〔보 문〕

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Analysis of the Three Dimensional Shape of Korean Hanbok Chima according to the Characteristics of Fabrics using 3-D Human Body Measuring System

3차원 인체계측시스템을 이용한 직물의 물성에 따른 한복치마의 입체형상 분석

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Abstract

한국 전통 의상인 한복 치마의 형태는 천의 특성에 크게 좌우된다. 이에 본 연구에서는 직물의 물성과 착장시 한복 치마 형태의 관계를 규명하고자, 8가지 직물을 선택하여 물성을 측정하고, 비접촉 3차원 인체계측시스템을 이용하여, 치마 착장시의 5개 수평단면, 2개 수직단면을 작성하였다. 수직단면에서는 실루엣을 나타내는 각도, 수평단면에서는 단면의 부피감과 드레이프의 형태를 나타내는 노드 간격, 거리, 각도를 측정하였다.

첫째, 경연도, 신장률, 실 두께, 직물 무게의 직물물성요인에 따라 실험직물은 4집단으로 분류되었다.

둘째, 직물의 물성과 노드의 형태의 관계를 살펴본 결과, 직물이 빳빳하고 가벼울수록, 치마윗부분의 각도가 커지며, 부드럽고, 신축성이 있고, 무겁고, 두꺼운 실로 짜여지면, 튜블러 형태의 실루엣을 나타내었다.

셋째, 수직 단면도상 치마 위쪽과 아래쪽의 퍼짐각도 및 수평단면상의 둘레, 노드간의 거리, 가장 긴 파고와 같은 단면 계측치는 직물물성에 따라 추정이 가능한 것으로 나타났다.

Key words: three dimensional shape, Hanbok Chima, characteristics of fabrics, 3-D human body measuring system; 입체형상, 한복치마, 직물 물성, 3차원 인체계측시스템

I. Introduction

Clothing is the closest environment of human body in the human-environment system. Its beauty is evaluated by the 3-dimensional shape when dressed. The major influential factors of the 3-dimensional shape of a garment are design, fitness, and drapery. And these factors are reflected in the pattern, the guide in making dress. But, even though same pattern may be used, the silhouette of the dress differs, now that the fabric, which tends to stretch by its own weight, causes the drape to differ in shape.

So features of the fabric must be considered when constructing patterns and garments, suggesting the need to the study on the relationship between fabric features and 3-shape of garments.

In the case of Hanbok, the Korean traditional costume, it is characterized by the silhouette of

Chima, which is a high-waist, long skirt hanging from the chest to the floor. And the shape or the drape of Chima when dressed, are determined by the characteristics of fabric. Nevertheless, such studies have not been performed that manifest the relationship between the features of fabric and the shape of Chima.

So the purpose of this study is to investigate the relationship between the fabric and the 3-dimensional shape of Hanbok Chima; to extract the variables indicating the shape of Chima when dressed and make clear which characteristics of the fabric are related with these variables.

II. Methodology

1. Fabric characteristics test

In this study, eight fabrics having various characteristics were chosen; Five Korean traditional fabrics; fabric 1(sookosa), 2(nobang), 3(kapsa), 4(eunjosa), 6(newttong), and three control fabrics; 5(silk), 7(georgette), 8(muslin).

The measurement items were thickness of threads and fabrics, weight of fabrics, drape coefficient, softness/stiffness and elongation ratio of fabrics, softness/stiffness and elongation ratio of fabrics according to the eight directions of grain ; warp, weft, right and left bias of 22.5°, 45°, 67.5°. The measurements were taken three times.

2. Construction of Chima

Eight Hanbok Chimas were made with eight kinds of fabrics. The patterns used are displayed in Fig. 1. The length of the top was 25cm(back length-13cm) and that of the skirt was 110cm.

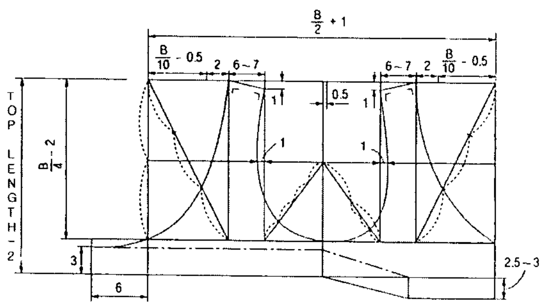
3. Photographing

Pictures of the body(9A2(N)) dressed with Chima were taken. The instruments and conditions of photographing are shown in Table 1.

