Lumbar shape factors extraction influencing the ratio of waist-darts' volumes for young female

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Abstract. To improve the fitness of bottoms of individuals, this study is proposed to extract lumbar shape factors influencing the ratio of waist dart's volumes of young females. A total of 27 measurement items including lumbar shapes and waist dart's volumes were collected through overlapped graphics of lumbar feature sections obtained from 30 female college students aged 18 and 24 via 3D body scanning method. Results of correlation analysis showed that the total waist dart's volume was significantly correlated with the lateral lumbar bending level (ylc), and the ratio of each waist dart's volume was significantly correlated with lumbar anteversion angle (β), lumbar anteverted amount (ytq) and buttock projected volume (ab) respectively with a correlation coefficient above $r=0.7$. Furthermore, a total of 2 factors with a characteristic value that was larger than 1 were extracted through principle component analysis, whose cumulative contribution rate reached 80.241%. Principle Component 1 represented factors of lumbar anteversion, which was related to the ratio of anterior/posterior waist dart's volume; and Principle Component 2 represented the lateral lumbar shape characteristics affecting the total waist dart's volume.

1 Introduction

Fitness is a core evaluating indicator of the quality of garment customisation [1]. In the field of bottom pattern-making for individuals, it is effective if the ratio of waist dart's volumes is matched with different lumbar shapes, so as to improve the fitness of bottoms. However, the waist-hip difference is a standard and the only parameter related to the total waist dart's volume for clothing mass production without taking the features of individual lumbar shapes into account.

There are many theoretical researches on parametric descriptions of somatotype differences and human body shape subdivisions [2] were oriented to garment customisations, according to statistical analyses based on multiple body shape variables collected via three-dimensional human body scanning method. Meanwhile, it is a widespread and potential approach that was applied in the field of basic researches, such as body type classification and garment customisation, etc.

There are some researches related to pattern making, such as parametrises of pants back piece corresponding to 4 types of gluteal groove morphologies by draping [3]; the clustering of upper crotch length of man's trousers based on linear regression relationships with lower body height variables [4] as well as the linear regression model of garment shoulder angle based on BMI and shoulder angle [5], through which the relationships between human body parameters and garment patterns were discussed based on statistical analyses considering differences in human body shapes.

For the dart's volume determination, studies on the waist-darts volume defined by standard young women mannequins [6] represented the average ratio of waist-darts, which was inadaptable to performing differences in human body shapes. Mathematical predicting models of breast and the back dart volumes were respectively established with characteristic variables of breast and acromion based on geometric features of chest and back of female bodies [7], and discussions on body shape characteristics were limited to specified geometric parameters that showed standardized human body shapes. Otherwise, Keiko Hitaragi [8] analysed relationships between morphological characteristics of female upper bodies and the ratio of each waist-dart's volume in a trunk basic pattern according to classifications of upper body shapes. This study provided theoretical clues for darts volume assignments related to garment pattern-making, which took differences in human body shapes into consideration.

Therefore, the purpose of this study is to extract lumbar shape factors influencing the ratio of waist dart's volumes based on characteristic analyses about lumbar shapes of young females. In this paper, lumbar shapes and dart's volumes measured through three-dimensional human body cross sections are main data sources for lumbar shape feature analyses.

2 Method of Data Acquisition of Lumbar

The subjects 72 young women aged 18 to 25 years old, were asked to wear light-coloured fitting shorts and vests.

2.1 Measurement Points of Lumbar

According to the definition of human body surface measurement point [9], there are 4 measurement points manually confirmed on lumbar surface, including lateral waist point, abdomen projected point, buttock projected point and maximum thigh point, all of which were marked with labels initially.

2.2. Method of Three-dimensional Human Body Scanning and Overlapping of Cross-sections

Body surfaces were scanned via an OKIO-Body Scan Tian Yuan human three-dimensional scanner. During the scanning, arms of subjects were spread out for about 30°, kept upright and looking ahead.

Characteristic cross-sections of lumbar belonging to aforementioned lumbar measurement points were selected and input into AutoCAD; then, these characteristic cross-sections were overlapped as a measuring graphics.

