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A Study on Changes to the Upper Body Shape of Elderly Japanese Women -Analysis of the Transverse Plane by Age Group-

Hee-Kyoung Oh†

Dept. of Organic Materials & Fiber Engineering, Soongsil University

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Abstract

This study determined how the upper body shape of elderly women changes with age in order to improve the fit of clothing worn by elderly women. Thirty-nine healthy elderly Japanese women had their body measurements taken by measuring tape and a 3D body line scanner (Hamamatsu Model #C9036-02) from December 2011 to March 2012 at a university in Tokyo. It was found that the shoulder line shortens in women between the ages of 70 and 74, but that the upper arm lengthens in women between the ages of 75 and 79. It was also found that the upper part of the scapular area rolls forward in women between the ages of 70 and 74, and that the point of the back which protrudes the most–the lower scapular area–rolls forward in women between the ages of 75 and 79. The results will be helpful for designing clothes for elderly women as their body shape changes with age.

Key words: Elderly women, Upper body, Body measurement, Transverse plane, Age group

I. Introduction

Japan has the world's highest proportion of people older than the age of 65, currently 27.3% of the total population. Indeed, Japan has been a super-aged society since 2007 (that is a society where the percentage of the elderly is at least 20.0%), and swiftly passed through the stages of an aged society in 1994 (14.0%), and an aging society in 1970 (7.0%). The average life expectancy is also increasing every year in Japan. In 2016, it reached 80.75 yrs for men, and 86.99 yrs for women, after first exceeding the age of 50 yrs for both males and females in 1947. Japanese life expectancy is currently also close to the highest in the world (Cabinet Office, Government of Japan, 2016).

Like most people, elderly Japanese women want the highest possible quality of life, and this can be helped by designing clothes that match the changes to their bodies as they age. Japanese women are also interested in clothes and generally express more desire than man to conceal their changing physical shape (Oh et al., 2013; Okada & Sakata, 2013). Elderly women are different from young women not only in the way that they physically function but also in their body shape (Akiyama et al. 1982; Ashdown & Na, 2008; Okada, 1999, 2000) Individual differences in elderly women's body shape exist, and an individual's body shape will change as they get older (Connell et al., 2006; Nakaho, 1991; Okabe et al., 1994; Okada, 2005; Shiraishi & Doi, 1982; Watanabe et al., 1999). Many elderly women are not satisfied with the aesthetics of poorly fitting ready-to-wear garments, and also suffer discomfort when such garments do not suit their changing bodies (Cone, 1984; Watanabe et al., 1997). In order to improve these problems, information is needed about the body morphology of older women, and new flat pattern designs for the elderly woman need to be pro-

†Corresponding author
E-mail: ohk@ssu.ac.kr
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duced (Okada & Sakata, 2013). Elderly Japanese woman can be divided into several age bands due to their long life span, and in this study we have categorized information about elderly women's physiques and body forms into four five-year age groups (65-69 yrs, 70-74 yrs, 75-79 yrs, and 80+ yrs respectively).

To contribute to clothes that better fit elderly Japanese women's upper torso, this study took body linear measurements of the upper body based on the short-measurement drafting system for each of the age groups (Miyoshi & Nakamoto, 1990; Tomita et al., 1987). The way that elderly women's upper bodies vertically bend with aging due to the deformation of the vertebra has been investigated (Iwasaki et al., 1998; Watanabe et al., 2000), however to date there has not been specific research into the lateral or horizontal changes that occur to elderly women's upper bodies as they age. As such this study seeks to address this omission by analyzing the transverse plane of elderly women's upper bodies and evaluating changes that occur in this area by age group.

II. Methods

1. Subjects

Thirty-nine elderly women participated in the study from December 2011 to March 2012 at a university in Tokyo, Japan. All the women were living in Tokyo, in good health, and able to walk to the school campus. For the study, each woman wore white short pants, a soft brassiere and a beanie hat for tucking hair up that were made of soft stretchable polyester material and would provide accurate silhouettes for measurements. <Table 1> shows the height and weight for the specific age groups in this experiment and from the『Japanese body size data book 2004-2006』(Research Institute of Human Engineering for Quality Life, 2008). The height and weight of the subjects showed no significant differences from data from the『Japanese body size data book 2004-2006』, except for the subjects aged 80+ yrs. For this latter group there was no corresponding information obtained.

