Investigations into the Influencing Fabric Properties Factors of the 3D Shape Evaluation of Korean Hanbok Chima

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Abstract : This study was designed to analyze the three-dimensional shapes of Hanbok Chima made with various fabrics and to clarify the relationship between fabric properties as well as the objective and subjective evaluations of the 3D shape. For 3D shape data, a dress form (9A2 (N; nude)) was scanned with eight Chima garments made with the same number of fabrics. The scanner used was a non-contact three-dimensional human body measuring system belonging to Bunka Women's University in Japan. Data concerning the objective evaluation of the 3D shape was obtained from the measurements of the vertical and horizontal sections: those for subjective evaluation were through the sensory test after exposure to photographs from a front and side view.

Four fabric factors were extracted from fabric physical properties: softness, extension, thickness of threads, and weight of fabric. Such factors as expansion (volume), sag of rear train, shape of nodes were influential in explaining the 3D shape of Hanbok Chima. From the analysis of the 3D shape, it can be deduced that with the constituent fabric stiffer, lighter, and less stretchable, the more expanded the 3D shape appeared to be.

Multiple regression results showed that vertical shape factors have a greater effect on the evaluation of the 3D shape. It also implies that dependent variables of this study such as the subjective evaluation and 3D shape can be derived from regression equations on independent variables as fabric property factors or 3D shape factors. These results can enable the manufacturers to predict the 3D shape of the garment as well as the human subjective assessment to improve the efficacy of production. The investigation method proposed in this study can also be applicable to other garment items.

Key Words : 3D (three dimensional) shape, Hanbok Chima, Fabric properties, Objective evaluation, Subjective evaluation, Regression equation

I. Introduction

In the context of consumer satisfaction in the apparel industry, emphasis is placed on the production of a garment with good fit and appearance. Many factors, such as design, fabric, pattern and sewing techniques, play important roles in making shapes. Insufficient knowledge concerning these factors can result in products with unexpected silhouettes. Hence it is indispensable for apparel makers to grasp the features of each factor and their effects on the three-dimensional shape of a garment. However, such research has rarely been conducted that attempted to discover the key factors or variables affecting the 3D shape and their influencing power.

Hanbok Chima, a Korean traditional costume, is a kind of skirt, which is characterized by a silhouette hanging from the chest to the floor. The three-dimensional shape or the drape of the Chima when worn, is a matter of consequence in terms of consumer decision making at the time of purchase. Even when

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the same design and pattern are used, the shape or the silhouette of the Chima is quite different, as this mainly depends on the physical properties of the fabrics.

The 3D shape of a garment is hard to capture and analyze because the flexibility of the fabric and space between the body and the garment allows it to move freely. Nowadays, it can be digitized by laser scanning or the moiré photography method in the form of a cross-section map. From this data, a quantitative analysis can be conducted on the internal space of a garment. A previous study quantitatively analyzed the distribution of the space length by measuring this value on the cross-section map under various conditions (Kim *et al*, 1988). The other evaluation for the physical space of a garment can be achieved by assessment of human perception measured through sensory tests. It is also important to estimate the shape of a garment from the fabric features as they have crucial effects on buying decisions. Recently, moreover, the growth of the on-line market has reinforced the importance of the estimation of the evaluation on the silhouette or appearance of garments, where consumers decide whether to buy based largely on assessment made upon viewing images of products on a computer screen.

Hence, the purpose of this study is to investigate the 3D shape of Hanbok Chima made with different fabrics and to elucidate the relationship between fabric properties, objective and subjective evaluations of the 3D shape by regression analysis. The findings will help garment makers to understand the relationship between 3D shapes, fabric properties and perceptual assessment to control the fabrics properties in order to create the customer's favorite silhouette prior to making the garment.

II. Method

1. Fabric physical property test

For the experiments, eight kinds of fabrics were chosen; three controlled fabrics, fabric 1 (silk jacquard), 3 (georgette) and 4 (cotton muslin) and five Korean traditional fabrics, fabric 2 (newttong), 5 (nobang), 6 (sookosa), 7 (kapsa) and 8 (eunjosa). Physical property tests were conducted for three times at the laboratory in Bunka Women's University in Japan. Physical properties for the test were drape coefficient, thickness of threads and fabrics, weight of fabrics and elongation ratio of fabrics, softness/stiffness and elongation ratio of fabrics. Specimens for every test item were prepared for eight directions of grain; warp, weft, right/left bias of 22.5˚, 45˚ and 67.5˚.

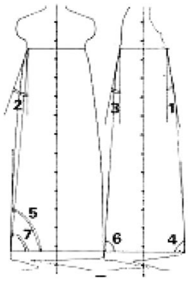
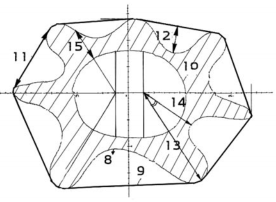
2. Experimental garment

The experimental garment was a Korean traditional costume, a Hanbok Chima with a top. The garment was made with reference to a pattern proposed by a previous study (Im & Yoo, 1991). The length of the skirt was 110cm. Eight Hanbok Chimas were made with eight kinds of fabrics noted above.

3. Measurement of section map

The measurement of section map was designed for an objective evaluation and numerical analysis of the 3D shape of Chima. Three dimensional shape data was obtained from the measurement of section maps taken from the 3D scanning data. For data collection, the dress form (9A2 (N; nude)) was scanned nine times, both naked and dressed in each Chima. The scanner used in this study was a non-contact 3-dimensional human body measuring system belonging to Bunka Women's University in Tokyo. The scanning procedure was executed with reference to the previous study (Miyoshi, 1987). Outputs of the scanning were two vertical sections (front and side view) and five horizontal sections for each Chima, a total of 56 sections. The five horizontal sections included the chest, the bust, waist, hip, and the hem of each Chima. The measurement items of the vertical and horizontal sections are shown in <Figure 1>.

Measurement items on the vertical sections were several flaring angles of the Chima, which describe the

Vertical section	1. Angle of upper part (Front) 2. Angle of upper part (Side) 3. Angle of upper part (Back) 4. Angle of lower part (Front) 5. Angle of lower part (Side): angle between horizontal line of hem and tangential line of side-lower part of Chima 6. Angle of lower part (Back) 7. Spreading angle of Chima: angle between horizontal line of hem and chest side point	
Horizontal section	8. Girth of horizontal section 9. Outward girth of horizontal section 10. Area of horizontal section 11. Distance between nodes 12. Depth of node 13. Node peak radius 14. Node bottom radius 15. Space length between dress form and garment	

<Figure 1> Measurement Items of Sections of Chima

silhouette. Measurement items on the horizontal sections included the girth, outward girth, area of section, space length between the dress form and Chima, node peak/bottom radius, depth, and interval of nodes, indicating the volume and shape of drapes. In the case of the horizontal section, measurements were performed on the overlapped section map of the dress form and Chima.

