Waist Hip Somatotype and Classification for Young Chinese Women

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Abstract

To analyze the influencing factors of the fit of pants structure design, the waist and hip body shape characteristics and categories of specific populations were studied. 2000 young Chinese women aged 18-26 were selected as the research subjects, and 18 waist and hip characteristic variables were obtained. Using principal component factor analysis, four morphological factors affecting the waist and hip body shape characteristics were obtained: circumference factor, height factor, ratio factor, and girth difference factor. Based on morphological factors, four variables were selected: waist circumference, waist to hip height, Waist transverse diameter, and D-value between hip circumference and waist circumference. A two-step clustering method was used to classify waist and hip body types, dividing young women into four categories. The first type is short round body, the second type is high flat body, the third type is short flat body, and the fourth type is high round body. The proportions of each type of body in the experimental sample are 11.3%, 23.3%, 35.2%, and 30.3%, respectively.

Keywords: classifications, waist and hip body types, young Chinese

1. Introduction

The human body shape reflects the characteristics and types of the human body's appearance. In product design, reasonable classification of human body shape can accurately design product specifications and dimensions, enabling products to meet the needs of different human body shapes. For fashion design, by segmenting the body shape, more accurate information about the controlled parts of the human body can be obtained and can achieve a better wearing experience.

The physical characteristics and classification of the human waist and hip area are the important basis for the structural design of clothing underwear, comfortable fit and optimization of clothing pattern.Due to the human waist, abdomen and buttocks have more curved surfaces and complex structure, the deep understanding of the relevant human body type data is needed in order to design a reasonable trouser pattern.

In the study of human body type characteristics and classification, the determination of body type classification indexes is the key to body type segmentation. In the current research, waist and hip body type classification indexes are mainly based on circumference difference, circumference ratio, height circumference ratio, etc..

Zhang Zhongqi [1] classified male college students in the central and western regions into 5 categories by using 2 indicators of waist-height-waist ratio and hip-waist difference as classification items.Huang Ying et al [2] used waist and hip difference as the standard of body type classification to study the classification of lower body type of adult females in the East China region.

Congsan et al. [3] used principal component analysis to obtain three major factors representing buttock characteristics, and used them as the basis for clustering analysis of female body types.

Karla Simmons et al [4] classified 253 female body types into 9 different body types, based on which they designed and developed a female body type recognition software for clothing using multivariate analysis of variance (ANOVA) as an evaluation index, with a recognition rate of more than 90%. Alexander et al [5] studied the impact of hip morphology and size changes on clothing sales of obese women in the U.S. national size series; Chih-HungHsu [6] studied 16 variables of 956 adult females, including 9 linear variables and 7 circumference variables, classified the variables into 2 categories using Ward's minimum variance method, and then categorized the samples into 5 categories of body types,by using the K-mean value, and applied it to the new industrial standard.

Research has shown that age, gender, region, marital and reproductive status, and lifestyle can all affect the body's physical characteristics. To analyze the influencing factors of the fit of pants structure design, this article studied the waist and hip body shape characteristics and categories of young women aged 18-26 in China.

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2. Data resources

2.1. Experimental Equipment and Samples

From 2014 to 2018, the China National Institute of Standardization (CNIS) conducted a nationwide survey of ergonomic parameters. Data were collected using a combination of manual measurement and 3D scanning. Manual measurements were made using a Martin measuring tape, and the subjects were measured one by one by uniformly trained surveyors; 3D scanning was performed using the VITUS SMART 3D anthropometric system to obtain 3D point cloud data of the subjects, and human body size parameters were extracted based on the 3D point cloud data.

This nationwide body size measurement was conducted by stratified random cluster sampling, in which the sampling locations and number of people were determined according to the distribution of the population in each stratum, the standard deviation of each type of data, and the required sampling precision to ensure the representativeness of the sample. Due to the vastness of China, the body size of adults in different regions varies greatly. In order to make the resulting sample more representative of the whole country, the sampling program stratified the different geographical areas.

In on-site measurement, 3D scanning is used to collect 3D human body data in accordance with GB/T 23698-2009 "General Requirements for 3D Scanning Human Body Measurement Methods" [7]. The subjects wearied tight fitting clothing and measuring caps. During measurement, the tester standed naturally with their feet parallel to each other, approximately shoulder width apart, their upper arms extended outward, and their forearms naturally drooping. The subject should breathe naturally, look ahead, and try to avoid shaking.

In this study, the body size data of young women collected from 2014-2018 was selected, with a sample size of 2,000 individuals in the age group of 18-26 years.