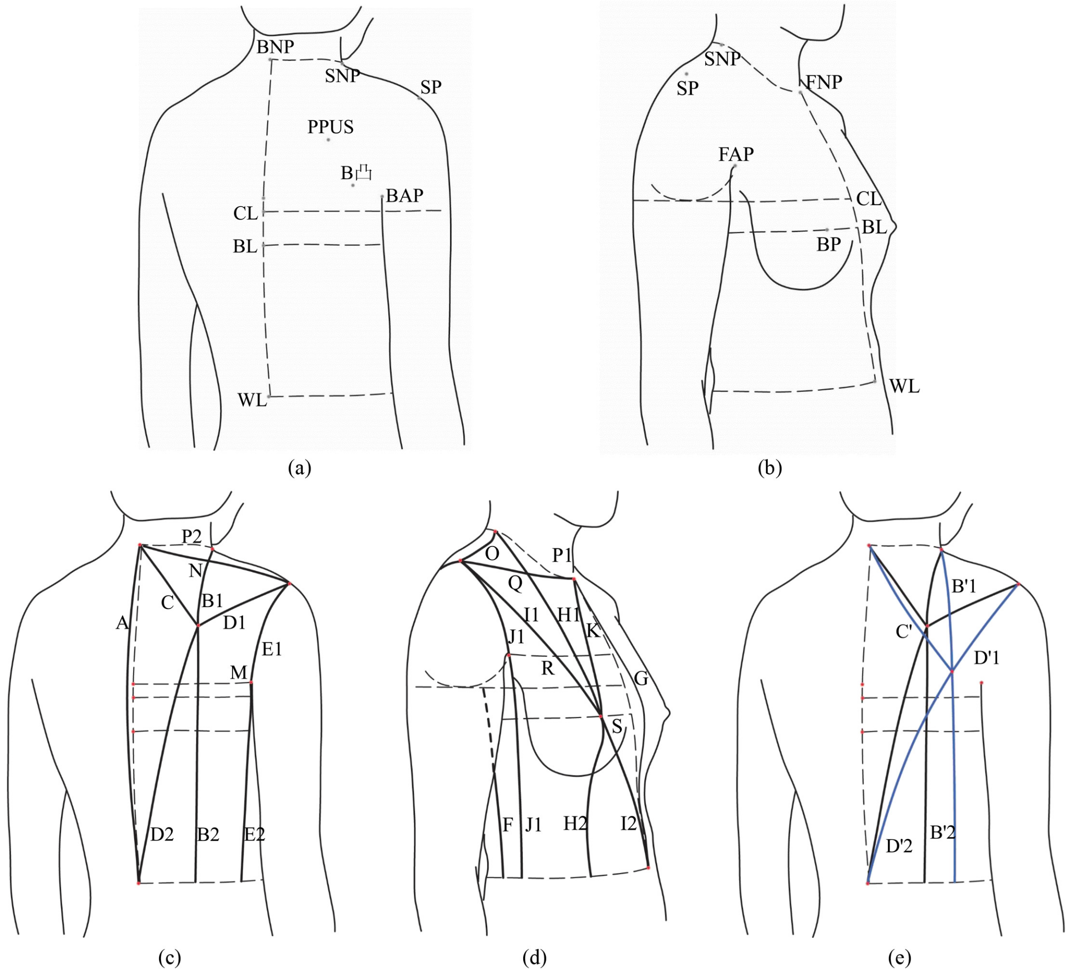
2. Body Measurement and Data Processing

<Fig. 1> and <Table 2>–<Table 3> show body measurement points and positions on the right side of the torso. These measurements taken corresponded with the short-measurement drafting system<Fig. 2>, which needs liner measurements through points of the body and as such differs from the proportional method drafting system where calculations are based solely on bust measurement (Miyoshi, 2000). <Fig. 1(a)>–<Fig. 1(b)> show measurement points at upper body for the short measurement draft system. The short measurement drafting system requires 25 measurement items <Fig. 1(c)>–<Fig. 1(d)>, for drawing flat patterns. However, following the fitting experiment of Tabata (1998), these measurements do not fully suit elderly people. Therefore in this study five variable lines <Fig. 1(e)> were added to the point of the back that protrudes the most (B凸) below the scapular bone, to take into account forward body bends in elderly women (Nakaho, 1991). Thus for body measurements there are a total of 30 values, and they were taken using both a measuring tape and a 3D body line scanner (Hamamatsu Model #C9036-02).