4. Photographing

Photographs of the dress form (9A2 (N)) dressed with the Chima were taken. The instruments and conditions of photographing were set up as shown in <Table 1> with reference to a previous study (Park & Miyoshi, 2001). These photos were used as the materials for the sensory tests.

<Table 1> Photographing Conditions and Instruments

Conditions	Distance	10m
	Height of lens	Height of waist line of dress form
	Source of light	Sunlight
	Angle of photographing	0˚(front), 90˚(side), 180˚(back)
Instruments	Camera	Canon F-1
	Lens	200mm telephoto-lens
	Film	ASA 400 Black and white film
	Background	Screen with grid of 10cm interval

5. Sensory test

In order to provide a subjective evaluation of the 3D shape of Chima, sensory tests were conducted. Subjects recruited for this study were 100 university students majoring in Clothing and Textiles. The data of the sensory tests was collected by questionnaire. The questionnaire was made up of 30 items wherein respondents were asked to evaluate the silhouette of the Chima on a 5-point Likert-type scale with responses ranging from “strongly disagree” (1) to “strongly agree” (5) after looking at front and side view images.

6. Data analysis

Using SPSS 10.0 for Windows, statistical analyses were performed. In order to summarize the data, a principal component factor analysis with a varimax rotation was used for the fabric physical properties, and the measurements of vertical and horizontal sections. These composite factors served as dependent or independent variables in the subsequent analysis. For classifying the silhouette of Chima silhouettes, a cluster analysis was performed using the factor score of the vertical section measurements. ANOVA with a post-hoc test (S-N-K method) was used to compare and discriminate the differences among the clusters. Multiple regression analyses were conducted in order to reveal the relationship among 3D shape factors, fabric properties factors, and the results of the sensory tests. The results enabled us to create the regression equation for estimation of the dependent variables.

III. Results and Discussion

1. Extraction of fabric physical property factors

In order to extract the main factors of the fabric properties, a principal component analysis was done by the method of a varimax rotation with Kaiser Normalization. Finally, four factors of fabric properties were extracted, accounting for 91.91% of the total variance (Table 2).

The measurements of fabric properties falling under F. factor (Fabric factor) 1 were the softness/stiffness of all kinds of grains and drape coefficient. Hence, factor 1 was named 'softness/stiffness'. A fabric of high F. factor score 1 can be evaluated as a soft fabric. As seen in the table, drape coefficients had a negative factor loading value to F. factor 1. This suggests that a higher drape coefficient corresponds with a proportionally stiffer fabric. F. factor 2 was denoted as 'extension', where the measurements of the extension items had positive and high factor loading values. Hence, a fabric with high factor score in F. factor 2 can be assumed to be stretchable. F. factor 3 was the 'thickness of threads', with a negative factor loading value in the warp and a positive value for the weft. Consequently, a fabric having a high factor score in F. factor 3 may be woven with thin warp and thick weft. F. factor 4 was the 'weight of fabric', where the thickness and weight of the fabric corresponded. A high factor score in this factor suggests that the fabric is thick and heavy.

<Table 2> Factor Analysis for Fabric Properties (Rotated Component Matrix)

Fabric Factors / Measurements	F. factor 1 (Softness/stiffness)	F. factor 2 (Extension)	F. factor 3 (Thickness of threads)	F. factor 4 (Weight of fabric)
Softness (L-bias 67.5°)	.961	.140	-4.6E-03	.160
Softness (Warp)	.960	.109	.107	6.157E-02
Softness(R-bias 22.5°)	.952	.118	-4.3E-02	.174
Softness (Weft)	.939	8.821E-02	5.369E-02	8.289E-02
Softness (R-bias 45°)	.935	.132	.159	.198
Softness (L-bias 22.5°)	.920	5.716E-02	-.260	5.994E-02
Softness (R-bias 67.5°)	.917	.107	.182	.221
Softness (L-bias 45°)	.917	.107	-.287	8.206E-02
Drape coefficient	-.765	-.279	-.435	-.219
Extension (L-bias 22.5°)	1.143E-03	.978	5.071E-02	8.979E-02
Extension (R-bias 22.5°)	1.636E-02	.966	7.590E-02	-.222
Extension (L-bias 45°)	.120	.940	.149	.219
Extension (R-bias 45°)	-4.9E-02	.935	-2.8E-02	.110
Extension (L-bias 67.5°)	.270	.892	.220	.213
Extension (R-bias 67.5°)	.284	.835	5.918E-02	.285
Extension (Warp)	.414	.674	8.578E-02	-6.8E-02
Thickness (Weft)	-.193	-.157	-.881	.180
Thickness (Warp)	-.269	.166	.828	.347
Thickness (Fabric)	.350	.213	6.636E-02	.885
Weight (Fabric)	.604	.173	6.734E-04	.749
Variance explained (%)	42.790	29.477	9.848	9.793
Cumulative variance (%)	42.790	72.267	82.115	91.908

2. Extraction of 3D shape factors of Chima

In order to extract the main factors explaining the 3D shape of Chima, a principal component analysis was carried out by a varimax rotation with regard to the measurements of vertical sections indicating the silhouette of the Chima. The factor summary and factor loadings are presented in <Table 3>.

The measurements of the vertical sections indicating the silhouette of front and side were summarized into two factors. The variance accounted for 88.23% of the total variance. The measurements of the vertical section map corresponding to V. factor were the angles of upper part (front, back), lower part (front, side) and spreading angle of the Chima. The angles of the upper part (front, back) had high positive factor loading values; however, the spreading angle of the Chima, angles of the lower part (front, side) had high negative values. It can be assumed that the rise in the upper part (front, back) results in the descent in the lower part (front, side). If a factor score of V. factor 1 is high, it can be said that the Chima has an expanded silhouette especially in the front and back of the upper part. Therefore, V. factor 1 is denoted as the "expansion" factor. The measurements loading on V. factor 2 were the angles of the lower part (back) and upper part (side). The former had a high negative factor loading value. If it is large, it can be said that the Chima sagged in the back. The low factor score of V. factor 2 indicates that the rear train sags. Hence factor 2 is called "sag of rear train". The "expansion" and "sag of rear train" factors were extracted as describing factors from the silhouette of the Chima.

<Table 3> Factors of Measurements of Vertical Sections (Rotated Component Matrix)

V. Measurement \ V. Factor	V. factor 1 (expansion)	V. factor 2 (sag of rear train)
Angle of upper part (Front)	.961	.116
Spreading angle of Chima	-.943	.172
Angle of upper part (Back)	.927	.283
Angle of lower part (Front)	-.925	2.037E-02
Angle of lower part (Side)	-.823	.349
Angle of lower part (Back)	.268	-.919
Angle of upper part (Side)	.561	.704
Variance explained(%)	65.588	22.640
Cumulative variance(%)	65.588	88.228

As the same manner of vertical measurements, a principal component analysis by varimax rotation was carried out for measurements of the horizontal sections (Table 4).