The measuring method of overlapping graphic of lumbar cross-sections is shown in Figure 1, and measurement procedures are as follows: 1) Via the waist dart measuring method [9], encircling lines of characteristic cross-sections of lumbar are drawn through connecting the measurement feature points; 2) The x-axis (1/2 point of the distance between central point 'f' of the waist thickness and central point 'e' of the outer circumferential thickness) and the y-axis (1/2 point of the waist breadth) intersect at point 'o', then take the length of 1/2 waist thickness (c'o') on y-axis to determine the focal point 'o' ; 3) Take the focal point 'o' as central point, draw the rays at an interval of 30° as waist dart lines and the midlines between each two adjacent waist dart lines (dotted line, II-V).

2.3. Measurement Items of Overlapping Graphic of Lumbar Cross-sections

A total of 27 items were measured on the overlapping graphic of lumbar cross-sections, including 21 for the measurement of lumbar shapes and 6 for that of waist-darts.

Measurement items of lumbar shapes include circumferences, widths and thicknesses of lumbar, and calculation items include waist flattening rate, etc.

A difference between encircling and waist lines is the total waist dart volume; and a difference among midlines of each two adjacent waist-dart lines is each waist-dart's volume. A part of definitions of lumbar shape measurement items and waist-dart's ratios are shown in Table 1.

Figure 1. Waist overlapping sections diagram.

Table 1. Measurement items in the graphic of partial waist overlapping sections.

Ordina	Measuring project	Definition
1	Buttock projected volume (ab)	The distance between the encircling and the WL line at the front center.
2	Abdomen projected volume (cd)	The distance between the outer perimeter and the WL line at the back center.
3	Lumbar anteverted amount (ytq)	The distance between the outer perimeter thick coronal line 'e' and the WL thick coronal line 'f'.
4	Lateral lumbar bending level (ytc)	The distance between outer perimeter line of lateral lumbar line and WL line.
5	Lumbar anteversion angle (β)	The angle of a right triangle with 'ytq' and 'ytc' as right-angled edges.
6	Total waist dart's volume (s)	Difference between the encircling line and the WL line.

7	Dart 1 (%)	The difference between the encircling line and the WL line between Front Center I and Dart Midline II, and its percentage to the total dart's volume.
8	Dart 2 (%)	The size difference between the outer perimeter and the WL perimeter between Dart Midline II and Dart Midline III accounting for the percentage of the total dart's volume.
9	Dart 3 (%)	The size difference between the outer perimeter and the WL perimeter between Dart Midline III and Dart Midline IV accounting for the percentage of the total dart's volume.
10	Dart 4 (%)	The size difference between the outer perimeter and the WL perimeter between Dart Midline IV and Dart Midline V accounting for the percentage of the total dart's volume.
11	Dart 5 (%)	The size difference between the outer perimeter and the WL perimeter between Dart Midline V and Posterior Central VI accounting for the percentage of the total dart's volume.

3 Basic Statistics of Lumbar Shape

According to results of Kolmogorov-Smirnov test through SPSS statistics 23, all lumbar feature variables follow a normal distribution.

Taking A-type upper body size in GB/T+1335.2-2008--"standard sizing for garment-women" as a test value, one-sample t-tests were done, whose results are shown in Table 2. The average waist circumference of subjects taken in this study was significantly different from the national standard of A-type, which showed the basic characteristics of subjects taken in this study.

Tab 2. Results of single-sample t-tests at the control site compared with national A-type women.
n=30

Control variable	Average value (cm)	Standard deviation	Inspection value (cm) 160/84A	<i>t</i>	Significance
Height	160.00	4.70	160.00	-0.008	N.S. ^a
WL	66.42	4.20	68.00	-2.067	* ^b
HL	90.84	4.88	90.00	0.948	N.S. ^a

^a $p > 0.05$: No significant difference;

^b $0.01 < p < 0.05$: difference;

^c $p < 0.01$: Significant difference.

4 Correlative Relationships between Waist-darts Volume and Lumbar Shape Features

The results of correlation analyses between waist-darts and the measurement of lumbar morphological features on overlapped diagrams are shown in Table 3. Abdomen projected volumes (cd) respectively showed a highly significant correlation over $r=0.8$ with the waist darts.

Tab 3. Results of correlation analyses between waist shape variables and the allocation rate of dart's volume.