In order to make precise physical measurements, black triangle stickers were placed on the subject's bo-

Table 1. The height and weight by age group

	Measurement in this experiment				Research Institute of Human Engineering for Quality Life	
Age group	65-69	70-74	75-79	80-	60-69	70-79
Number of persons	10	8	10	11	426	399
Anthropometric dimension	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Height (cm)	148.51 (4.35)	149.89 (3.64)	151.50 (4.22)	147.29 (3.86)	148.51 (4.35)	149.89 (3.64)
Weight (Kg)	50.07 (5.29)	50.90 (10.91)	54.07 (7.42)	46.17 (5.77)	50.07 (5.29)	50.90 (10.91)



(a) and (b) show points on the body, (c) shows the back of the body, (d) shows added lines at the back of the body for elderly woman, (e) shows the front of the body.

Fig. 1. Short-measurement drafting system with body linear measurements of points and positions in elderly women.

dies to mark all measurement points (Makabe, 1991). Most body linear measurements were taken directly above the body with measuring tape, except lengths A and G. A is the distance from the back neck point (BNP) to the back center waist line (BCWL). Length A was measured by placing celluloid plates on top of the right and left scapular bone so as not to measure the hollow adhered to the back of the body. G is the distance from the front neck point (FNP) to the front center waist line (FCWL). Length G was also measured by placing celluloid plates on top of the right and left bust points so as not to measure cleavage adhered to the front of the body.

The transverse plane of the body shape can be discerned using a 3D body line scanner (Hamamatsu Model #C9036-02) (Miyoshi, 2000). In order to ascertain all body measurement points through body scanning, silver circle reflection stickers were placed on the body at all points. While having their measurements taken, subjects were required to maintain a natural standing posture with their feet 20cm apart so that clear scans of the crotch area could be taken, and to

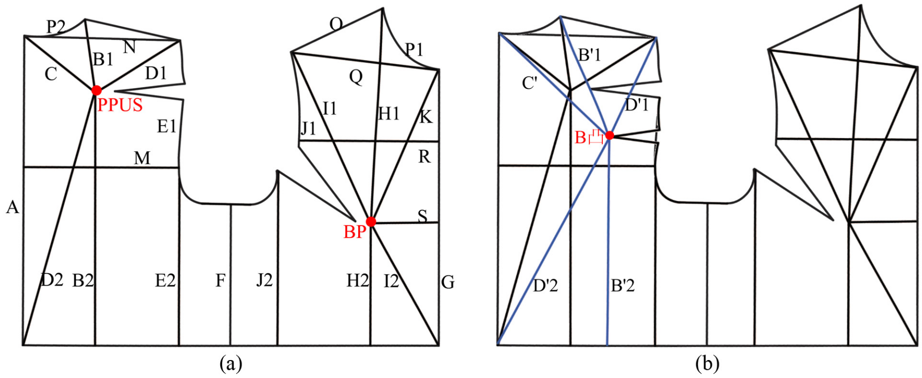
Table 2. Point abbreviations and their full names from <Fig. 1>

Division	Acronym	Somatometry
Point	FNP	Front Neck Point
	BNP	Back Neck Point
	SNP	Side Neck Point
	SP	Sholder Point
	BP	Bust Point
	FAP	Front Axillary Point
	BAP	Back Axillar Point
	B凸	The most Protruding Point at Back
	PPUS	Protruding Point at Upper Part of the Scapula
Line	ML	Median Line
	CL	Chest Line
	BL	Bust Line
	WL	Waist Line
	FCWL	Front Center Waist Line
	BCWL	Back Center Waist Line

Table 3. Values of the short-measurement drafting system for elderly women and related distances

No.	Fig. 1	Variables	Measurement distance
1	(c)	A	from BNP to WL
2		B1	from SNP to PPUS
3		B2	from PPUS to WL
4		C	from BNP to PPUS
5		D1	from SP to PPUS
6		D2	from PPUS to BCWL
7		E1	from SP to BAP
8		E2	from BAP to WL
9		N	from BNP to SP
10		M	from BML to BAP
11		P2	from SNP to BNP
12	(d)	B'1	from SNP to B凸
13		B'2	from B凸 to WL
14		C'	from BNP to B凸
15		D'1	from SP to B凸
16		D'2	from B凸 to BCWL
17	(e)	F	from CL to WL
18		G	from FNP to WL
19		H1	from SNP to BP
20		H2	from BP to FCWL
21		I1	from SP to BP
22		I2	from BP to FCWL
23		J1	from SP to FAP
24		J2	from FAP to WL
25		K	from FNP to BP
26		O	from SNP to SP
27		P1	from FNP to SNP
28		Q	from FNP to SP
29		R	from FAP to FML
30		S	from BP to FML

Variables are illustrated in <Fig. 1>.