This analysis resulted in four factors, accounting for 81.32% of the total variance.

H. factor 1 consisted of the distance of node (waist, hip, and hem), depth of node (hip and waist), maximum node radius (hip and hem), suggesting that this factor

<Table 4> Factors of Measurements of Horizontal Sections (Rotated Component Matrix)

H. Measurement \ H. Factor	H. factor 1 (shape of the node)	H. factor 2 (volume of section)	H. factor 3 (minimum node radius of hip)	H. factor 4 (minimum node radius of waist)
Distance between nodes (Hem)	.864	.112	8.106E-03	2.261E-03
Distance between nodes (Hip)	.845	.125	-.118	-1.486E-02
Node peak radius (Hip)	.831	9.308E-02	.211	-2.459E-02
Node peak radius (Hem)	.803	7.716E-02	4.194E-02	.182
Depth of node (Hip)	.775	2.982E-02	-.502	-7.440E-02
Distance between nodes (Waist)	.735	.203	-5.693E-03	-.331
Depth of node (Waist)	.666	.152	-3.389E-02	-.528
Outward girth of horizontal section	.178	.977	-1.064E-02	-8.916E-03
Area of horizontal section	.235	.914	-2.058E-02	4.637
Girth of horizontal section	3.160E-03	.904	7.217E-03	-.103
Node bottom radius (Hip)	3.999E-02	-1.166E-02	.986	2.674E-03
Node bottom radius (Waist)	2.720E-02	3.018E-03	6.046E-03	.919
Variance explained(%)	37.245	22.635	10.729	10.709
Cumulative variance(%)	37.245	59.880	70.608	81.317

represented the “shape of the node”. If the H. factor score 1 is high, the Chima has a shape such that the node that is expanded and wide. The measurements corresponding to factor 2 were the girth and area of horizontal section, and therefore, this factor is called the “volume of section” factor. Factors 3 and 4 were the minimum node radius of hip and waist, respectively.

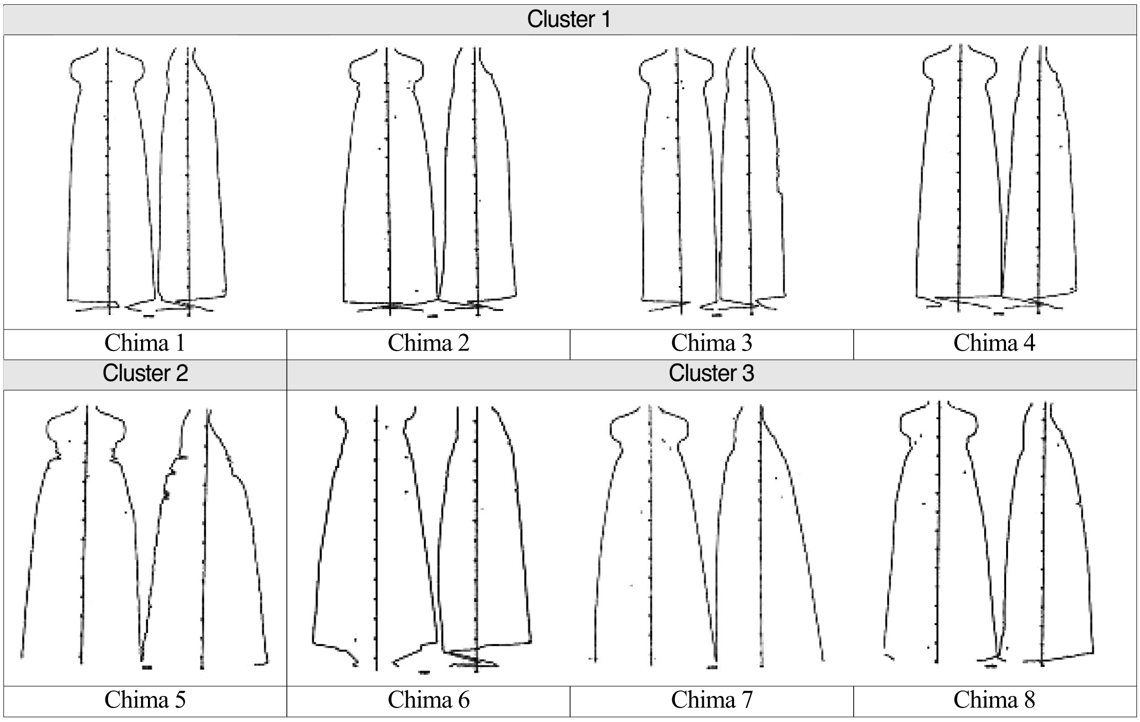
3. Classification and analysis of 3D shape of Chima

For a more effective analysis of the 3D shape, Chimas were grouped on the basis of common silhouette features. A cluster analysis was performed using factor scores of vertical section measurements indicating the silhouette of the Chima. Eight kinds of Chimas were classified into three clusters. Chimas 1 (silk jacquard), 2 (newttong), 3 (georgette) and 4 (cotton muslin) belonged to cluster 1; Chima 5 (nobang) to Cluster 2; Chimas 6 (sookosa), 7 (kapsa) and 8 (eunjosa) to Cluster 3.

<Figure 2> shows the vertical sections of the front and side of each Chima respectively.

The results of the ANOVA with a post-hoc test with regard to factor scores and measurements of vertical sections among the three clusters are shown in <Table 5>. All the factor scores and measurements were significantly different among the three clusters ($p<.001$). V. factor score 1 of cluster 1 was significantly smaller than the others, and the angles of upper part (front, back) decreased in order of cluster2 > cluster3 > cluster1. The spreading angle of the Chima and the angle of the lower part (side) showed an order of cluster 1 > cluster2 > cluster 3. The angle of the lower part (front) decreased in order of cluster 1> cluster3 > cluster2. Judging from these results, the lower part flaring angles varied according to the direction of the visual point. This also suggested that the silhouette of the Chima was more diverse in the lower part than the upper.

