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Developing of Grading Method using 3D Body Measurement Data of Women in Their Thirties

-Focusing on Their Proper Body Types-

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Abstract : The purpose of the present study is to develop a grading deviation, which is appropriate for the body type of women in thirties, by analyzing the three-dimensional body type. The materials for the study were adopted from the body measurement data of women in the age group of 30 to 39 years old, provided from Size Korea. By reflecting the factor analysis results using the three-dimensional shape measurement, deviations were derived. First, six factors influencing the changes in human body shape were derived as waist-hip length factor, bust-waist shape factor, back protrusion back shoulder factor, bust length factor, shoulder length factor, and frontal waist dart factor. The bust size and height, which can be easily utilized for the top original grading, were used for deriving a regression formula, and the deviation was set in accordance with the result. Second, by applying the deviation which reflects the changes in the body shape, the crimps which were generated due to the application of existing deviation were remarkably reduced, indicating that the grading of the present study is more fitting than the existing one. The deviation derived by the analysis of actual increase and decrease of body size was more fitting than the existing one. This was proved by actual wearing experiment, which represents the significance of this study.

Key words : master pattern, 3D scan data, grading, grade rule development, female body shape, grading deviation

1. Introduction

Grading, which refers to the increase or decrease in the size level of a certain pattern, can be utilized as an efficient system suitable for many persons depending on the appropriateness of the standard pattern. One of the most typical issues shown in the grading of existing ready-made clothing is poorly fitting clothes as the wearer's size deviates from the standard size, due to uniform deviation that does not reflect the characteristics of body types (Bye et al., 2007; Petrova & Ashdown, 2008; Taylor & Martin, 1984). The reason for this is the lack of standardized data, and the fact that the setting of the size mainly depends on the experience of pattern makers. Even though pattern grading is an essential process for ready-made clothes manufactured for the many and unspecified, domestic clothing companies still apply standard sizes, units, and ranges of measurement, and deviations, which are not alike. In addition, the criteria for the lack of scientific or systematic basis have been reported (Sohn & Hong, 2005). Setting standardized sizes, characteristics, and the change mode of women's body types should be considered while setting the grading deviation. Especially, busts of women in their thirties are lower than in their twenties due to pregnancy and childbirth, and they have thicker waists and sagged hips, along with a dimmed curve when looked at from the side. Women have a thicker waist and trunk with increasing age. This should be reflected in the manufacturing process of clothes, but the trunk grading of common clothing companies is not applied according to body analysis. Patterns should reflect the length and circumference and also the difference in the length between the bust and shoulder and the dart for each size of body type (Choi, 2001; Jang, 1997). The largest size is the most problematic for customers' fitness with regard to grading (Bye et al., 2007).

Data acquired by a three-dimensional scanner not only enables the collection of simple figures, but also the establishment of complex DB including various characteristics such as the human body cross-section, datum points, angles, area of body surface, or length of body surface. The degree of fitness of clothes with sizes far from the standard can be increased by basing the grading deviation on human body measurements (Schofield & Labat, 2006) and the three-dimensional body shape data should be utilized to determine

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the grading deviation.

Previous studies relating to grading concerned suggesting a size system (Cho & Choi, 2002; Jeon, 2004; Jung, 2009; Kwon, 1997; Lim, 2010), a grading method (Cho, 1994; Schofield & Labat, 2006), and grading of virtual attire (Ng, 2011; Wang & Huang, 2011). However, few studies involved setting a deviation derived from the search of three-dimensional changes in the human body type, or led to actual verification.

This study aims to analyze the three-dimensional body shape of women in their thirties to determine the grading deviation that reflects their characteristics, and to reflect the body shape in the grading of clothing patterns.

2. Method

2.1. Materials

The somatotype classification of the upper body of lateral view was based on previous studies. In this study, 3D body scan images and lateral shoulder to the lateral waist line were used to classify the side somatotype. The study included 138 women who were found to have the proper body type in the lateral body type classification, selected by a group of five clothing experts, among a total of 456 women in the age group of 30 to 39 years from the fifth Korean human body measurement project (Korean Agency for Technology and Standards, 2004). The bust circumference and height of examinees with the proper body type was divided into intervals of 3cm and 5cm, according to the size interval suggested in the adult women's size standard (KS K 0051: 2009), while a bust circumference of 91cm and height of 160cm were used as the master size.