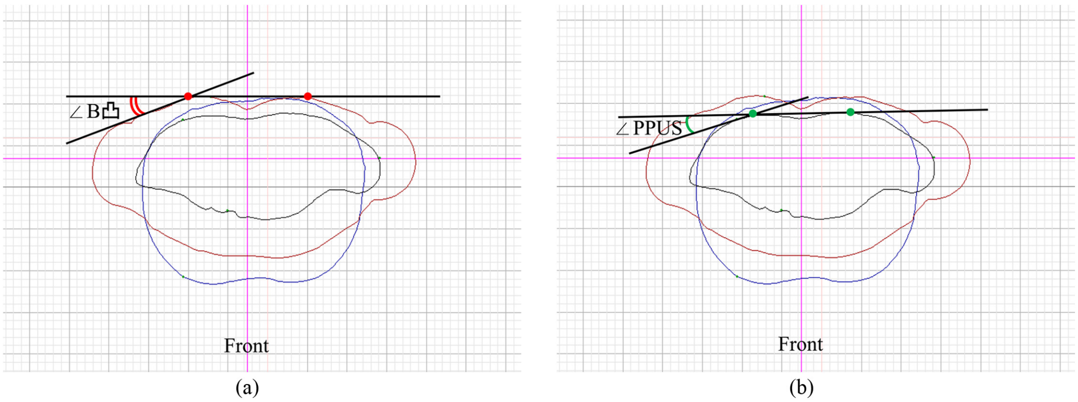
(a) is for adult upper body; (b) is added lines at the back for elderly women.

Fig. 2. The upper body short-measurement drafting system for elderly women.

stretch out their arms to approximately 30 degrees for measurements of the axillary area. Transverse planes were graphed at 3 heights of the body on one page. The first was the protruding point at the upper part of the scapula (PPUS), the second was the point that protrudes out furthest at the back (B凸), and the third was the bust point (BP) for distinguishing the front and back of the body. <Fig. 3> shows the method used to measure angle PPUS (∠PPUS) and angle B凸 (∠B凸). ∠PPUS is between the horizontal extension line at right and left at PPUS and the tangent line on it's right side. ∠B凸 is between the horizontal extension line at right and left at B凸 and the tangent line on it's right side.

3. Statistical Analysis

All quantitative data for the thirty-nine body linear measurements and the two angle values were expressed as mean and standard deviations (Mean, ±S.D.). In order to analyze the elderly women's body changes as they aged a Kruskal-Wallis Test was performed for the four different age groups. Once a significant main effect was found, post hoc analysis using the Mann-Whiteny U-test was undertaken. In order to identify the position of the protruding point at the upper part



(a) ∠PPUS, (b) ∠B凸; Abbreviations of body measurement variables are shown above in <Fig. 1>.

Fig. 3. Measuring degree of ∠PPUS and ∠B凸 in transverse plane.

of the scapular (PPUS) and the point that protrudes out furthest at the back (B凸), paired *t*-tests were performed between the length of lines between points B1&B'1, B2&B'2, C&C', D1&D'1 and D2&D'2 respectively. All statistical analysis of experimental data was carried out using SPSS (Version 24.0, SPSS Inc., USA).

III. Results and Discussion

1. Body Linear Measurements

Paired-samples *t*-tests were conducted to evaluate the impact of the length of lines from PPUS and B凸 at the back of the upper body. There was a statistically significant difference in length B1&B'1 (t=–31.089, p<.000), B2&B'2 (t=–26.485, p<.000), C&C' (t=32.866, p<.000), D1&D'1 (t=–13.728, p<.000) and D2&D'2 (t=–24.571, p<.000). Additionally, this difference was significant in all age groups. Further, there was a statistically significant increase in length between B1&B'1 (Mean=9.652, ±S.D.=1.913), C&C' (Mean=6.905, ±S.D.=3.100, and D1&D'1 (Mean=8.107, ±S.D.=1.887). But there was a significant decrease in length between B2&B'2 (Mean=–9.252, ±S.D.=1.735) and D2&D'2 (Mean=–10.231, ±S.D. =2.566).