The upper part of vertical section cluster 2 had the most expanded shape while cluster 1 had the slimmest silhouette. In the lower part (side) of the vertical section, the slope of cluster 1 was the steepest and that



<Figure 2> Vertical Sections of Chima

<Table 5> ANOVA with Post-hoc Test for Factor scores and Measurements of Vertical Sections

Factor score \ Cluster		Cluster 1	Cluster 2	Cluster3	F
VERTICAL SECTION	V. Factor score 1	-.939 b	1.03 a	.909 a	780.87***
	V. Factor score 2	.086 b	1.72 a	-.688 c	122.11***
	Angle of upper part (Front)	12.33 c	23.50 a	23.13 b	497.01***
	Angle of upper part (Back)	14.73 c	35.90 a	27.57 b	298.40***
	Angle of lower part (Front)	88.45 a	83.90 c	85.10 b	215.54***
	Angle of lower part (Side)	88.63 a	88.00 b	85.13 c	551.12***
	Spreading angle	85.45 a	81.50 b	81.03 c	938.91***
	Angle of upper part (Side)	19.43 c	30.80 a	23.90 b	86.32***
	Angle of lower part (Back)	87.60 b	85.40 c	91.10 a	152.65***

***p<.001, **p<.01, *p<.05 Means with different letters indicate a significant difference among clusters at a level of p<.05 as determined by SNK method (a > b > c).

of cluster 3 was the most gentle. Therefore, it can be concluded that cluster 1 is a tubular shape, cluster 2 is a fully expanded bell shape, and cluster 3 is slightly sloped bell shape. Using the same patterns, the factor which brought about these differences in silhouette might be the shape of the drapery caused by the different properties of the various fabrics.

The order of the horizontal factor score 2 (sag of rear train factor) was cluster 2 > cluster 1 > cluster 3 and that of angle of the lower part (back) was opposite, because it had a negative factor loading value. This means that cluster 1 had a steep silhouette of rear train, cluster 2 had a gentle one, and cluster 3 had an obtuse-angle silhouette. Hence it may be concluded that cluster 2 had the most expanded rear train and cluster 3 had the most sagged train.

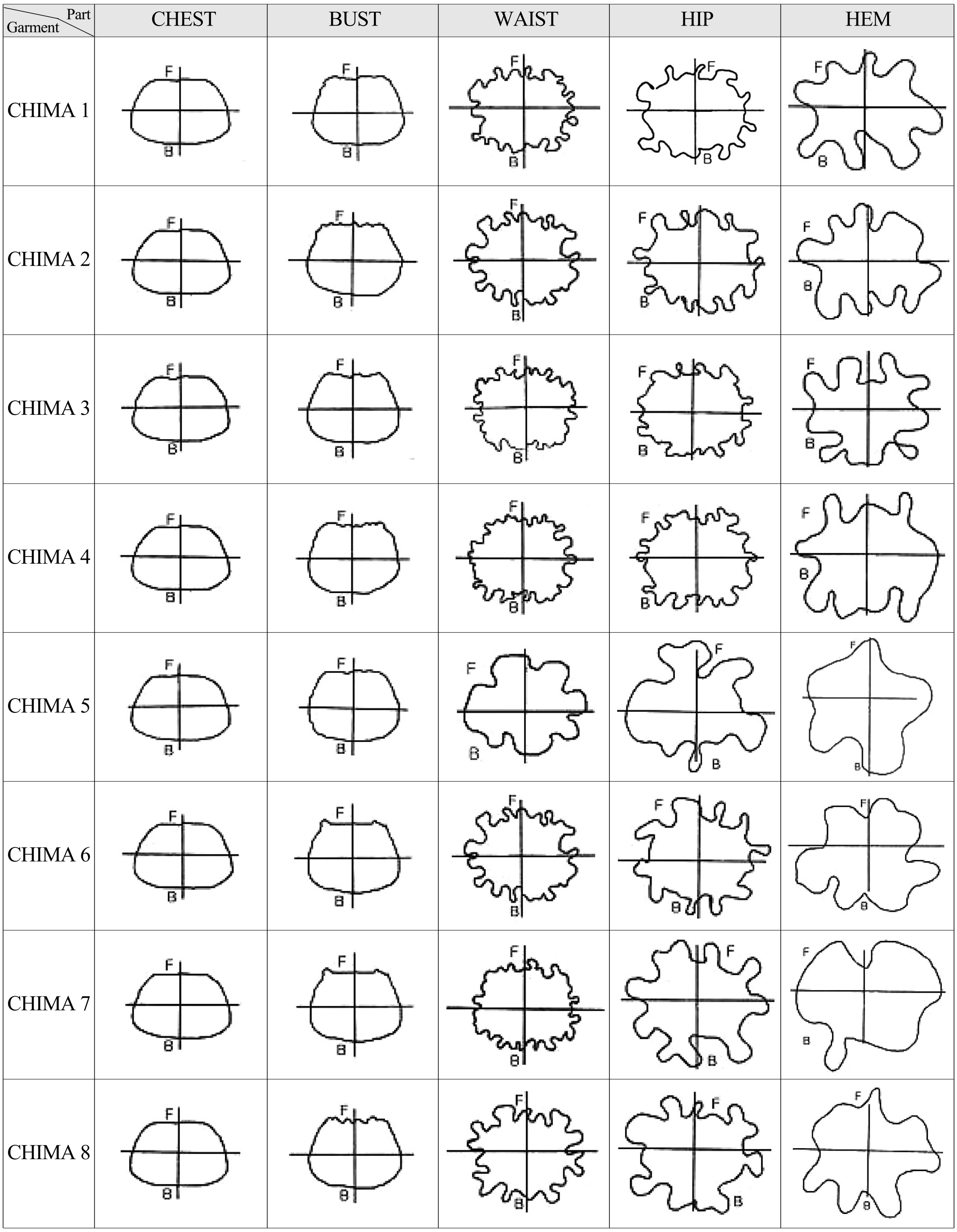
For a more descriptive analysis of the 3D shape, ANOVA with a post-hoc test was used for factor scores and measurements of horizontal sections (Table 6). The horizontal sections of each Chima are presented in <Figure 3>.

Most of the factor scores and measurements of the

<Table 6> ANOVA with Post-hoc Test for Factor Scores and Measurements of Horizontal Sections

Factor scores and Measuremests \ Cluster	Cluster 1	Cluster 2	Cluster 3	F
H. Factor score 1	-.79 c	1.63 a	.52 b	296.51***
H. Factor score 2	-.11	.19	.09	1.40
H. Factor score 3	.02 a	-.44 b	.12 a	3.03*
H. Factor score 4	-.06 b	.60 a	-.12 b	5.45**
Girth of horizontal section	151.55	163.71	161.97	.97
Outward girth of horizontal section	108.89 b	131.23 a	122.19 a	7.95***
Area of horizontal section	757.01 c	1162.46 a	982.54 b	11.25***
Node peak radius(Waist)	16.19 c	19.57 a	17.92 b	34.07***
Node bottom radius (Waist)	13.35 b	14.48 a	13.13 b	4.62*
Distance between waves (Waist)	4.62 c	8.65 a	7.26 b	50.08***
Depth of node (Waist)	2.70 b	4.71 a	4.26 a	32.63***
Node peak radius (Hip)	18.39 c	23.99 a	21.35 b	77.81***
Distance between waves (Hip)	7.45 c	11.70 a	17.03 b	145.07***
Depth of node (Hip)	3.59 c	8.77 a	5.77 b	95.34***
Node peak radius(Hem)	21.91 c	33.46 a	30.02 b	157.74***
Node bottom radius (Hem)	14.48 c	22.41 a	19.64 b	63.90***
Distance between waves (Hem)	13.16 c	28.16 a	21.14 b	209.98***
Depth of node (Hem)	6.92	6.23	7.59	1.96

***p<.001, **p<.01, *p<.05 Means with different letters indicate a significant difference among clusters at a level of p<.05 as determined by SNK method (a > b > c).