Waist dart	Lumbar anteversion angle (β)	Lumbar anteverted amount (y _{tq})	Buttock projected volume (ab)	Abdomen projected volume (cd)	Lateral lumbar bending level (y _{tc})
Total waist dart's volume	0.031	0.223	.389*	0.151	.830**
Dart 1 (%)	-.917**	-.910**	-.780**	.865**	0.15
Dart 2 (%)	-.841**	-.814**	-.863**	.494**	0.238
Dart 3 (%)	-.367*	-0.312	-.509**	-0.092	0.244
Dart 4 (%)	.796**	.813**	.774**	-.625**	0.015
Dart 5 (%)	.949**	.911**	.896**	-.685**	-0.302

** At level 0.01 (two-tailed), the correlation is significant;

* At level 0.05 (two-tailed), the correlation is significant.

A significant correlation of $r=0.815$ was shown between the total waist-dart's volume and the lateral lumbar bending level (ytc), which indicated a close relationship between the side waist shape and the total waist dart's volume.

Morphological variables of lumbar anteversion angle (β), lumbar anteversion amount (ytq), lateral lumbar bending level (ytc) and buttock projected volume (ab) were negatively correlated with the ratio of front waist dart's volumes over $r=0.7$ (Dart 1%, Dart 2%), which were positively correlated to the ratio of back waist-dart's volumes (Dart 4, Dart 5) respectively. It is shown that the ratio of front waist-dart's volumes decreased with increases in the degree of lumbar anteversions, and the ratio of back waist-dart's volumes increased with increases in the degree of lumbar anteversions.

5 Extraction of Lumbar Shape Feature Factors Affecting the Ratio of Waist Dart's Volumes

Based on the relationship shown between the ratio of waist-dart's volume and the lumbar morphological feature variables, principle component analyses were

carried out to extract lumbar shape feature factors affecting the ratio of waist-dart's volumes. 11 variables featured lumbar shapes were selected after eliminating variables uncorrelated with waist-dart's volumes and verified non-collinear. Results of principle component analyses through maximum variance method are shown in Table 4.

A total of 2 factors with a characteristic root that was larger than 1 were extracted, whose cumulative contribution rate reached 80.241%. In Principle Component 1, ratios of front and back waist dart's volumes (Dart 1, Dart 2, Dart 4 and Dart 5) and characteristic variables (β , ytq, and ab) showed a high loading coefficient that was above 0.7, thus, this principle component could be interpreted as a lumbar anteversion factor; in Principle Component 2, the total waist-dart's volume and the lateral lumbar bending level (ytc) showed a high loading coefficient that was above 0.8, which was interpreted as a lateral lumbar shape factor.

In summary, two factors influencing the ratio of waist-dart's volumes were extracted, of which Feature Factor 1 affected the ratio of front and back waist-dart's volumes, and Feature Factor 2 affected the total waist-dart's volume.

Tab 4. Results of factor analyses.

Variable	Factor	
	1	2
Lumbar anteverted amount (ytq)	0.972	0.099
Lumbar anteversion angle (β)	0.971	-0.081
Dart 5(%)	0.961	-0.124
Dart 1 (%)	-0.932	0.137
Buttock projected volume (ab)	0.901	0.257
Dart 2 (%)	-0.888	0.023
Dart 4 (%)	0.853	0.133
Abdomen projected volume (cd)	-0.755	0.239
Lateral lumbar bending level (ytc)	-0.017	0.888
Total waist-dart's volume	0.264	0.885
Wide outer perimeter	-0.222	0.602
Characteristic root	6.700	2.127
Variance contribution rate (%)	60.906	19.335
Cumulative contribution rate (%)	60.906	80.241

6 Conclusion

Waist morphological features that affected the ratios of waist-dart's volumes of young women were extracted in this study. Main conclusions are as follows:

1)In the results of correlation analyses, the total waist-dart's volume significantly showed a correlative relationship with the lateral lumbar bending level (ytc), and the ratio of waist-dart's volumes was significantly correlated with variables representing the degree of lumbar anteversions.

2)Two principle component factors influencing the ratios of waist-dart's volumes were extracted through principle component analysis. Principle Component 1 was interpreted as a lumbar anteversion factor that

affected the ratio of each waist-dart's volumes; and Principle Component 2 was interpreted as a lateral lumbar factor that affected the total waist-dart's volume.

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