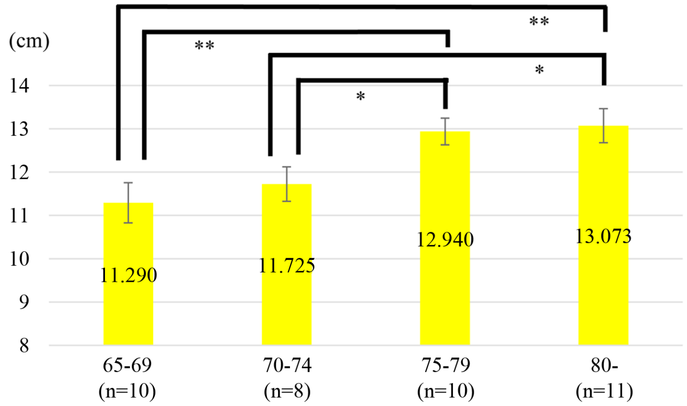
<Table 4>, < Fig. 4>–< Fig. 5> show the mean and standard deviation of the thirty-nine body linear mea-

Table 4. Body linear measurements in four different age groups

	65-69	70-74	75-79	80-	Kruskall-Walls Test
	n=10	n=8	n=10	n=11	
Linear (cm)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	χ^2
A	34.810 (2.122)	35.138 (1.166)	36.060 (2.412)	35.409 (1.325)	2.245
B1	9.300 (1.356)	8.463 (1.324)	9.800 (1.249)	9.127 (1.300)	4.162
B2	26.870 (2.207)	28.450 (1.400)	28.620 (2.206)	27.645 (1.925)	6.209
C	11.420 (1.761)	10.400 (1.369)	10.290 (3.976)	11.336 (1.440)	2.206
D1	11.090 (1.231)	9.838 (.789)	10.660 (2.061)	10.500 (1.590)	3.541
D2	28.520 (2.477)	30.563 (1.627)	30.050 (3.101)	29.264 (2.252)	5.337
E1	16.940 (1.149)	18.400 (1.560)	17.450 (1.490)	17.645 (1.590)	5.613
E2	13.700 (2.312)	13.263 (1.952)	14.770 (1.842)	13.209 (1.275)	3.812
N	17.900 (1.701)	16.725 (.759)	17.540 (1.147)	16.945 (1.391)	4.591
M	16.720 (1.208)	16.763 (2.135)	17.520 (1.482)	17.027 (1.426)	2.214
P2	7.990 (.863)	7.438 (.731)	7.956 (.665)	7.609 (.975)	4.625
B'1	18.333 (1.435)	18.313 (1.548)	19.530 (2.926)	18.800 (1.458)	1.290
B'2	17.956 (1.596)	19.325 (2.223)	18.900 (2.014)	18.573 (2.211)	1.945
C'	17.300 (1.609)	16.875 (1.464)	18.530 (1.914)	17.945 (1.646)	3.842
D'1	18.222 (1.057)	18.738 (2.009)	19.170 (2.092)	18.309 (1.431)	1.409
D'2	18.467 (1.622)	20.375 (2.240)	19.490 (2.403)	19.182 (1.843)	3.453
F	14.370 (1.529)	14.988 (1.136)	14.070 (2.507)	13.964 (2.452)	3.764
G	29.790 (2.296)	29.138 (4.124)	30.310 (1.789)	29.418 (1.795)	0.967
H1	26.620 (1.780)	26.838 (2.312)	27.740 (1.619)	27.500 (2.041)	1.738
H2	9.780 (3.119)	10.663 (2.499)	9.710 (2.344)	8.864 (1.937)	2.029
I1	23.350 (1.420)	23.863 (2.193)	24.654 (1.671)	24.436 (1.886)	3.905
I2	12.690 (2.357)	12.575 (2.682)	12.880 (2.131)	11.673 (1.625)	3.884
J1	11.290 (1.469)	11.725 (1.129)	12.940 (.978)	13.073 (1.308)	14.641**
J2	18.320 (2.117)	18.938 (1.761)	17.780 (1.777)	16.755 (2.213)	2.263
K	21.520 (1.749)	21.538 (2.462)	22.690 (1.704)	22.336 (1.945)	1.615
O	11.960 (1.490)	10.338 (.659)	10.860 (1.016)	10.391 (1.177)	8.523*
P1	10.830 (.558)	11.388 (.772)	11.130 (.975)	10.464 (.726)	4.550
Q	17.200 (1.106)	16.625 (.992)	17.050 (1.113)	16.345 (.927)	3.285
R	15.820 (1.033)	16.000 (1.276)	16.200 (.839)	15.682 (1.112)	1.435
S	8.590 (1.273)	8.675 (1.201)	8.640 (1.617)	7.845 (1.223)	2.407