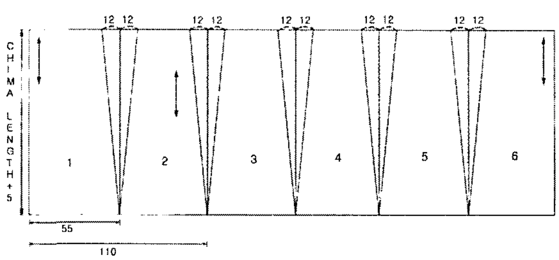
4. Measurement of section of Chima

Using non-contact 3-dimensional human body measuring system of the Bunka Women's University in Japan, the body (9A2(N)) was scanned both naked and dressed in eight kinds of Chimas. 56 section images were drawn up; two for longitudinal and five for horizontal sections. Five cross sections were the chest, the bust, the waist, the hip and the hem of each Chima. Measurements of the sections are shown in Fig. 2.

Measurements were the flared angle of Chima indicating the silhouette in longitudinal sections and the space between the body and Chima, the angle, depth, length and interval of nodes in each cross section, suggesting the volume and shape of drapes.



1) pattern for top of Chima



2) pattern for skirt of Chima

Fig. 1. Pattern of Chima (S. Im & K. Yoo, 1999) (unit:cm)

Table 1. Instruments and Conditions of Photographing

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

5. Statistical analysis

For data analysis, the factor analysis, the cluster analysis, the one way analysis of variance, with post-hoc test(S-N-K test) and the regression analysis were performed using SPSS Windows for version 10.0.

Ⅲ. Results and Discussion

1. Fabric characteristics factors

The principal component analysis was done for fabric characteristics by Varimax rotation with Kaiser Normalization. The variance explained was 91.91% of the total variance. The results of the factor analysis for fabric characteristics are shown in Table 2.

Four factors of fabric characteristics were

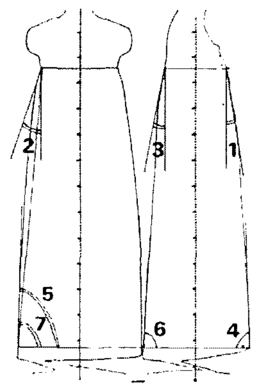
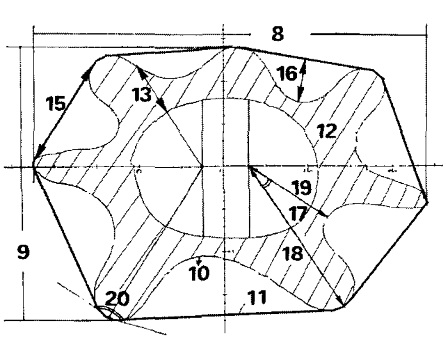
Longitudinal section		1. Angle of upper part (Front) 2. Angle of upper part (Side) 3. Angle of upper part (Back) 4. Angle of lower part (Front) 5. Angle of lower part (Side) : angle between horizontal line of hem and tangential line of side-lower part of chima 6. Angle of lower part (Back) 7. Flared angle : angle between horizontal line of hem and the chest side point
Cross section		8. Width of cross section 9. Thickness of cross section 10. Girth of cross section 11. Outward girth of cross section 12. Area of cross section 13. Vacant space distance between body and garment 14. Number of nodes 15. Distance between waves 16. Depth of node 17. Angle of wave 18. Maximum wave length 19. Minimum wave length 20. Angle of the peak of node

Fig. 2. Measurements of Sections of Chimas

Table 2. Factor Analysis for Fabric Characteristics (Rotated component matrix)

Factor / Measurements	Factor 1 (Softness/stiffness)	Factor 2 (Extension)	Factor 3 (Thickness of threads)	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

extracted. The measurements corresponding to factor1 were softness/stiffness of all kinds of grains and drapes coefficient, so factor 1 was named as the 'softness/stiffness factor'. However, drape coefficients had negative factor loading value. It suggests that higher the drape coefficients is, stiffer the fabric is. If the factor score 1 of a fabric is large, it can be considered as soft fabric. Factor 2 was 'extension factor', to which the measurements of the stretch had positive factor loading. So the fabric with high factor score of this factor can be estimated as stretchable. Factor 3 was the 'thickness of threads factor', with negative factor loading in the warp and positive in the weft. So the fabric having high factor score of factor 3 may be woven with thick weft and thin warp. Factor 4 was the 'weight of fabric factor', in which the thickness and weight of fabric included. So high factor score of this factor means that the fabric is thick and heavy.