<Figure 3> Horizontal Sections of Chima

horizontal section, except horizontal factor score 2, girth of horizontal section and depth of node (hem), showed significant differences among the clusters in the order of cluster 2 > cluster 3 > cluster 1 ($p<.001$). In H. factor (horizontal factor) score 1 (shape of node) and its related measurements such as distance between nodes, node peak radius and depth of node, the means decreased in the order of cluster 2> cluster 3 > cluster 1. Therefore, cluster 2 had the widest and most expanded nodes. In the measurements describing the volume of horizontal section including outward girth and area of horizontal section, cluster 2 was significantly larger than the others, suggesting that it was the widest in the horizontal section.

The factor score of cluster 2 was significantly lower in H. factor 3 and higher in H. factor 4, indicating that the node bottom of cluster 2 expanded in the waist part and shriveled in the hip part. These results for the horizontal section measurements were consistent with those of the horizontal section shape and silhouette in that cluster 2 had a fully bell shape silhouette.

In summary, cluster 1 was a tubular shape with a steep rear train and shallow nodes and cluster 2 was a fully expanded bell shape with expanded and wide nodes and cluster 3 was a slightly sloped bell shape with a sagged rear train. These differences in 3D shapes among the clusters might result from the fabric properties because the experiment was carried out under the same conditions with the exception of fabric variation.

4. Analysis of fabric physical properties of each cluster

The main cause of the aforementioned differences in the 3D shape of Chima might originate in the diversity of the fabric properties, as the experiments were carried on under the same conditions excluding the fabric factors. Hence, in order to understand the physical fabric property of each cluster, ANOVA with a post-hoc test was performed (Table 7).

Most of the fabric factors and measurements were significantly different among the clusters ($p<.001$), meaning that each cluster had quite different fabric properties.

In F. factor 1 (softness factor) and its related measurements except drape coefficient with a negative factor loading value, cluster 1 had the highest and cluster 2 had the lowest value, indicating that cluster 1 was made with soft fabrics and cluster 2 made with stiff fabrics. In F. factor 2 and some measurements of extension, there was no significant difference among the clusters. Although each had positive factor loading values to F. factor 2 respectively, some of the measurements showed different tendencies in the post-hoc tests. However, on the whole, it can be said that cluster 1 was more stretchable. The mean of cluster 2 was significantly higher in F. factor 3(thickness of threads) and thickness (warp) and lower in thickness (weft) than the others. Thus it can be said that cluster 2 was made with a fabric woven with thick threads in warp and thin in weft. On the contrary, the thread of cluster 3 was thin in warp and thick in weft. In F. factor 4, thickness (fabric) and weight (fabric), the mean of cluster 1 was higher than the others, indicating that it is heavy and thick. Cluster 2 was made with a light and medium-thick fabric while cluster 3 was made with a thin and light fabric.

In conclusion, cluster 1 was made with soft, stretchable, thick and heavy fabrics, to which Chima 1 (silk jacquard), 2 (newttong), 3 (georgette) and 4 (cotton muslin) corresponded. Cluster 2 of Chima 5 (nobang) was made with very stiff, unstretchable, light fabric of thick threads in warp. Cluster 3 was made with unstretchable, thin, light fabric of thick threads in weft and thin threads in warp. Cluster 3 was comprised of garments largely utilizing Korean traditional fabrics, Chima 6 (sookosa), 7 (kapsa) and 8 (eunjosa).

5. Estimation of 3D shape of Chima from fabric physical property factors

In order to establish the relationship between variables and predict the 3D shape of Chima from the

<Table 7> ANOVA with Post-hoc Test of Fabric Physical Properties

Measurements \ Cluster	Cluster 1	Cluster 2	Cluster3	F
F. Factor score 1 (Softness/stiffness)	.87 a	-1.82 c	-.56 b	1103.33***
Softness (Warp)	71.25 a	29.84 c	43.77 b	739.62***
Softness (Weft)	75.25 a	22.37 c	43.49 b	546.47***
Softness (R-bias 67.5˚)	78.22 a	29.01 c	36.32 c	1167.85***
Softness (L-bias 67.5˚)	76.31 a	23.30 c	46.13 b	916.70***
Softness (R-bias 45˚)	78.31 a	39.23 c	47.78 b	1102.03***
Softness (L-bias 45˚)	77.90 a	9.09 c	54.73 b	1714.03***
Softness (R-bias 22.5˚)	75.43 a	29.84 c	49.73 b	1145.87***
Softness (L-bias22.5˚)	75.82 a	15.94 c	52.81 b	1101.54***
Drape coefficient	.44 c	.74 b	.84 a	304.93***
F. Factor score 2 (Extension)	.097	.046	-.144	1.28
Extension (Warp)	5.09 a	1.63 b	2.44 b	16.21***
Extension (Weft)	6.22 a	2.41 b	1.83 b	64.35***
Extension (R-bias 67.5˚)	19.60 a	14.21 b	12.45 b	33.35***
Extension (L-bias 67.5˚)	24.20 a	20.51 b	15.20 c	30.20***
Extension (R-bias 45˚)	26.86	26.81	24.42	2.11
Extension (L-bias 45˚)	32.70 a	31.44 a	24.81 b	13.91***
Extension (R-bias 22.5˚)	16.83	17.01	15.79	.60
Extension (L-bias22.5˚)	18.04	18.15	15.80	2.11
F. Factor score 3 (Thickness of threads)	.26 b	1.77 a	-.94 c	309.03***
Thickness (Warp)	.19 b	.35 a	.12 c	345.76***
Thickness (Weft)	.20 b	.24 c	.34 a	101.50***
F. Factor score 4 (Weight of fabric)	.310 a	.314 a	-.518 b	19.04***
Thickness (Fabric)	.33 a	.21 b	.15 c	59.47***
Weight (Fabric)	1.16 a	.50 b	.54 b	153.98***

***p<.001, **p<.01, *p<.05 Means with different letters indicatea significant difference among clustersata level of p<.05 as determined by SNK method (a > b > c).

fabrics physical properties, multiple regression analyses by a stepwise method were performed. The fabric property factors were input as independent variables: dependent variables included the 3D shape factors. The standardized coefficients (β) of the independent variables (fabric factors) of each regression model having a significance (p<.05) are shown in <Table 8>.