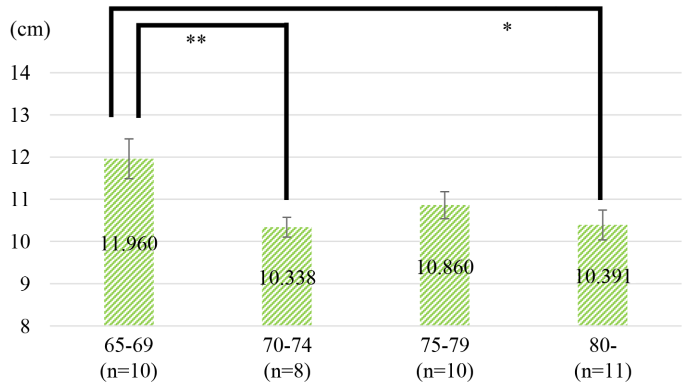
*p<.05, **p<.01

p-values for the main effect of Kruskal-Wallis Test are shown: Abbreviations of measurement variables are shown in <Fig. 1>–<Fig. 2>.



*p<.05, **p<.01
Significant findings obtained from post hoc analysis are Mann-Whiteny U-test;
Abbreviations of measurement variables are shown in <Fig. 1>−<Fig. 2>.

Fig. 4 Linear measurements of J1 (from shoulder point to front axillary point) in four different age groups.



*p<.05, **p<.01
Significant findings obtained from post hoc analysis are Mann-Whiteny U-test;
Abbreviations of measurement variables are shown in <Fig. 1>−<Fig. 2>.

Fig. 5 Linear measurements of O (from side neck point to shoulder point) in four different age groups.

surements and also *F*-ratios and *p*-values in each age group by Kruskal-Wallis Test. It reveals a statistically significant difference in two values, those of the front upper armhole from the shoulder point to the front axillary point (length J1) and the shoulder line from the side neck point to the shoulder point (length O). Length J1 increased from the younger to the older age group χ^2(3, n=39)=14.641, p<.01, in other words the recorded mean increased with aging. However on the contrary, for length O across four different age groups χ^2(3, n=39)=8.523, p<.05, the recorded mean decreased overall with aging. In order to ascertain which of the age groups are statistically significantly different from one another in length J1 and O, a Post hoc analysis was conducted. The result of the Mann-Whitney U-test revealed statistically significant different length J1 and O for each age group. Length J1 shows a significant increase in the 75-79 yrs and 80+ yrs groups compared to the 65-69 yrs and 70-74 yrs. But length O shows a significant decrease in the 70-74 yrs and 80+

yrs age groups compared to the 65-69 yrs age group.

In general, an elderly woman's upper body shape curves with aging. The short-measurement drafting system has only one protruding point at the upper part of the scapula (PPUS) as a reference point for guiding back darts. The upper part of the scapular area is the part of the back upper body in young women that protrudes out the most, but for elderly women who hunch their upper bodies forward, the point that protrudes the most is below the area of the scapular bone (Nakaho, 1991). Therefore in this study a new B凸 reference point for elderly women was added to the short-measurement drafting system, and five lines of body measurements were created from it. The lines were made from B凸 to the side neck point (B'1), the back neck point (C'), the shoulder point (D'1), the waist line (B'2), and the back center waist line (D'2). The length of lines were significantly different in the five lines from PPUS and B凸 as in between B1&B'1, B2&B'2, C&C', D1&D'1 and D2&D'2 and this was observed in each age group as well as for the totality of elderly women. Essentially this means that PPUS and B凸 at back upper body are at a different position in all elderly woman bending forward. Additionally, lengths B'1, C', D'1 were greater than B1, C, D1, but lengths B'2 D'2 were less than B2, D2 respectively. This shows that the B凸 position is significantly below the PPUS position. However, lengths B1, B2, C, D1, D2 and B'1, B'2, C', D'1, D'2 did not show a significant difference in any age group, which means that the position of PPUS and B凸 are quite similar across age groups.