2.2. Study items and method

A total of 54 three-dimensional body shape analysis items were used in the study, comprising the cross-sectional arc length, cross-sectional factors, length of body surface, and shoulder. SPSS 16.0 for Windows was used for the statistical analysis. The three-dimensional human body measurements were performed using Rapidform 2006 (INUS Technology, Inc. Korea), and AutoCAD2005 (Autodesk, Inc.). The Super-Alpha plus program (Youthhitech, 1997) was used for incision-type grading.

2.2.1. Analysis of the length of body surface

Items 33 through 54 in Table 1 relate to the length of the body

Table 1. Body measurement items

Height length(6)		20	Bust	38	HC Back Arc
1	Stature	21	Waist	**CF reference plane surface length(4)**	
2	Acromion	22	Hip	39	CF B-W
3	Cervical	**Breadth items(4)**		40	CF W-H
4	Bust	23	Chest	41	CB B-W
5	Waist	24	Bust	42	CB W-H
6	Hip	25	Waist	**BP reference plane surface length(4)**	
Length items(10)		26	Hip	43	Front face B-W
7	Waist front	**Depth items(4)**		44	Front face W-H
8	Cervical to waist	27	Armscye	45	Back face B-W
9	Scyedepth	28	Bust	46	Back face W-H
10	Waist back	29	Waist	**Shoulder surface length(8)**	
11	BP to BP	30	Hip	47	Biacromion
12	Waist to hip	**Etc.(2)**		48	Back neck point to shoulder protrusion
13	Shoulder	31	Right shoulder slope	49	Shoulder point diagonal
14	Bishoulder	32	Drop	50	Side neck point to shoulder protrusion
15	Interscye, front	**Arc length(6)**		51	Shoulder
16	Interscye, back	33	BC front	52	Shoulder front
Circumference items(5)		34	BC back	53	Shoulder point front diagonal
17	Neck	35	WC front	54	Side neck point to bust point
18	Neck base	36	WC back		
19	Chest	37	HC front		

*Note: BC(Bust Circumference), WC(Waist Circumference), HC(Hip Circumference), CF(Center Front), CB(Center Back), B-W(Bust-Waist), W-H(Waist-Hip), B-W(Bust-Waist)

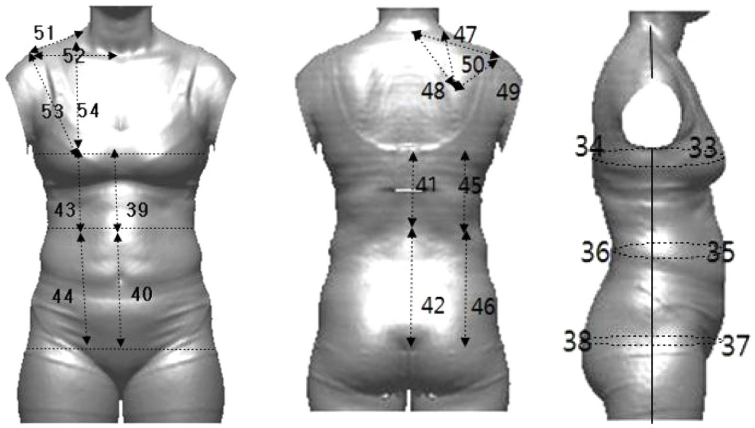


Fig. 1. Parts measured to determine the length of the body surface of the three-dimensional human body shape.

surface, while the parts measured with the length of the body surface are shown in Fig. 1.

2.2.2. Analysis of cross-sectional factor

In this study, 3D body scan images were used to classify the side somatotype. The plumb line passed through tragion, the bust depth and abdomen depth region laterally. Since the human body has different thickness ratios on both the front and back, depending on the baseline, the thickness ratios of the respective front and backsides for each measurement interval should be analyzed and reflected in the grading.

2.2.3. Analysis of shoulder shape

To measure the length of body surface, the point which is most protruded when looked at from above, while setting the frontal side as the bottom, based on the middlemost side of the human body, was set as the shoulder bone upper protrusion point, and the remaining standard points were marked to measure the length of the body surface. The line, which connects the back neck point and lateral shoulder point usually does not follow the normal index of the human body. Therefore, a plane connecting the back neck point and lateral shoulder is set for the measurement of length of body surface, as shown in Fig. 2.