Four fabric property factors affect the dependent variables (3D shape factors), V. factor 1, 2 and H. factor (p<.05). In particular, in the regression equation for V. factors 1 (expansion) and 2 (sag of rear train),

<Table 8> Results of Regression for 3D Shape Factors and Fabric Factors

3D Shape Factor \ F. Factor(β)	F. Factor 1 (Softness)	F. Factor 2 (Extension)	F. Factor 3 (Thickness of threads)	F. Factor 4 (Weight of fabric)	constant	R^2	F
V. Factor 1 (expansion)	-.901**	-.106**	-.251**	-.206**	-1.52E-14	.929	635.68**
V. Factor 2 (sag of rear train)	-.254*	.094*	.632**	.416**	-3.73E-14	.646	89.006*
H. Factor 1 (shape of the node)	-.871**	-.142**		-.094*	-3.19E-15	.787	241.33**

** p<.001, * p<.05

the standardized coefficients (β) of four fabric factors had significant effects on the dependent variables, whose R^2 was 92.9% and 64.6% respectively.

In order of strength, F. factors 1 (softness, β=-.901, p<.000), 3 (thickness of threads, β=-.251, p<.000), 4 (weight of fabric, β=-.206, p<.000) and 2 (extension, β=-.106, p<.000) had significant effects on V. factor 1. In the case of V. factor 2 (sag of rear train), it was F. factor 3(β=-.632, p<.000), 4(β=.416, p<.000), 1(β=-.254, p<.05) and 2(β=.094, p<.05) that had a significant effect on V. factor 2. However, it was found that the influencing power was concentrated in the first variable; F. factor 1 for V. factor 1 and factor 3 for V. factor 2. F. factors 1, 2 and 4 had significant effects on the horizontal 3D shape factor 1 (shape of node) whose R^2 was 78.7%. The most effective variable was F. factor 1 (softness, β=-.871, p<.000) for H. factor 1 (shape of node). Hence it can be derived that if the fabric is soft, the Chima will have many shallow nodes. The regression models for estimating the independent variables (3D shape of Chima) from fabric property factor scores are displayed in <Table 9>.

<Table 9> Regression Equations for 3D Shape Factors from Fabric Property Factors

Independent Variable	Regression Equation
V. Factor 1 = (expansion)	- 1.52E-14 - 0.901 × F. Factor 1(Softness) - 0.106 × F. Factor 2(Extension) - 0.251 × F. Factor 3(Thickness of threads) - 0.206 × F. Factor 4(Weight of fabric)
V. Factor 2 = (sag of rear train)	- 3.73E-14 - 0.254 × F. Factor 1(Softness) + 0.094 × F. Factor 2(Extension) + 0.632 × F. Factor 3(Thickness of threads) + 0.416 × F. Factor 4(Weight of fabric)
H. Factor 1 = (shape of the node)	- 3.19E-15 - 0.871 × F.Factor 1(Softness) - 0.142 × F.Factor 2(Extension) - 0.094 × F.Factor 4(Weight of fabric)

6. Analysis of subjective evaluation results

100 Korean males and females were asked to indicate their degree of agreement with 30 items upon looking at pictures of Chima (front and side views). The results of the ANOVA and the post-hoc test of the sensory test are shown in <Table 10>.

Most of the items of the sensory test demonstrated significant differences among the clusters at a level of p<0.05, but no remarkable differences were found in the items of Q 3 (side), 10 (front) and 11 (front and side). The results relating to comfort may have been influenced by the fact that subjects only speculated upon this variable from the picture without having worn the garment.

In Q1 (expansion of hem), Q2 (softness), Q4 (transparency), Q5 (width of drape), Q6 (interval between drapes), and Q8 (number of drapes), the means of the sensory test decreased in the order of cluster 2 > cluster 3 >, and cluster 1, indicating that cluster 2 was made with the softest and most transparent fabric and had the bulkiest and most expanded silhouette and few wide drapes. The results for cluster 1 showed an opposite trend, that is, it was perceived to be made with the stiffest and most opaque fabric, had the most drooped and shriveled silhouette with many shallow drapes. These results are consistent with those of the fabric properties comparison, with the exception of Q2 (softness). The reason for the inconsistency might be the curved and expanded silhouette of cluster 2 because a curved line lends a softer expression than the straight and tubular shape of cluster 1.

In Q3 (3D silhouette), 12 (chest fit ease), 13-side (bust fit ease), 14 (waist fit ease) and 15 (hip fit ease), cluster 2 received higher scores than the others, suggesting that it had a bulky and three-dimensional shape in these parts. The beauty of the drape (Q9) received the lowest evaluation in cluster 1, indicating that Koreans prefer a bell-shaped silhouette to tubular ones when evaluating Chima.

In conclusion, the tendency of the human subjective evaluation was similar to that of the objective evaluation based on measurements of 3D shape

<Table 10> Results of ANOVA and Post-hoc test of Sensory Test

Item	Cluster	Cluster1	Cluster2	Cluster3	F
Q1. Chima has an expanded hem without drooping.	Front	2.00 c	4.40 a	3.20 b	140.21***
	Side	1.87 c	4.56 a	3.09 b	178.88***
Q2. Chima appears to be made of soft fabric.	Front	2.38 c	4.88 a	4.11 b	166.98***
	Side	2.30 c	4.76 a	3.83 b	133.52***
Q3. Chima has a three-dimensional silhouette.	Front	3.11 b	3.84 a	3.45 b	7.70***
	Side	3.13	3.92	3.33	1.26
Q4. Chima looks transparent.	Front	2.09 c	4.84 a	4.09 b	198.96***
	Side	2.24 c	4.76 a	3.83 b	32.03***
Q5. The width of drape of Chima appears wide.	Front	2.74 c	4.40 a	3.40 b	33.81***
	Side	2.69 c	4.56 a	3.41 b	48.48***
Q6. The interval between drapes of Chima appears wide.	Front	2.40 c	4.28 a	3.28 b	54.91***
	Side	2.59 c	4.24 a	3.36 b	36.37***
Q7. The drapes look beautiful.	Front	3.39 a	2.64 b	3.09 a	9.44***
	Side	3.20 a	2.76 b	3.13 a	3.11*
Q8. There are not many drapes.	Front	2.21 c	4.48 a	3.24 b	72.89***
	Side	2.90 c	3.88 a	3.47 b	12.25***
Q9. Chima has a traditional beauty.	Front	2.60 b	2.96 a	3.23 a	14.69***
	Side	2.57 b	3.04 a	3.19 a	13.59***
Q10.Chima has a traditional silhouette.	Front	2.74	2.80	3.20	.93
	Side	2.42 b	2.96 ab	3.64 a	5.81**
Q11. Chima looks comfortable for movement.	Front	3.16	2.92	3.17	.90
	Side	3.25	2.88	3.25	.30
Q12. Fit surplus at chest	Front	2.98 b	3.32 a	2.89 b	4.00*
	Side	2.89 b	3.24 a	2.85 b	3.28*
Q13. Fit surplus at bust	Front	2.98 a	3.48 a	3.51 a	1.44
	Side	2.95 b	3.68 a	3.12 b	8.91***
Q14. Fit surplus at waist	Front	3.46 b	4.28 a	3.72 b	13.27***
	Side	3.46 b	4.24 a	3.75 b	12.10***
Q15. Fit surplus at hip	Front	3.41 c	4.36 a	3.87 b	14.17***
	Side	3.41 c	4.32 a	3.87 b	12.67***

