made of measurement values of the transverse diameter and thickness diameter and their differences at waist position and abdominal position. The results are shown in Table 3. The abdominal dimensions of elderly women were larger than that of younger women, and significant differences ($p < 0.05$) between the two groups were observed. Between the two groups, thickness diameters were larger than the dimensions change rates in the transverse diameters; as for waist oblateness, elderly women was 80.5% and younger women was 69.7%, showing that thickness was a body shape characteristics of elderly women. It is thought that this is because elderly women have more accumulation of subcutaneous fat in the abdomen than younger women.

Table 2. Measurement values of upper body in a standing posture of elderly women and younger women and dimensions change rates of the two groups (unit: cm)

Item	Younger		Elderly		change rate（%）	*t*-test
	Mean	SD	Mean	SD		
(a) Back protrusion point-cervicale horizontal distance	4.9	1.3	6.3	2.0	30.3	*
(b) Back protrusion point-back waist point horizontal distance	3.6	1.0	2.9	1.9	-20.2	
(c) Cervicale-right side neck point horizontal distance	3.4	0.8	3.3	0.7	-3.1	
(d) Cervicale-back protrusion point vertical distance	15.3	1.2	15.9	1.8	3.9	
(e) Back side angle of inclination（ °）	17.6	5.0	21.6	5.6	22.4	
(f) Front side angle of inclination（ °）	25.2	2.6	24.0	7.3	-4.6	

*: $p < 0.05$

3.3 Cross-section views comparison of elderly women and younger women

Shown in Fig. 5 are horizontal and vertical sectional views of the two women overlapped at the back waist point with subjects of an elderly woman and a younger woman close to the mean values selected for upper body and abdomen comparison items. The side silhouette of the elderly woman differs from that of the younger woman; especially clear are the roundness and thickness in the back, and mastoptosis. Also remarkable is the protuberance of the trunk anterior surface of the elderly woman, and it is clear that the cross-section shape of the trunk of the elderly woman is thicker, and closer to a round shape, compared with that of the young woman.

Table 3. Transverse diameter and thickness diameter of abdomen of elderly women and younger women (unit: cm)

	Transverse diameter				Thickness diameter			
	Younger	Elderly	Change rare(%)	*t*-test	Younger	Elderly	Change rate (%)	*t*-test
Waist position	25.4	27.8	9.3	*	17.7	22.4	26.8	**
Abdominal position	29.0	31.5	8.7	**	19.8	24.4	23.8	**

*: $p < 0.05$, **: $p < 0.01$

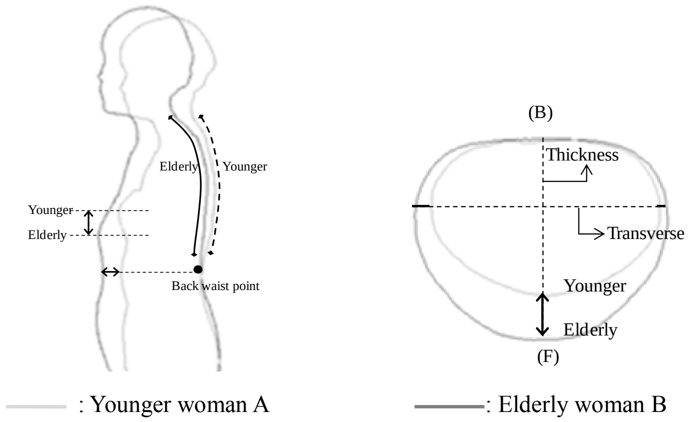


Fig. 5 Cross-section views overlapped at the back waist point with an elderly woman and a younger woman (left: vertical sectional view, right: horizontal sectional view)

3.4 Principal component analysis using the homologous models for elderly women, and comparisons with younger women

To investigate shape from the difference results between the two groups as in the horizontal and vertical sectional views, using the 3D scan-derived data of 30 elderly women, standing posture homologous models were created, and the principal component analysis (PCA) was made therewith. The results of PCA of the homologous models were, as shown in Table 4, such that since up through the sixth principal component the cumulative contribution ratio was 81.44%, interpretation was performed up through the sixth principal component. The principal component scores from the first principal component to the sixth principal component are shown in Table 5.