2. Classification and comparison of fabric features among clusters

Using factor scores of fabric characteristics, 8 kinds of fabrics were classified into 4 clusters. Cluster 1 is made up with fabric 1(sookosa), 3(kapsa) and 4(eunjosa). Cluster 2 was composed with fabric 2(nobang). Cluster 3 was composed of fabric 5(silk), 7(georgette), 8(muslin) and fabric 6(newttong) was included in cluster 4.

The results of the ANOVA with the post-hoc test

Table 3. ANOVA with Post-hoc Test of Factor Scores among Four clusters

Cluster / Factor score	Cluster 1	Cluster 2	Cluster3	Cluster 4	F
Factor score 1	−.560 b	−1.818 a	1.042 d	.374 c	1567.06***
Factor score 2	−.144	.046	.035	.282	1.24
Factor score 3	−.938 a	1.767 d	.513 c	−.493 b	381.22***
Factor score 4	−.518 a	.314 b	−.396 a	2.430 c	685.56***

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

Means were marked with different letters having significant difference at the level of p<.05(a<b<c<d).

Table 4. ANOVA with Post-hoc Test of Fabric Measurements among Four clusters

Cluster / Measurements	Cluster 1	Cluster 2	Cluster3	Cluster 4	F
Softness(Warp)	43.77 b	29.84 a	73.83 d	63.48 c	720.56***
Softness(Weft)	43.39 b	22.37 a	77.26 d	69.24 c	403.18***
Softness(R-bias 67.5°)	36.32 b	29.01 a	79.22 d	75.23 c	806.48***
Softness(L-bias 67.5°)	46.13 b	23.30 a	76.78 c	74.91 c	613.62***
Softness(R-bias 45°)	47.78 b	39.23 a	79.20 d	75.66 c	770.92***
Softness(L-bias 45°)	54.73 b	9.09 a	77.55 c	78.95 c	1144.66***
Softness(R-bias 22.5°)	49.73 b	29.84 a	75.69 c	74.66 c	763.56***
Softness(L-bias22.5°)	52.81 b	15.94 a	76.63 d	73.41 c	753.63***
Drape coefficient	.84 d	.74 c	.42 a	.51 b	220.25***
Extension(Warp)	2.44 a	1.63 a	5.71 b	2.23 a	14.36***
Extension(Weft)	1.83 a	2.41 a	5.02 b	9.82 c	91.79***
Extension(R-bias 67.5°)	12.45 a	14.21 a	18.21 b	23.75 c	30.17***
Extension(L-bias 67.5°)	15.20 a	20.51 b	23.20 b	27.22 c	22.38***
Extension(R-bias 45°)	24.42 a	26.81 a	25.47 a	31.02 b	4.52**
Extension(L-bias 45°)	24.81 a	31.44 b	30.98 b	37.89 c	12.80***
Extension(R-bias 22.5°)	15.79 a	17.01 a	17.67 a	14.30 a	1.98
Extension(L-bias22.5°)	15.80 a	18.15 ab	17.19 ab	20.58 b	2.70*
Thickness (Warp)	.12 a	.35 d	.19 b	.21 c	242.73***
Thickness (Weft)	.34 d	.12 a	.17 b	.31 c	131.41***
Thickness (Fabric)	.15 a	.21 b	.25 c	.56 d	418.38***
Weight (Fabric)	.54 a	.50 a	.99 b	1.69 c	531.74***

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

Means were marked with different letters having significant difference at the level of p<.05(a<b<c<d).

of factor scores among 4 clusters are shown in Table 3 and 4. All factor scores except factor score 2(Extension), were significantly different among clusters at the level of p-value < 0.005, which meant that each cluster had quite different features in these factors.