2.2. Selection of human body dimension parameters

Referring to GB/T 5703-2010 "Basic human body measurements for technological design" [8], 18 variables were selected for the analysis of waist and hip body shape characteristics, as shown in Table 1.

Table 1. human body dimension parameters

No.	Measurement Items	No.	Measurement Items
1	waist circumference	10	crotch length
2	hip circumference	11	Waist transverse diameter (waist breadth/waist depth)
3	abdominal circumference	12	abdominal transverse diameter (waist breadth/waist depth)
4	abdominal breadth	13	hip transverse diameter (waist breadth /waist depth)
5	hip breadth	14	waist-to-crotch height
6	hip depth	15	waist-to-hip height
7	waist breadth	16	hip-waist circumference difference
8	abdominal depth	17	abdominal -waist circumference difference
9	waist depth	18	hip-abdominal circumference difference

3. Comparative Analysis of Waist and Hip Shape Characteristics

The comparison results of the average waist and hip data between young women (18-26) and middle-aged and elderly women (36-55) are shown in Table 2 and Figure 1.

Table 2. Comparison of data between young and middle-aged women

Human Body Dimension Parameters	Dimension for Age Groups, mm	
	18-26	36-55
waist circumference	702	810
hip circumference	902	936
abdominal circumference	771	877
hip breadth	340	352
hip depth	224	247
waist breadth	271	302
waist depth	194	235
crotch length	691	713
Waist transverse diameter (waist breadth/ waist depth)	1.4	1.3
hip transverse diameter (waist breadth/waist depth)	1.52	1.44

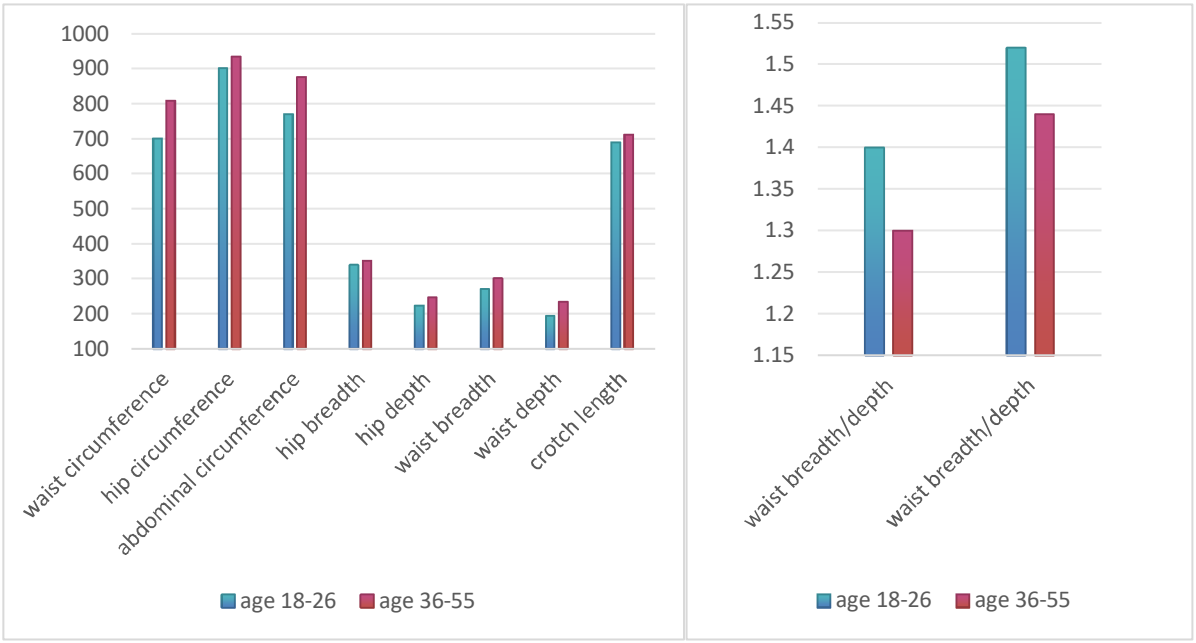

Fig. 1. Comparison of data between young and middle-aged women

From Table 2 and and Figure 1, it can be seen that there are significant differences among different age groups. The circumference, breadth, depth, and crotch length of women aged 36-55 are greater than those of women aged 18-26. The ratio of waist transverse diameter to hip transverse diameter is smaller in females aged 36-55 than in females aged 18-26.Overall, young women aged 18-26 are thin and flat at the waist and hips, while women aged 36-55 are fat and round. This shows that there are obvious differences in the body shape of the waist and hips of women of different ages.