2.3. Verification of grading deviation

The development of master patterns used in this study was suggested by Shin and Nam (2015). The master patterns and grading deviation that was developed used the grading deviation of Y, a CAD system company, as the existing deviation (Table 2). The expert group comprises five persons who are either doctoral students of apparel study, or have more than 5 years of work experience in the field of apparel studies. The evaluation of the clothed status was carried out using the five-point Likert technique. The internal consistency of the expert group was reviewed using Cron-

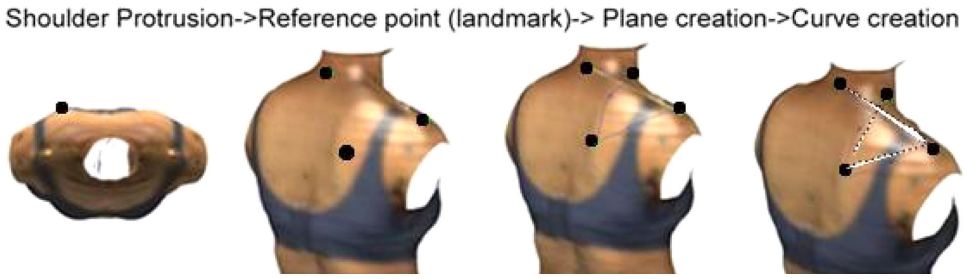


Fig. 2. Shoulder body surface length measurement method.

Table 2. Comparison (Domestic Y company) grading part and deviation value

Deviation part	Bust circumference	Waist circumference	Hip circumference	Shoulder circumference	Clothes length	Vibration circumference
Deviation value	3cm	3cm	3cm	0.5cm	1cm	0.5cm

bach's α coefficient.

3. Results and discussion

3.1. Derivation of deviation part using factor analysis

The grading deviation and selection of the part to which to apply the deviation was performed by conducting factor analysis using the cross-sectional factor, shoulder factor, length of body surface, etc. Principal component analysis (PCA) was used as a method for extracting factors, and orthogonal rotation according to the Varimax method was used to investigate the structure of the factors. The Scree test was conducted to determine the number of factors with more than one specific value as six. The total explanatory value was 85.9%. The number of factors was set as six, and was conducted with factor rotation (Varimax orthogonal rotation). The constituents of the variables for each factor were reviewed to decide the name of the factor (Table 3).

3.2. Selection of deviation part and derivation of deviation

The six factors and their referring body parts are suggested in Fig. 3. Factor 1 is the length of the body surface items of the front and backsides measured by the standard bust plane and frontal central standard plane. The high proportion range of this study is a total of 4, in the height interval 150cm to 165cm. The height item, which is highly correlated to the measured length of the body surface on the four height intervals, was used to constitute the regression formula.

The lateral line length was maintained constant by reflecting the measured front side waist – hip length and the backside waist – hip length and the deviation value 0.8cm was used as the deviation of Factor 1. Unlike the length-related items from the waist circumference level to the hip circumference level in Factor 1, Factor 2 involves the factors shown from the bust circumference line to the waist circumference line of the front and backsides. The deduction of the waist circumference back arc from the bust circumference back arc derived from Factor 2, and the deduction of waist circumference back arc from the hip circumference back arc influence the back waist dart (Table 4).

The length factor between the bust and waist circumference levels is 0.4cm, while the deviation of the back waist dart factor is 0.1 when smaller than the standard size of 91cm, and 0.2cm when larger, depending on the size interval of the bust circumference, as applied on the patterns.

Factor 3 comprises items such as the neck back shoulder bone upper protrusion length, end shoulder diagonal line length, and neck lateral shoulder bone upper protrusion length. The items were