Cluster 1 was stiff, light, thin and made with fine threads in warp. Cluster 2 was very stiff, light, thick and woven with very thick threads in warp. Cluster 3 was very soft, heavy, thick and made with thick threads in warp. Cluster 4 was soft, very heavy, thick and made with thick threads in warp.

Also, in most measurements of softness, cluster 2 had the highest and cluster 3 had the lowest value. So the order of softness was cluster 3 〉 cluster 4 〉 cluster 1 〉 cluster 2. But, the order of drape coefficient, with negative factor loading, was opposite.

Most measurements of extension except for the extension(R-bias 22.5°) were significantly different among clusters. Extension (warp) was highest in cluster 3 and extension (weft) was in cluster 4. In the case of 45° and 67.5° bias, extension of cluster 4 was higher than other clusters. But as the angle of bias slacked, the difference among fabrics appeared insignificant. The order of thickness of threads was cluster2 〉 cluster4 〉 cluster3 〉 cluster1 in warp and cluster 1 〉 cluster 4 〉 cluster 3 〉 cluster 2 in weft, indicating that the thickness of warp and weft had an opposite tendency. Weight of fabric was in the order of cluster4 〉 cluster 3 〉 cluster 1, 2. In conclusion, cluster 1 was made up with fabric 1(sookosa), 3(kapsa) and 4(eunjosa), which were stiff, light, thin and made with fine threads in warp. Cluster 2, very stiff, light, thick and made with very thick threads in warp, was composed with fabric 2(nobang). Cluster 3 was very soft, heavy, thick and made with thick threads in warp, to which fabric 5(silk), 7(georgette) and 8(muslin) corresponded. Fabric 6(newttong), very soft, heavy, thick and made with thick threads, conformed to cluster 4.