The elderly woman's upper body changes were present across all of the age groups. Analyses from all thirty-nine body linear measurements in the women show that only two length values (J1 and O) were significantly different in each age group. Shoulder line (O) becomes significantly shorter from 70 yrs, and front upper armhole (J1) became significantly longer from 75 yrs. In other words, thirty-nine body linear measurements and the body shapes they reflected found in 65-69 yrs elderly woman's did not visibly change until 70+ yrs. Further, analysis also shows that lengths J1 and O change across age groups significantly. Watanabe et al. (1997) survey on the fitting of elderly women's ready-to-wear garments found the highest levels of dissatisfaction with the shoulder and arm hole areas. Specifically, the shoulder point area did not fit well, and also drops. Further, wrinkles appear in the front and back sleeves' arm holes and it is difficult for wearers' of these garments to raise their hands while wearing these clothes. Additionally, when they put their arms forward for writing, their backs were tight, and the back hems were raised up. Furthermore, Okada (2005) found that the arm joint's range narrows with the aging process due to decreasing physical ability, so women who are 70 yrs and over generally prefer front opening clothes over pullover style clothing. Therefore, in order to properly design elderly women's clothes, adequate concern must be paid to changes in the shoulder area shape with aging.

2. Angles Measurements

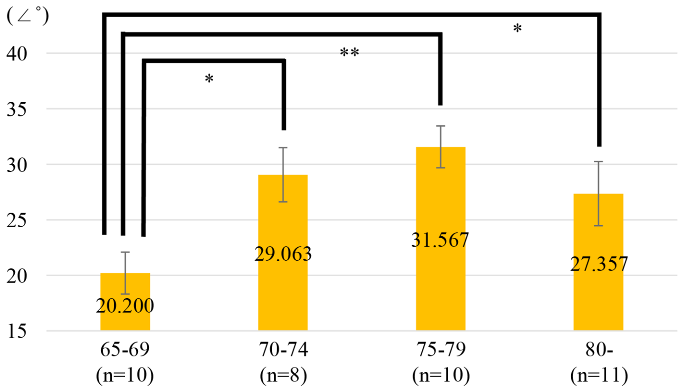
<Table 5>, <Fig. 6>–<Fig. 7> present the average values and standard deviations for two angle measurements along with the *F*-ratios and *p*-values of each age group by Kruskal-Wallis Test. They revealed a statistically significant difference in ∠PPUS across the four different age groups χ^2 (3, n=39)=10.027, $p<.05$, showing that the recorded mean increased with aging. And ∠B凸 across the four different age groups χ^2 (3, n=39)=15.329, $p<.05$, also showed a recorded mean that increased with aging. In order to know which of the age groups are statistically significantly

Table 5. Body angle measurement at ∠PPUS and ∠B凸 in four different age groups

	65-69 (n=10)	70-74 (n=8)	75-79 (n=10)	80- (n=11)	Kruskall-Wallis Test
Angle (°)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	χ^2
∠PPUS	20.200 (5.344)	29.063 (6.887)	31.567 (5.670)	27.357 (7.640)	10.027*
∠B凸	25.856 (3.297)	25.463 (9.922)	37.067 (5.423)	36.586 (6.458)	15.329**

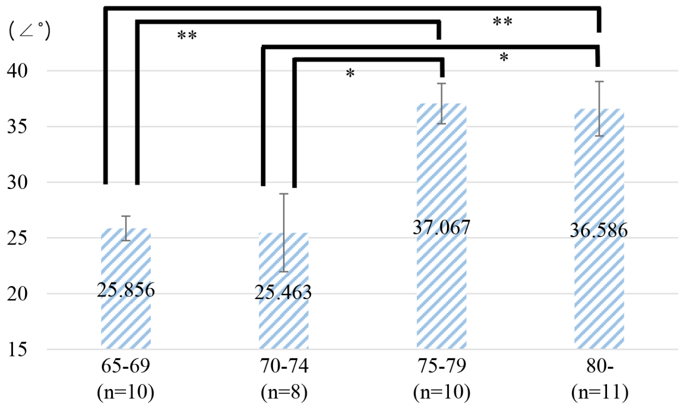
*$p<.05$, **$p<.01$

p-values for the main effect of Kruskal-Wallis Test are shown; Abbreviations of measurement variables are shown above in <Fig. 3>.