Table 3. Factors and factor loads by orthogonal rotation

Factor name	Measurement item	Factor					
		1	2	3	4	5	6
Waist-hip length	Frontal waist - hip length	**0.980**	-0.073	-0.016	0.035	0.032	0.021
	Back waist - hip length	**0.980**	0.008	-0.035	-0.043	-0.031	0.082
	Frontal central waist – hip length	**0.977**	-0.041	-0.009	0.083	0.058	0.034
	Back central waist – hip length	**0.972**	0.059	-0.067	-0.115	0.002	0.100
Bust-waist shape	Back central bust – waist length	-0.066	**0.938**	-0.080	-0.169	0.054	-0.020
	Back bust – waist length	-0.044	**0.925**	-0.015	-0.125	0.018	-0.121
	Frontal bust– waist length	-0.153	**0.811**	0.057	0.397	-0.021	-0.081
	Bust waist back arc difference	0.176	**0.560**	0.062	-0.454	-0.049	0.018
	Hip waist back arc difference	0.269	**0.496**	-0.142	-0.360	-0.076	0.247
	Frontal central bust– waist length	-0.036	**0.494**	-0.384	0.151	0.017	-0.054
Back shoulder	Back neck point to shoulder protrusion length	-0.058	-0.078	**0.877**	0.201	0.186	-0.049
	Side neck point to shoulder protrusion length	-0.019	-0.010	**0.866**	0.107	0.081	-0.170
	Shoulder point diagonal length	-0.075	-0.061	**0.849**	0.252	0.182	0.049
Bust length	Shoulder point front diagonal length	0.089	0.011	0.238	**0.897**	0.037	0.092
	Side neck point to bust point length	-0.014	-0.122	0.260	**0.875**	0.126	0.010
Shoulder length	Biacromion length	-0.037	-0.061	0.158	0.114	**0.907**	-0.007
	Shoulder front length	0.081	0.041	0.085	0.088	**0.875**	0.139
	Shoulder length	0.016	0.030	0.133	-0.038	**0.852**	-0.026
Frontal waist dart	Bust waist frontal arc difference	0.065	-0.082	-0.090	0.154	0.069	**0.912**
	Hip waist frontal arc difference	0.429	-0.108	-0.083	-0.380	0.075	**0.519**

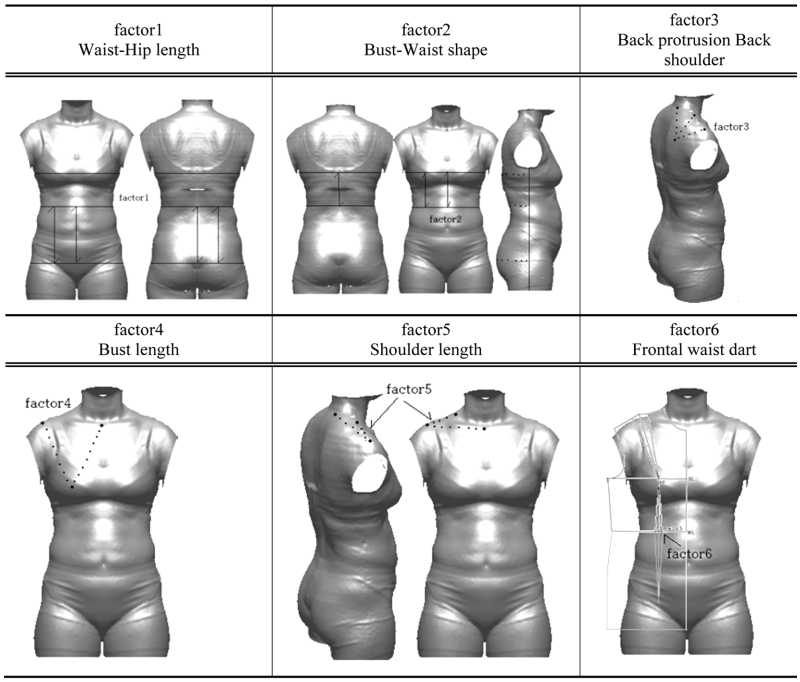


Fig. 3. Part for each factor.

Table 4. Regression formula using the measured items of Factor 1, and Factor 2

Factor	Measured length of body surface item	Regression formula	β	R^2	*P*-value	Deviation value(cm)
1 Waist-hip length	Frontal central waist hip L	=-5.662+0.169*H	0.510	0.260	0.000	0.84
	Back central waist hip L	=-2.580+0.151*H	0.477	0.228	0.000	0.75
	Front side waist hip L	=-3.917+0.158*H	0.490	0.240	0.000	0.79
	Back side waist hip L	=-3.984+0.160*H	0.502	0.252	0.000	0.80
2 Bust-waist shape	Front side bust waist L	y=6.561+0.064*H	0.217	0.042	0.016	0.3
	Frontal central bust waist L	y=-12.055+0.177*H	0.310	0.039	0.021	0.8
	Back side bust waist L	y=2.007+0.087*H	0.781	0.093	0.000	0.4