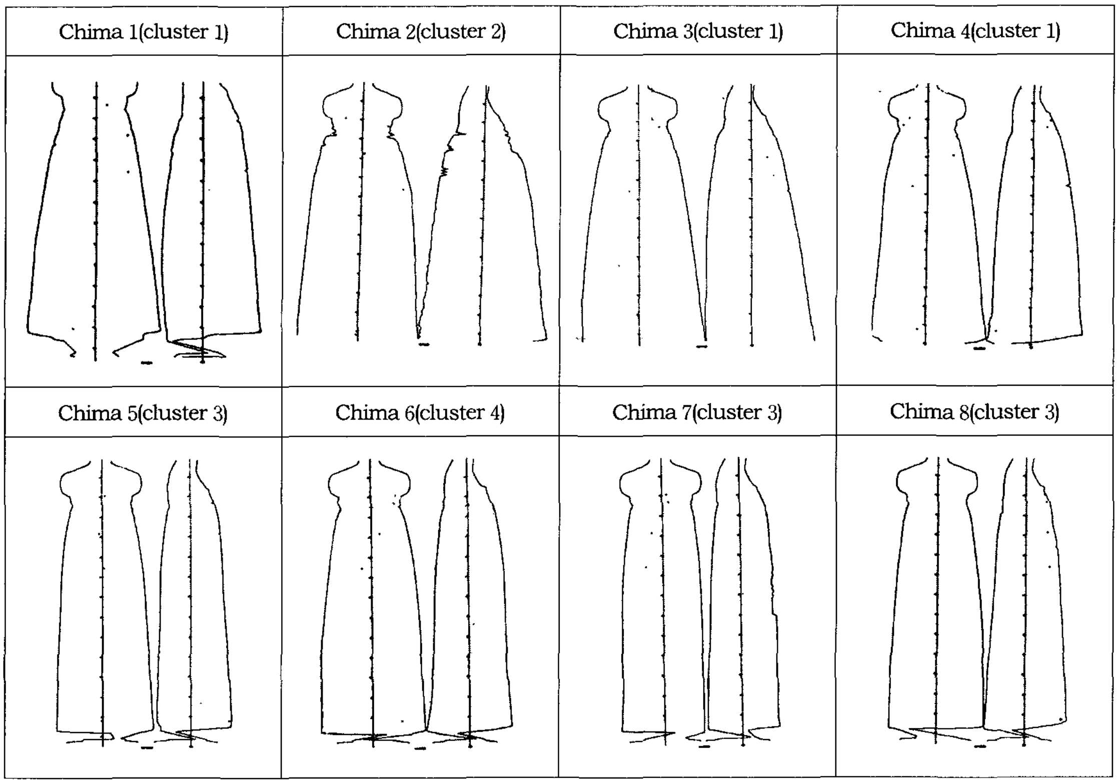


Fig. 3. Longitudinal Sections of Chimas

Table 5. ANOVA with Post-hoc Test of Measurements of Longitudinal Section of Chimas

Measurements \ Cluster	Cluster 1	Cluster 2	Cluster3	Cluster 4	F
Angle of upper part (Front)	23.13 c	28.50 d	11.83 a	13.80 b	348.79***
Angle of upper part (Side)	23.90 b	30.80 c	18.27 a	22.90 b	74.82***
Angle of upper part (Back)	27.57 b	35.90 c	14.53 a	15.30 a	198.63***
Angle of lower part (Front)	85.10 b	83.90 a	88.63 d	87.90 c	149.81***
Angle of lower part (Side)	85.13 a	88.00 b	88.50 c	89.00 d	387.58**
Angle of lower part (Back)	91.10 d	85.40 a	87.87 c	86.80 b	108.21***
Flared angle	81.03 a	81.50 b	85.80 d	84.40 c	1039.59***

***$p<.001$ **$p<.01$

Means were marked with different letters having significant difference at the level of $p<.05$($a<b<c<d$).

3. Comparison of measurements of longitudinal section among clusters

The front and side longitudinal section of Chima was presented in Fig. 3.

Results of the ANOVA with the post-hoc test among four clusters are shown in Table 5. All measurements of the longitudinal section showed significant differences among clusters at the level of $p<0.01$, indicating that each cluster had quite different silhouette. Every angle of upper part had the order of cluster 2 〉 cluster 1 〉 cluster 4 〉 cluster 3, which was due to the softness/stiffness of fabric. But the tendency of the lower part angle was slightly different according to the angle of photographing. This proved that the diversity of silhouette of Chima was bigger in the lower part than the upper part. The factor which brought about these results can be estimated as the shape of drapery ditermined by the features of fabrics and the draped condition. In view of the results so far achieved, clusterl, stiff, light and made with fine threads, had slightly bell-shaped silhouette with large angle in the upper part and small angle in the lower part. Cluster 2, very stiff, heavy and made with very thick threads, had fully bell-shaped silhouette with the largest angle in the upper part and medium angle in the lower part. Cluster 3, very soft, light and made with thick threads, had tubular silhouette with smallest angle in the upper part and large angle in the lower part. Cluster 4, soft, very heavy and made with fine threads, had the slightly trumpet silhouette in side view, with small angle in the upper part and large angle in the lower part except back. The rear slightly sagged due to the weight of the fabric.

4. Comparison of measurements of cross section among clusters

The cross sections of each Chima were represented in Fig. 4 and the results of ANOVA with post-hoc test of measurements of cross section among four clusters are shown in Table 6.

Most of the measurements of cross section of the waist, the hip, and the hem showed significant differences among clusters at the level of $p<0.01$, meaning that each cluster had significantly different shape of section.

The width, the thickness and the girth of cross section revealed no difference among clusters. But the outward girth and the area of the section showed the order of cluster 2 〉 cluster 1, cluster 4 〉 cluster 3, indicating that even with the same girth, the volume of the section of cluster 2 was biggest.