***p<.001, **p<.01, *p<.05 Means with different letters indicate a significant difference among clusters at a level of p<.05 as determined by SNK method (a < b < c < d).

(sections) and fabric properties except for such cases as traditionalism and comfort where diverse standards exist and fabric softness varies greatly. In this regard, a curved silhouette may mislead the subject to evaluate a material as being soft.

7. Estimation of subjective evaluation results of Chima

In order to validate the relationship among variables and extract the fabric property factors influencing the evaluation of the silhouette of Chima, a regression analysis with a stepwise method was carried out. The results are shown in <Table 11>.

The dependent variables were the sensory test items and the independent ones were the fabric property factors. The influencing independent variables for estimating the results of subjective evaluation results were displayed at a significance level of p<.05.

Items of the sensory test such as expansion of hem, softness of fabric, width, and number and interval of drapes were found to be effectively estimated from the

<Table 11> Results of Regression for Sensory Test and Fabric Factors

Item \ factor(β)		F. Factor1 (Softness)	F. Factor2 (Extension)	F. Factor3 (Thickness of threads)	F. Factor4 (Weight of fabric)	constant	R^2	F
Q1. Chima has an expanded hem without drooping.	Front	-.787***				2.750	.62	322.06***
	Side	-.805***		.108**		2.665	.66	190.32***
Q2. Chima appears to be made of soft fabric.	Front	-.745***	-.119**		-.219***	3.340	.62	105.16***
	Side	-.737***	-.110**		-.169***	3.180	.58	91.72***
Q5. The width of drape of Chima appears wide.	Front	-.534***				3.195	.29	79.10***
	Side	-.593***				3.195	.35	107.63***
Q6. The interval between drapes of Chima appears wide.	Front	-.619***	.206***			2.965	.43	73.11***
	Side	-.555***	.173**			3.085	.34	50.30***
Q8. There are not many drapes.	Front	-.666***				2.880	.44	157.61***

***p<.001, **p<.01, *p<.05

fabrics physical properties. In Q1 (expansion of hem-front and side), fabric factor 1(softness, β=-.787 and -.805, p<000) affected the prediction of the results of the subjective evaluation. It suggested that if the fabric is stiff, the participants evaluated the Chima as being expanded. F. factors 1 (softness), 2 (extension) and 4 (weight of fabric) affected the subjective evaluation of the softness of fabrics, meaning that a soft, light, unstretchable fabric could be evaluated as soft. Fabric factor 1 also was the most effective variable in terms of predicting the subjective evaluation on the width and number of drapes. The evaluation on the interval between nodes might be estimated from F. factors 1(softness) and 2(extension).

The relationship among variables can be verified through the regression equations (p<.001) displayed in <Table 12>. In this case, the subjective evaluation of the 3D shape was the dependent variable and the fabric property factors were dependent variables.

In order to validate the relationship of the subjective evaluation of the silhouette of the Hanbok Chima effect to the objective evaluation, a regression analysis with a stepwise method was performed to establish an equation between the variables. The 3D shape factors were input as independent variables. In the same manner as <Table 11>, the significant independent variables (p<.05) are displayed (Table 13).

It can be seen from the results in <Table 13> that

<Table 12> Regression Equations for Subjective Evaluation from Fabric Property Factors

Independent Variable	Regression Equation
Q 1 (front) =	2.750- 0.787 × F. Factor 1(Softness)
Q 1 (side) =	2.665 - 0.802 × F. Factor 1(Softness) + 0.108 × F. Factor 3(Thickness of threads)
Q 2 (front) =	- 3.340 - 0.745 × F. Factor 1(Softness) - 0.119 × F. Factor 2(Extension) - 0.219 × F. Factor 4(Weight of fabric)
Q 2 (side) =	- 3.180 - 0.737 × F. Factor 1(Softness) - 0.110 × F. Factor 2(Extension) - 0.169 × F. Factor 4(Weight of fabric)
Q 5 (front) =	3.195 - 0.534 × F. Factor 1(Softness)
Q 5 (side) =	3.195- 0.593 × F. Factor 1(Softness)
Q 6 (front) =	2.965 - 0.619 × F. Factor 1(Softness) + 0.206 × F. Factor 2(Extension)
Q 6 (side) =	3.085 - 0.555 × F. Factor 1(Softness) + 0.173 × F. Factor 2(Extension)
Q 8 (front) =	2.880 - 0.666 × F. Factor 1(Softness)

vertical shape factors 1 (expansion) and 2 (sag of rear train) are of statistical significance, suggesting high relevance of these independent variables to the

<Table 13> Results of Regression for Sensory Test and 3D Shape Factor

3D Shape factor(β) / Item		V.Factor 1 (expansion)	V.Factor 2 (sag of rear train)	H.Factor1 (shape of the node)	H.Factor 2 (volume of section)	H.Factor 3 (minimum node radius of hip)	H.Factor 4 (minimum node radius of waist)	Constant	R^2	F
Q1. Chima has an expanded hem without drooping.	Front	.704***	.298***					2.750	.585	138.70***
	Side	.709***	.343**					2.665	.621	161.382***
Q2. Chima appears to be made of soft fabric.	Front	.744***						3.340	.553	244.93***
	Side	.715***						3.180	.511	207.200***
Q4. Chima looks transparent.	Front	.742***					.095*	3.185	.554	122.143***
Q5. The width of drape of Chima appears wide.	Side	.494***	.269***					3.195	.317	45.674***
Q6. The interval between drapes of Chima appears wide.	Front	.541***	.235***		.144*			2.965	.389	41.563***
	Side	.505***	.227***					3.085	.307	43.628***
Q8. There are not many drapes.	Front	.607***	.303***					2.880	.460	84.028***
	Side	.701***	.291***	-.370**				3.235	.218	18.168***

***p<.001, **p<.01, *p<.05

dependent ones such as Q1 (expansion of hem)-front and side, Q5 (width of drape), Q6 (interval between drapes), and Q8 (number of drape). V. factor 1 had a greater effect than the others on the subjective evaluation of the softness (Q2) and transparency (Q4) of the fabric. It can be deducted from these results that the vertical shape factors had a greater effect on the evaluation of the 3D shape than the horizontal shape factors.