*Abbreviation: L(Length), H(Height)

measured to reflect the shape of the shoulder, and all three items reflect the back protrusion point. All three items were shown to be correlated to the bust circumference, thus the following regression formula was used. Factor 4 refers to the 'bust length' factor, comprising the end shoulder frontal diagonal line length, and bust length. Both items include the bust point in common. When examining the changes in body shape caused by the increase of bust circumference, since the location of the bust point changes as the bust circumference increases, the reflection of length changes of the top wear is of paramount importance. The result obtained with the

Table 5. Regression formula using the Factor 3and Factor 4

Factor	Measured length of body surface	Regression formula	β	R^2	*P*-value	Deviation (cm)
3	Neck back shoulder bone upper protrusion length	=8.063+0.093*BC	0.377	0.142	0.000	0.27
	End shoulder diagonal line length	=6.339+0.123*BC	0.465	0.216	0.001	0.36
	Neck lateral shoulder bone upper protrusion length	=5.521+0.140*BC	0.382	0.146	0.042	0.42
4	End shoulder frontal diagonal line length	=9.977+0.155*BC	0.629	0.396	0.000	0.56
	Bust point length	=8.362+0.193*BC	0.689	0.475	0.000	0.67

*Abbreviation: BC(Bust Circumference)

Table 6. Technical statistics of shoulder length factor for each bust circumference interval (unit: cm)

Item \ Bust circumference		79	85	88	91	94	97	100	106
End shoulder length	*M*	18.70	19.11	19.46	19.36	19.23	19.25	20.38	19.23
	SD	1.28	1.24	1.01	1.14	1.16	1.22	1.28	1.87
Shoulder length	*M*	11.50	11.69	11.75	11.79	11.72	11.75	12.41	11.22
	SD	0.83	0.98	0.88	0.74	0.90	1.26	0.55	1.35
Shoulder frontal length	*M*	18.07	18.29	18.18	18.61	18.25	18.16	19.36	18.02
	SD	0.88	0.95	1.24	0.86	1.36	0.75	1.33	1.29

*Abbreviation: *M*(mean), *SD*(standard deviation)

Table 7. Deviation chart of frontal dart factor (unit: cm)

Bust circumference item	82	85	88	91	94	97	100
Frontal waist dart	0.1	0.1	0.1	0	-0.2	-0.2	-0.2

*Shadow means median.

regression formula derived by substituting the bust circumference is provided in Table 5.

Factor 5 is a shoulder length-related factor, and comprises the end shoulder length, shoulder length, and shoulder frontal length. Only the end shoulder length, among the 3 items, showed low correlation with the bust circumference (Table 6). However, in the case of the shoulder length factor, since it is unlikely to be explained, it was not satisfactory for constituting the regression formula. Therefore, the technical statistical values of the 3 items were used to derive the deviation of the bust circumference as 0.1cm (Table 7).

Factor 6 can reflect the items to the waist dart. Especially, in terms of a dart of a general form, since the upper and lower parts of the dart have the same shape, the difference between the bust and waist circumferences are set as the dart. Therefore, the regression formula was derived from the bust circumference. The frontal waist dart of the existing master patterns was set as 1.5cm, and the evaluation result was determined as appropriate. Therefore, based

Table 8. Verification model applied with existing deviation, and deviation of the present study

Front		Lateral		Back	
Existing deviation	Deviation of the present study	Existing deviation	Deviation of the present study	Existing deviation	Deviation of the present study
85-155					
					
88-160					
					

Table 8. Verification model applied with existing deviation, and deviation of the present study(continued)

91-165					
					

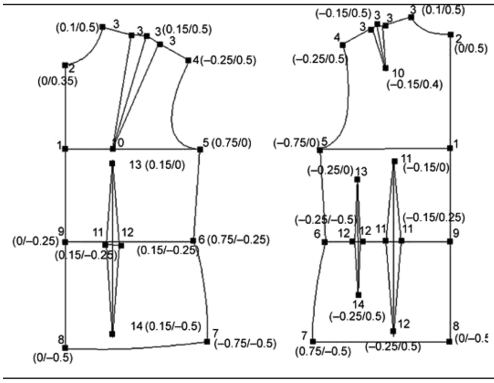
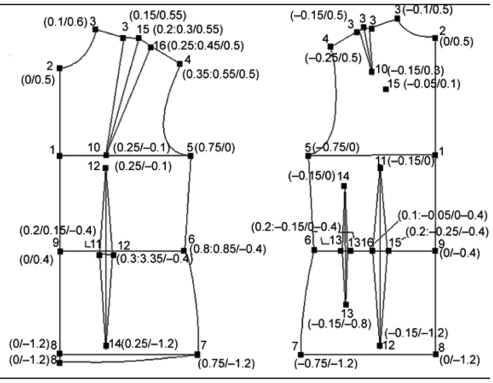
Deviation change	
Existence deviation	Deviation change of the present study
	