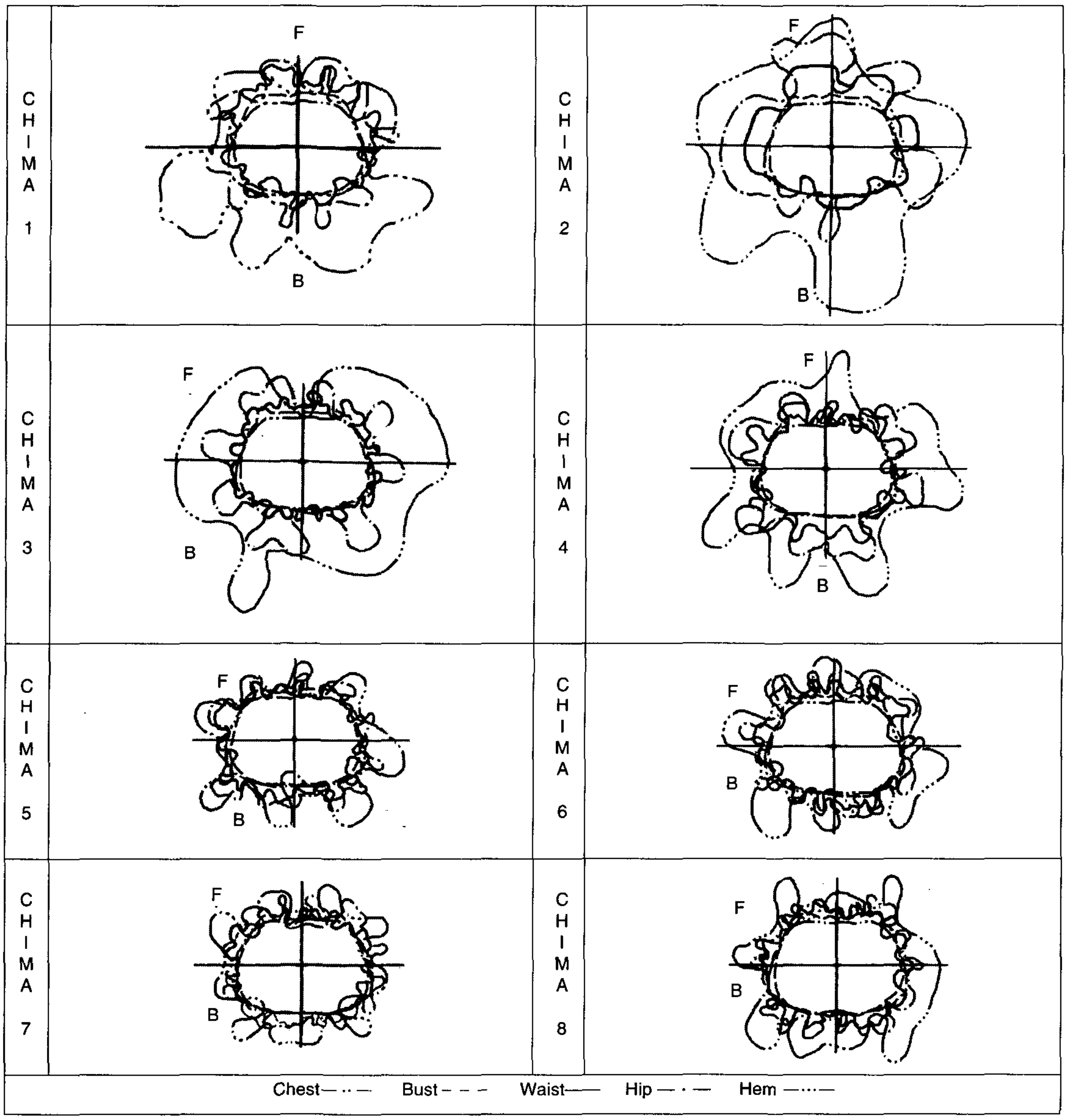


Fig 4. Cross section of Chimas

The vacant space distance between body and the garment, minimum wave length (waist), angle of peak of node(hip) of cluster 2 was larger than any other cluster, indicating that cluster 2 had the largest vacant space in waist section and round nodes in the hip section. The angles of the peak of the node (waist, hem) of clusters 1 and 2 were larger than other clusters, having more rounded peaks in the node. The angle of the wave (hip), the maximum wave length (waist, hip, hem), the minimum wave length(hem), the distance between waves(hip, hem) decreased in the order of cluster