The regression equation to estimate the results of the subjective evaluation from the 3D shape with a significance of p<.001 are displayed in <Table 14>. This finding implies that the dependent variables (subjective evaluation of the 3D shape) can be predicted by performing regression analysis on the independent variables (objective evaluation of the 3D shape).

IV. Conclusion and Implications

The decision to purchase garments via the on-line market largely depends on the consumer's subjective evaluation of the static images. Therefore, it could be extremely helpful for manufacturers to be able to define these influencing variables to predict what kind of assessment the garment will elicit from the consumers. However, such research has rarely been conducted that analyzes the 3D shape of garments and investigates the variables affecting the subsequent evaluation of it. Hence, this study aimed to figure out the variables affecting the evaluation of the 3D shape of Hanbok Chima, focusing on the fabrics properties and its objective and subjective evaluation.

Through factor analysis, four fabric factors were extracted from fabric physical properties: softness, extension, thickness of threads and weight of fabric. The measurements of vertical and horizontal sections describing the 3D shape of the Chima were categorized into 6 factors such as expansion, sag of rear train, shape of nodes, volume of section, minimum node radius of hip section, and minimum node radius of waist section. This outcome indicates that such factors as expansion (volume), sag of rear train, shape of nodes can explain the 3D shape of Hanbok Chima. The experimental Chimas were classified into 3 clusters and they showed statistically significant differences concerning fabric features and 3D shape. From the findings, it can be deduced that with the fabric of stiffer, lighter, and less stretchable, the more expanded the 3D shape appeared.

The tendency of the human subjective evaluation

<Table 14> Regression Equations for Subjective Evaluation from 3D Shape Factors

Independent Variable	Regression Equation
Q 1 (front) =	2.750 + 0.704 × V. Factor 1(expansion) + 0.298 × V. Factor 2 (sag of rear train)
Q 1 (side) =	2.665 + 0.709 × V. Factor 1(expansion) + 0.343 × V. Factor 2(sag of rear train)
Q 2 (front) =	3.340 + 0.744 × V. Factor 1(expansion)
Q 2 (side) =	3.180 + 0.715 × V. Factor 1(expansion)
Q 4 (front) =	3.185 + 0.742 × V. Factor 1(expansion) + 0.095 × H. Factor 4(minimum node radius of waist)
Q 5 (side) =	3.195 + 0.494 × V. Factor 1(expansion) + 0.269 × V. Factor 2(sag of rear train)
Q 6 (front) =	2.965 + 0.541 × V. Factor 1(expansion) + 0.235 × V. Factor 2(sag of rear train) + 0.144 × H. Factor 2(volume of section)
Q 6 (side) =	3.085 + 0.505 × V. Factor 1(expansion) + 0.227 × V. Factor 2(sag of rear train)
Q 8 (front) =	2.880 + 0.607 × V. Factor 1(expansion) + 0.303 × V. Factor 2(sag of rear train)
Q 8 (side) =	3.235 + 0.701 × V. Factor 1(expansion) + 0.291 × V. Factor 2(sag of rear train) - 0.370 × H. Factor 3(shape of the node)

was similar to that of the objective evaluation based on the measurements of the 3D shape (sections). The questionnaire items that did not correspond with subjective evaluation were those related to traditionalism and comfort, wherein diverse standards exist. Furthermore, in this regard, a curved silhouette potentially misled the subjects to evaluate a material as being soft. It was found that the participants of this study preferred bell-shaped silhouettes to tubular ones.

Multiple regression analyses were conducted by a stepwise method in order to verify the relationship between variables and extract the effective independent factors in terms of predicting the dependent variables. The most effective fabric factor was F. factor 1 (softness) for vertical factor 1 (expansion) and horizontal factor 1(shape of node) and F. factor 3 (thickness of threads) for V. factor 2 (sag of rear train). Therefore, the Chima made with a stiff fabric can be estimated to have an expanded silhouette with deep and wide nodes. It was also found that the vertical shape factors had a greater effect on the objective and subjective evaluation of the 3D shape than the horizontal shape factors. From these outcomes, it was certified that dependent variables of this study such as subjective evaluation and 3D shape can be derived from regression equations on independent variables such as the fabric property factors or its 3D shape factors. These results can provide manufacturers with a basis to predict the 3D shape of Chima and human subjective assessment, enabling them to improve the efficiency of production and to create a desirable shape.

In this research, the relationships among fabric factors and objective and subjective evaluation were investigated only for Hanbok Chimas made with specific fabrics, however, the proposed method is applicable to other garment items as well.

■ References

Miyoshi, M. (1978). Factors of patternmaking-regarding to the effect of characteristics of fabrics-(first volume). *Journal of Life of Clothing, 21(1)*, 26-30.

Miyoshi, M. (1987). Non-contact body measuring system-regarding to the validity in clothing construction and the possibilities-. *Annual Journal of Faculty Research Bunka Women's University,* Tokyo, Japan, 14, 7-8.

Miyoshi, M. (1999). *Clothing Construction - Theory*, Tokyo: Bunka Publishing Bureau.

Miyoshi, M., & Iasojaki, A. (1991). The improvement and the test of accuracy on the non-contact body measuring system. *Annual Journal of Faculty Research Bunka Women's University*, Tokyo, Japan, 23, 1-17.

Kim, H. *et al*. (2001), *Clothing Ergonomics Experimental Methodology* (2nd edit.), Seoul: Kyomoon-sa publishing Co., Ltd.

Kim, H. *et al*. (1988). A Study on the wearing Evaluation Method of Slacks. *Journal of Asian Regional Association for Home Economics, 5(2)*, 10-16.

Min, G. (1997). *Traditional fabrics*, Seoul: Daewonsa publishing Co., Ltd., 45-51.

Im, S., & Yoo, K. (1991). *Hanbok Construction*, Seoul; Kyomoon-sa publishing Co., Ltd., 170-171.

Park, S., & Miyoshi, M. (2001). Analysis of the three dimensional Shape of Korean Hanbok Chima according to the Characteristics of Fabrics using 3-D Human Body Measuring System. *Journal of Korean Society of Clothing and Textiles, 25(9)*, 1571-1582.

KRISS-92-144-IR (1992). National anthropometric survey of Korea.

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