Fig. 4. Deviation from existing deviation, and the deviation of the present study.

on the frontal waist dart of 1.5cm at the bust circumference, the dart reflects shrinkage when the size exceeds the standard and enlargement when the size is smaller than the standard (Table 7). The girth and length grading deviations were reflected to produce blocks for 3 combination ranges of 85-155, 88-160 and 91-165 (Table 8).

The deviation change was applied with the existing deviation and is shown in Fig. 4. As a result, the torso block standard lines did not fall out when applied in the study and existing grading deviations, the lines stayed horizontal, the part of the hem that came up in the front was improved. Also the wrinkles from the existing grading deviations were significantly reduced thanks to the appropriate deviation amounts. With the support of the results above, the grading deviations of this study when applied to the pattern got the higher scores from exports.

3.3. Verification of grading deviation of the present study

3.3.1. Application of grading deviation and clothed-status evaluation

By reflecting the developed deviation for each interval and each length on the master patterns, a torso of three intervals was manufactured for the final verification.

The expert group suggested baseline-related items by dividing the items according to the front, lateral, and backsides. The surplus, dart, crimps, overall exterior, and other items were suggested in the same way, by dividing the items into more specific sub-items. The result shows that, compared to the existing deviation, the waist and hip circumference lines were improved with their horizontality, the best at the interval of 85-155cm. The waist circumference line showed improvements in all three sizes on the front side, by reflecting the deviation derived from the length analysis, compared with the existing deviation (Table 10).

Many of the items requiring the exterior of the dart showed a higher average value when the new deviation was applied. However, the frontal waist darts in the interval of 85-155cm showed a higher result when applying the existing deviation. However, the exterior evaluation did not show a significant difference for most items. Since the range of dart deviation is only 0.1 to 0.2cm, which is not much, the difference could not have been easy to recognize by merely looking at the exterior shown in the photograph. The silhouette evaluation on the frontal and backsides on the lateral side

Table 9. Grading deviation change

Front side				Back side			
Exi1	(0, 0)	Pre.1	(0, 0)	Exi1	(0, 0)	Pre.1	(0, 0)
2	(0, 0.35)	2	(0, 0.5)	2	(0, 0.5)	2	(0, 0.5)
3	(0.1, 0.5) dart (0.15/0.5)	3	(0.1, 0.6)	3	(0.1, 0.5)dart (-0.15, 0.5)	3	(-0.1, 0.5)dart(-0.15, 0.5)
4	(-0.25, 0.5)	4	(0.35:0.55, 0.5)	4	(-0.25, 0.5)	4	(-0.25, 0.5)
5	(0.75, 0)	5	(0.75, 0)	5	(-0.75, 0)	5	(-0.75, 0)
6	(0.75,-0.25)	6	(0.8:0.85, -0.4)	6	(-0.25, -0.5)	6	(0,0)
7	(-0.75,-0.5)	7	(0.75, -1.2)	7	(0.75, -0.5)	7	(-0.75, -1.2)
8	(0, -0.5)	8	(0, -1.2)	8	(0, -0.5)	8	(0, -1.2)
9	(0, -0.25)	9	(0, 0.4)	9	(-0.15, 0.25)	9	(0. -0.4)
10	(0, 0)	10	(0.25, -0.1)	10	(-0.15, 0.4)	10	(-0.15, 0.3)
11	(0.15,-0.25)	11	(0.2:0.15,-0.4)	11	(-0.15, 0)	11	(-0.15, 0)
12	(0.15,-0.25)	12	(0.3:0.35,-0.4)	12	(0.25, -0.5)	12	(-0.15, -1.2)
13	(0.15, 0)	13	(0.25, -0.1)	13	(-0.25, 0)	13	(0.2:0.15,0.4) (-0.15,-0.8)
14	(0.15, -0.5)	14	(0.25, -1.2)	14	(-0.25, 0.5)	14	(-0.15, 0)
		15	(0.2:0.3, 0.55)			15	(0.2:-0.25,-0.4)
		16	(0.25:0.45, 0.5)			16	(0.1:-0.05,-0.4)

*Exi-existing deviation, Pre-deviation of the present study

showed improved results with the new deviation.