Table 6. ANOVA with Post-hoc Test of Measurements of Cross Section

Measurements \ Cluster	Cluster 1	Cluster 2	Cluster3	Cluster 4	F
Width of cross section	41.32	43.02	36.27	38.75	1.88
Thickness of cross section	34.08	39.63	28.60	30.28	1.66
Girth of cross section	149.37	163.72	137.17	160.47	0.93
Outward girth of cross section	122.19 ab	131.23 b	107.93 a	111.78 a	5.39***
Area of cross section	982.54 bc	1162.47 c	744.64 a	802.10 ab	7.59***
Vacant space distance between body and garment	4.05 a	6.39 b	2.53 a	3.28 a	9.03***
Angle of wave (Waist)	13.62 b	12.93 b	8.03 a	10.16 a	15.09***
Angle of wave (Hip)	18.51 b	30.78 c	12.39 a	13.39 a	19.21***
Angle of wave (Hem)	32.79 b	35.89 b	22.06 a	18.78 a	8.29***
Maximum wave length (Waist)	17.92 b	19.57 c	15.98 a	16.80 a	23.96***
Minimum wave length (Waist)	13.13 a	14.48 b	13.43 a	13.14 a	3.20*
Distance between waves (Waist)	7.26 c	8.65 d	4.29 a	5.60 a	36.67***
Depth of node (Waist)	4.26 c	4.71 c	2.45 a	3.44 b	25.45***
Angle of the peak of node (Waist)	160.05 ab	164.40 b	155.73 a	157.84 a	5.43***
Maximum wave length (Hip)	21.35 b	24.00 c	18.21 a	18.95 a	52.83***
Minimum wave length (Hip)	14.71	13.80	14.50	14.40	1.12
Distance between waves (Hip)	11.70 b	17.03 c	7.36 a	7.72 a	96.50***
Depth of node (Hip)	5.77 c	8.78 d	3.39 a	4.20 b	65.81***
Angle of peak of node (Hip)	163.39 a	168.98 b	162.01 a	161.34 a	5.50***
Maximum wave length (Hem)	30.02 b	33.46 c	21.69 a	22.58 a	105.59***
Minimum wave length (Hem)	19.64 b	22.41 c	14.27 a	15.11 a	42.87***
Distance between waves (Hem)	21.14 b	28.16 c	13.54 a	12.02 a	142.65***
Depth of node (Hem)	7.59	6.23	7.04	6.58	1.44
Angle of peak of node (Hem)	171.42 b	171.36 b	170.55 b	168.15 a	2.80

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

Means were marked with different letters having significant difference at the level of p<.05(a<b<c<d).

2 〉 cluster1 〉 cluster 3, 4. It meant that cluster 2 had the largest volume and fewest waves in the hip and the hem. The distance among waves(waist), depth of node(hip) decreased in the order of cluster 2 〉 cluster 1 〉 cluster 4 〉 cluster 3.

The angle of the peak of the node(hem) of cluster 4 was the smallest, showing that cluster 4 had the most pointed nodes in the hem section. And this result was somewhat different from that of the hip. That is, in the hip section clusters 1, 3 and 4, in the hem section clusters 1, 2 and 3 had no different shapes of nodes. In the view of the result so far achieved, in the hip section, only cluster 2 was bulky because of the stiffness and the lightness, however, in the hem section, only cluster 4 sagged due to the softness and the weight. As a result, cluster 2, which was stiff and light, had the largest space between the body and Chima and fewer and deeper nodes with round peak. On the contrary, cluster 4, soft and heavy, had many shallow nodes with pointed peak.

Table 7. Regression of Measurements of Longitudinal Sections

Factor(β) / Measurements	Factor1 (softness)	Factor2 (Extension)	Factor3 (Thickness of threads)	Factor4 (Weight of fabric)	Constant	R^2	F
Angle of upper part (Front)	−.924***		−.075**	−.120***	18.400	.87	451.074***
Angle of upper part (Back)	−.877***			−.142***	22.188	.79	368.66***
Angle of lower part (Front)	.873***	.200***	.151**	.154***	86.625	.85	272.98***
Angle of lower part (Side)	.524***	.154***	.584***	.448***	87.238	.84	255.06***
Angle of lower part (Back)			−.643***	−.435***	88.637	.60	149.65***
Flared angle	.876***	.160***	.397***	.152***	83.300	.97	1718.81***

***p<.001 **p<.01

Means were marked with different letters having significant difference at the level of p<.05(a<b<c<d).