Table 4. Results of principal component analysis using standing position homologous models of elderly women

PC	Content	Eignvalue	Contribution ratio(%)	Cumulative contribution ratio(%)
No 1	high-low of the height items	10071.00	25.86	25.86
No 2	extent of curvature of the spine	8010.30	20.57	46.42
No 3	backward-forward inclination of the spine	4821.10	12.38	58.80
No 4	right-left differences of the spinal inclination	4195.90	10.77	69.57
No 5	rate of fatness-thinness	2512.20	6.45	76.02
No 6	extent of protrusion of trunk anterior surface	2112.00	5.42	81.44

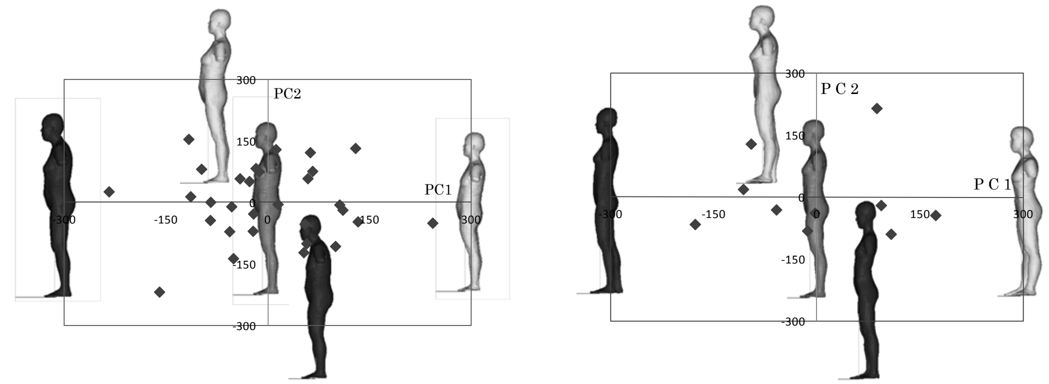
The scatter diagrams for the principal component scores of elderly women are shown at the left side of Fig. 6. Further shown is an overlap with the body shape image created from the 3D scan-derived data and the PCA results. Here, the middle image shows the average shape, while the right and upper images show the shape of mean value (M) + 3 standard deviation (SD), and the left and bottom images show the shape of M – 3 SD. Together therewith, the scatter diagrams for the principal component scores of 10 younger women is shown at the right side of Fig. 6.

The scatter diagram of (a) of elderly women shows the first principal component (1PC) on the x-axis, and the second principal component (2PC) on the y-axis. As for the shape of 1PC, as the height dimension showed major changes, this was interpreted as a factor showing “high-low of the height items.” As for the shape of 2PC, as the back shape showed major changes, this was interpreted as a factor showing “extent of curvature of the spine.” The

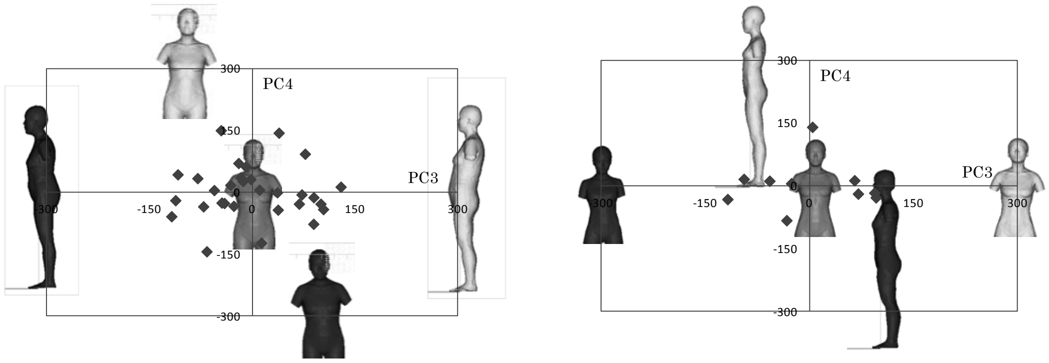
Table 5. Principal component scores using standing position homologous models of elderly women

No.	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
1	65.84	77.03	-20.15	69.49	54.58	14.24
2	-27.48	52.27	-27.22	-34.45	31.01	-16.20
3	-85.18	-42.94	99.97	-29.22	25.30	-75.91
4	-117.03	155.29	10.38	4.70	-38.97	-9.72
5	110.50	-17.77	13.20	-123.83	-28.40	-37.01
6	14.70	-3.67	-118.07	-59.67	49.12	17.99
7	132.84	-46.26	-17.12	34.46	-97.78	-4.61
8	-17.83	84.09	37.50	-43.74	-11.12	-29.92
9	-53.74	-9.34	-71.47	-35.67	29.98	-150.61
10	54.47	-52.03	-112.24	-20.69	-56.12	27.26
11	52.81	-121.53	-45.76	149.07	-84.59	-38.48
12	99.61	-106.38	-2.24	30.55	23.42	112.87
13	-21.46	-27.07	-66.62	-144.72	-68.70	29.32
14	243.15	-49.54	-13.67	25.81	59.60	-46.25
15	11.74	130.19	-44.73	-26.53	42.34	-5.35
16	-234.72	27.14	72.20	-6.69	-66.03	38.58
17	-22.11	-69.31	-40.85	-27.49	6.45	19.22
18	-98.20	82.19	-108.87	42.00	-27.43	8.74
19	-160.28	-217.98	-31.87	16.47	97.56	14.13
20	-84.62	1.54	-9.49	61.12	11.17	10.62
21	57.09	-99.74	89.42	-78.03	54.95	30.26
22	129.23	133.16	103.76	-42.30	-3.78	27.53
23	-41.38	58.97	89.65	-13.48	70.37	30.57
24	-56.72	-70.29	36.44	-1.55	-5.60	47.92
25	58.85	59.30	38.82	142.98	34.66	-31.40
26	-13.00	76.10	77.10	91.97	2.26	24.95
27	105.84	-5.10	68.35	-29.23	-22.81	-9.76
28	62.42	122.84	-55.77	3.81	-28.97	34.44
29	-114.23	15.08	-79.97	32.79	25.14	6.12
30	-51.08	-136.23	129.32	12.07	-77.62	-39.56