4. Conclusion

The present study used three-dimensional human body shape data as ingredients for a factor analysis for the development of grading deviation to reflect changes in the body shape. The analysis resulted in identifying six factors: waist-hip length; bust-waist shape; back protrusion back shoulder; bust point length; shoulder length; and frontal dart. A 0.8-cm deviation was set as the deviation

Table 10. Experts' appearance evaluation of line

Item	Evaluation questions	85-155		88-160		91-165	
		Ex	Pe	Ex	Pe	Ex	Pe
1	Proper position of center front line	4.2	4.6	3.4	4.8	3.6	4.2
2	Proper position of bust line	3.0	4.4**	3.2	4.6**	3.8	4.6
3	Horizontal of bust line	3.2	4.6*	3.0	4.6*	4.0	4.6
4	Proper position of waist line	3.0	4.6**	3.4	4.6*	2.4	4.6*
5	Horizontal of waist line	3.2	4.6**	3.2	4.6*	4.0	4.6
6	Proper position of hip line	3.2	4.4**	3.6	4.4	2.4	4.4**
7	Horizontal of hip line	3.4	4.4*	3.4	4.2	3.8	4.4
8	Proper position of armscye circumference	3.8	4.4	3.8	4.4	4.0	4.2
25	Is the Side seam divided body in equilibrium?	2.8	4.8**	3.0	4.6**	3.6	4.6*
26	Proper position of bust line	2.8	4.8**	3.0	4.4**	4.0	4.4
27	Horizontal of bust line	2.6	4.8***	2.6	4.6**	3.4	4.6*
28	Proper position of waist line	2.8	4.8*	3.2	4.4**	2.8	4.6**
29	Horizontal of waist line	2.8	4.8***	2.6	4.4**	3.4	4.4*
30	Proper position of hip line	3.8	4.4	3.8	4.4	2.6	4.6**
31	Horizontal of hip line	3.0	4.4**	3.6	4.2	3.4	4.0
32	Proper position of armscye circumference	3.2	4.4	3.0	3.8	3.8	4.0

Table 10. Experts' appearance evaluation of line (continued)

43	Proper position of center back line	4.2	4.4	3.8	4.6	3.8	4.6
44	Proper position of bust line	3.2	4.6	3.4	4.2*	3.4	4.2
45	Horizontal of bust line	3.2	4.4*	3.2	4.2*	3.4	4.4
46	Proper position of waist line	3.2	4.6**	3.4	4.6*	2.4	4.6**
47	Horizontal of waist line	2.8	4.8**	3.0	4.4**	3.6	4.6*
48	Proper position of hip line	3.6	4.4	3.2	4.4**	2.2	4.6**
49	Horizontal of hip line	3.6	4.2	3.4	4.4*	3.8	4.6
50	Proper position of armscye circumference	3.2	4.2*	3.4	4.0	3.6	3.8

*Ex-existing deviation, Pr-deviation of the present study

for each interval of the waist-hip length factor, whereas the bust-waist shape factor was derived with the circumference-related component along with the length-related component. Therefore, -0.2cm was applied to bust intervals over 91 cm, while +0.1cm was applied to intervals below 91cm. The back protrusion back shoulder and bust point length factors were applied with deviations of 0.4cm and 0.7cm, respectively, whereas the deviation of the shoulder length factor was 0.1cm. Finally, the deviation of the dart factor was reduced by -0.2cm and enlarged by +0.1cm for a bust circumference over and under 91cm, respectively. The neck circumference, vibration circumference, and frontal bust dart were concluded by exterior evaluation, and were reflected in the deviations to derive the final grading deviation.

The final verification was as follows: bust circumference (85cm) and height 155cm (85-155), bust circumference (88cm) and height 160cm (88-160), and bust circumference (91cm) and height 165cm (91-165). The excellence of the developed grading deviation was verified by selecting existing deviations used by the general apparel CAD company. The exterior evaluation showed that the baseline, dart, shoulder line, exterior, crimps, etc. showed an excellent result compared to the existing deviation. The evaluation by a group of experts found that the crimp and overall fitness were improved by reflecting the changes in the body shape, compared with the result shown by the existing deviation. As this study focused on women in their thirties, the plan is to study other age groups in future.

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