Table 8. Regression of Measurements of Cross Sections

Factor(β) / Measurements	Factor1 (softness)	Factor2 (Extension)	Factor3 (Thickness of threads)	Factor4 (Weight of fabric)	Constant	R^2	F
Girth of cross section	−.191***	.752***	−.119**	−.101*	156.977	.63	81.509***
Outward girth of cross section	−.346***	.638***		−.165**	116.67	.55	80.97***
Maximum wave length (Hem)	−.768***	−.130**	−.100*	−.143**	26.395	.64	85.808***
Distance between waves (Hem)	−.818***	−.094*	.111**	−.215***	18.026	.74	136.13***

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

Means were marked with different letters having significant difference at the level of p<.05(a<b<c<d).

5. Regression analysis on measurements of sections of Chima

In order to predict the silhouette of Hanbok Chima by characteristics of the fabric, the regression analysis was carried out. Results of the regression of measurements of the longitudinal section with $R^2 > .60$ were presented in Table 7.

It was factor 1(softness) and 4(weight of fabric) that had negative effect on the angle of the upper part(front, back), meaning that stiffer and lighter the fabric is, the angle of the upper part(front) becomes larger. And the angle of the lower part(front, side) and the flared angle were positively influenced by all factors, which indicated that the cluster soft, stretchable, heavy and made with thick threads, had the tubular silhouette. The angle of the lower part(back) was negatively affected by factor 3(thickness of threads) and 4(weight of fabric), implying that clusters, heavy and made with thick threads, showed small angle of lower part(back).

The result of the regression of measurements of the cross section with $R^2 > .55$ are shown in Table 8.

The Girth of the section and the outward girth of section were influenced by factor 1, 2, 3 and 4. It meant that cluster, stiff, stretchable, light and made with fine threads tended to have broad sections. The maximum wave length (Hem) and the distance between waves (Hem) were affected by factor 1, 2 and 4 negatively, meaning that stiff, non-stretchable, light fabrics tended to stretch in the hem and have rare nodes.

Ⅳ. Conclusion

This study was done to manifest the relationship between fabric features and the three-dimensional shape of Hanbok Chima when dressed.

First, Four characteristics of fabric factors were extracted; Factor1, softness: Factor 2, Extension: Factor 3, Thickness of threads: Factor 4, weight of fabric.

Second, Cluster 1 was made up with fabric 1(sookosa), 3(kapsa) and 4(eunjosa), which were stiff, light, thin and made with fine threads. Cluster 2, very stiff, light, thick and made with very thick threads, was composed by fabric 2(nobang). Cluster3 was very soft, heavy, thick and made with thick threads, to which fabric 5(silk), 7(georgette) and 8(muslin) corresponded. fabric 6(newttong), soft, very heavy, thick and made with thick threads, conformed to cluster 4.

Third, In the analysis of the longitudinal section, cluster1 had slightly bell-shaped silhouette: Cluster 2, fully bell-shaped silhouette: Cluster 3, tubular silhouette: Cluster 4, slightly trumpet silhouette in the view of side because the rear slightly sagged by the weight of fabric.

Forth, In the analysis of the cross section, cluster 2, which was stiff and light, had the largest space/volume between the body and the garment and fewer nodes with more round peaks than other clusters. And cluster 4, soft and heavy, had many shallow nodes with pointed peak.

Fifth, In the analysis of the relationship between fabric features and the shape of nodes, it may be summarized as follows. The stiffer and lighter the fabric is, the angle of the upper part(front) becomes larger. And soft, stretchable, heavy and made with thick threads in the warp had the tubular silhouette.

Sixth, Such measurements of the section as the angle of the upper and the lower part, the girth of the cross section, the maximum wave length and the distance between waves, were to be estimated by fabric characteristics with $R^2 > 0.6$.

This study contributes to an understanding of the relationship between fabrics and three dimen sional shape of a garment. This findings identify which features of fabrics and measurements of sections are useful to estimate the specific silhouette of a garment, implying that it is possible to realize the 3D shape based on the features of fabrics in the virtual space. Future studies may be done on more various items and fabrics for more accurate estimation. Also, investigation and extraction of the measurements of sections to explain the 3D shape will make it easy to connect the 3D shape and fabric features.

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