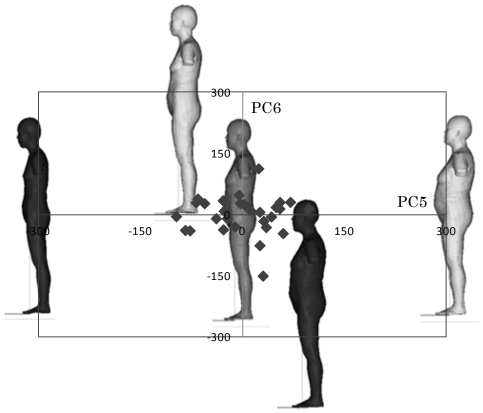
scatter diagram of (b) of elderly women shows the third principal component (3PC) on the x-axis, and the fourth principal component (4PC) on the y-axis. As for the shape of 3PC, since there were differences in the inclination of the body backward and forward, this was interpreted as a factor showing “backward-forward inclination of the spine.” As for the shape of 4PC, in contrast to the small changes in shapes of height, breadth and circumference, since there were changes in the inclination of the body right and left sides, this was interpreted as a factor showing “right-left differences of the spinal inclination.” The scatter diagram of (c) of elderly women shows the fifth principal component (5PC) on the x-axis, and the sixth principal component (6PC) on the y-axis. As for the shape of 5PC, In contrast to the small changes in height dimensions, since changes in the circumference and breadth were large, this was interpreted as a factor showing “rate of fatness-thinness.” As for the shape of 6PC, since there were changes in the trunk front anterior surface, this was interpreted as a factor showing “extent of protrusion of trunk anterior surface.”



(a) First and second principal components (left: elderly, right: younger)



(b) Third and forth principal components (left: elderly, right: younger)



(c) Fifth and sixth principal components (elderly)

Fig. 6 Scatter diagrams by principal component scores of homologous models in standing posture of elderly women and younger women, and body shapes

In regards to the PCA results for younger women, interpreted as the factors for expressing: the PC1 was “the balance of height items and breadth items,” the PC2 was “the balance of breadth items and depth items,” the PC3 was right-left differences of the spinal inclination,” and the PC4 was “the balance of body height and height items.”

From the results of the principal component analysis of the homologous models and body shapes, extracted for elderly women as factors concerning posture were spinal curvature, body backward-forward inclination, and protrusion of trunk anterior surface; many factors were thus extracted that are related to the spinal shape changes that are particular to elderly women. For younger women, extracted were factors expressing the balance of height, breadth, and depth dimensions. It was thus clear that research results can be summarized as showing that there exist completely different body shape characteristics between the two groups. In this way, the shapes of elderly women in a standing posture are various, and in order to design clothing that is highly appropriate for elderly women, it will be necessary to reflect the particular body shape characteristics of elderly women, especially changes of the spine.

Finally we aim clothing design that is suitable for the detailed body shape characteristics of elderly women, such that each designed item fits each individual body shape; this is done by the creation of 2D patterns from 3D average shape, and via the appropriate combination of dart quantities, stitch locations, etc.

4. Conclusion

Three-dimensional body data in a standing posture was extracted for 30 elderly women living in the Tokyo metropolitan area, and investigation was made of the characteristics of elderly women in a standing posture vis-a-vis a comparison with 10 younger women. The main results were as stated below.

(1) Compared with younger women, the back protrusion point-cervicale horizontal distance and the back side angle of inclination of elderly women were larger, and back protrusion point-back waist point horizontal distance and nipple to anterior waists length of elderly women were smaller; it was made clear that the neck of elderly women protruded forward, and the upper body of elderly women inclined and curved forward.

(2) As the principal component analysis results regarding the standing posture shape of elderly women, extracted as the first principal component was “high-low of the height dimension” with “extent of curvature of the spine” “backward-forward inclination of the spine” “left-right differences of the spinal inclination” “rate of fatness-thinness” and then “extent of protrusion of trunk anterior surface” following in order thereafter; for younger women, factors of height, breadth, and depth dimensions were extracted.

(3) One can summarize the analysis results as having made clear that elderly women and younger women have completely different body shape characteristics. In clothing design for elderly women, it is necessary to reflect their unique body shape characteristics, namely the curvature and inclination of the spine, and the protrusion of trunk anterior surface.

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