*p<.05, **p<.01
Significant findings obtained from post hoc analysis are Mann-Whiteny U-test;
Abbreviations of measurement variables are shown in <Fig. 3>.

Fig. 6 Angle measurements of ∠PPUS in four different age groups.



*p<.05, **p<.01
Significant findings obtained from post hoc analysis are Mann-Whiteny U-test;
Abbreviations of measurement variables are shown in <Fig. 3>.

Fig. 7 Angle measurements of ∠B凸 in four different age groups.

different from one another, a Post hoc analysis was conducted. The result of the Mann-Whitney U-test revealed a statistically significant different angle of ∠PPUS and ∠B凸 in each age group. ∠PPUS significantly increases in the 70-74 yrs, 75-79 yrs and 80+ yrs groups compared to the 65-69 yrs group. Also ∠B凸 significantly increases in the 75-79 yrs and 80+ yrs groups compared to the 65-69 yrs and 70-74 yrs age groups.

In general, the more that the upper torso bends forward in elderly women, the more the amount of back dart volume increases. Therefore, it is better that a flat pattern for the elderly has two darts in the back body so as to prevent bulging at the end of one of the darts (Hirokawa, 2008). However, up to now the optimum position for the additional dart has not been clear. This study suggests adding another back dart at the point that protrudes out the most (B凸), below the scapular area in elderly woman. In other words, in order to achieve the most subtle and finely tuned fit for elderly women's curved backs, there needs to be not only a back dart at the PPUS as is the case with clothing for young woman but also one more back dart at B凸.

Elderly women's upper bodies roll forward horizontally with aging. The degree of ∠PPUS and ∠B凸 increased between some age groups. Significantly, the degree of ∠PPUS soared from 70+ yrs, and the degree of ∠B凸 soared from 75+ yrs. In other words, two angle measurements found in the 65-69 yrs group of women's body shape did not visibly change until 70+ yrs. But from the age of 70, it was found that the upper part of the scapular area starts rolling inward horizontally, and it continues to roll at the part of the back that protrudes the most in women over the age of 75. Nakaho and Iwasa (1985) concluded that in order to show less curvature of the back of the body in an elderly woman whose upper body is bending forward, horizontal darts are a better design line than vertical darts. In order for clothes to best suit elderly women who are more than 70 yrs of age, 2 darts need to be adjusted in accordance with the wearer's body's changes. This study suggests upper back dart designs from PPUS to armhole, and lower back dart designs from B凸 to the armhole as well.

IV. Conclusions

This study was conducted in order to improve the fit and suitability of clothing for elderly women to better reflect the way that their bodies change as they age. Specifically, the study's analyses focused on changes to the back of the body morphology within body linear measurements based on the short-measurement drafting system and angle measurements through a transverse plane perspective. A total of 39 elderly subjects were measured across four different age groups (65-69 yrs, 70-74 yrs, 75-79 yrs, and 80+ yrs).

Japanese women have a long life expectancy and their bodies continue to change with age. Upper body linear measurements show that the shoulder line shortens where it is related to the neck side point from the shoulder point in women between the ages of 70 and 74, but the upper arm area lengthens in women between the ages of 75 and 79. Furthermore, their upper bodies bend forward so that the point which protrudes out the most is below the scapular, but this position does not differ across the different age groups. The upper body also tends to roll horizontally with age: the upper area of the scapular starts rolling in women from between the ages of 70 and 74 and the area which protrudes out the most, that is the lower area of the scapular, begins to roll in women from between the ages of 75 and 79. Therefore, elderly women aged 70's back darts should be divided into two rather than one dart because of the volume of the back darts. Furthermore, the 2 back darts should have a different volume from a 75 yrs old elderly woman, whose back dart from B凸 should be bigger than for a woman 74 yrs old or younger. In the near future it will be necessary to analyze the amount of darts required to allow elderly women's garments to fit appropriately and look aesthetically pleasing by extracting the darts at their back draping by toile. The present study suggests that in order for clothes to smoothly fit the upper body of elderly women, the design of their clothes needs to reflect the changing body shape of elderly women across different age groups.

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