4. Principal Component Factor Analysis

In order to reduce the inconvenience of high-dimensional data for subsequent processing, it is necessary to reduce the dimensionality before cluster analysis. In this study, 18 variables were factor analyzed using SPSS software, and the extracted factors were used as categorical indicators. After KMO and Bartlett's test, Bartlett's ball test was significant, indicating the existence of factor structure.
The results of extracting and factor rotation after factor analysis, the characteristic roots were ranked from the largest to the smallest. Based on the principle that the eigenvalue is greater than 1, four principal components were extracted, and their cumulative variance contribution rate reached 82.662% , indicating that these four components can basically describe the morphological characteristics of the waist and hip regions. The first principal component factor had its variance contribution rate of 50.695%, and the second principal component factor had its variance contribution rate of 16.008%. The factors explaining the total variance of the original variables are shown in Table 3.These four principal components contain most of the information of the original indexes, and can replace the original 18 variables to measure the female shoulder characteristics.

Table 3. Factors explaining the total variance of the original variables

Component	Total	Percentage of variance	Cumulative %
1	9.125	50.695	50.695
2	2.881	16.008	66.703
3	1.706	9.477	76.18
4	1.167	6.483	82.662

From the rotated factor loading matrix (see Table 4), it can be seen that Principal Component Factor 1 has a larger loading on the horizontal dimensions of the human body such as circumference, breadth, depth, etc., which can be defined as the horizontal circumference factor; Principal Component Factor 2 has a larger loading coefficient on the height variable, which can be defined as the height factor; Principal Component Factor 3 has a larger loading on the ratio of breadth, depth variable, which can be defined as ratio factor; Principal Component Factor 4 has a larger loading on the hip-waist difference, hip-abdomen difference,which can be defined as the circumference difference factor.

Table 4. Rotated factor loading matrix

Human Body Dimension Parameters	Principal Component Factors			
	1	2	3	4
waist circumference	0.943	-0.166	0.149	-0.172
hip circumference	0.846	0.369	0.063	-0.077
abdominal circumference	0.961	-0.048	0.164	0.15
abdominal breadth	0.866	0.008	0.364	-0.027
hip breadth	0.737	0.422	0.26	0.006
hip depth	0.893	0.068	-0.19	-0.087
waist breadth	0.7	0.014	0.504	-0.079
abdominal depth	0.958	-0.182	-0.084	0.047
waist depth	0.907	-0.118	0.011	0.035
crotch length	0.742	0.546	-0.19	-0.116
Waist transverse diameter (waist breadth/waist depth)	-0.502	0.189	0.659	-0.166
abdominal transverse diameter (waist breadth/waist depth)	-0.58	0.296	0.57	-0.111
hip transverse diameter (waist breadth/waist depth)	-0.542	0.252	0.489	0.13
waist-to-crotch height	0.488	0.647	-0.198	-0.147
waist-to-hip height	0.132	0.787	-0.101	-0.018
hip-waist circumference difference	-0.481	0.733	-0.164	0.185
abdominal-waist circumference difference	0.131	0.326	0.058	0.913
hip-abdominal circumference difference	-0.581	0.565	-0.206	-0.363

5. Waist-hip body type clustering

Four variables, namely, waist circumference, waist-to-hip height, waist breadth/waist depth, and hip-waist circumference difference, were selected from the four major factors of factor analysis to explore the classification of waist-hip body types of young Chinese women using a two-order clustering method. Second-order cluster analysis is an algorithm to realize clustering by two-step cluster analysis. Firstly, the preclustering is carried out, and then the system carries out the second clustering of the results of the above clustering according to the index characteristics of the algorithm itself to produce the final clustering results. The principle of the algorithm is as follows.

1) Assume that the variables are independently uncorrelated, and set the categorical and continuous variables to obey the joint multivariate normal distribution, such an assumption makes it able to deal with both categorical and discrete variables.

2) Pre-clustering the data, and compare and analyze the clustering results of the pre-clustering, the algorithm can automatically determine the optimal number of clusters according to the differences in the model of the results, and combined with the Bayesian quasi-lateral, to complete the secondary clustering.

3) Use the algorithm to construct a clustering feature (CF) tree, through the results of the second clustering, record the summary of data with features, all the customer information with a large amount of data to evaluate the clustering effect, and get the clustering results.

The Second-order cluster analysis found that Chinese young women's waist-hip body types could be classified into 4 categories. The proportion of samples of each body type was 11.3%, 23.3%, 35.2% and 30.3%, respectively, and the mean values of the characteristic variables of each body type category after clustering are shown in Table 5.

Table 5. Mean values of characteristic variables of each body type clustering category

No.	waist circumference	Waist transverse diameter (waist breadth/waist depth)	waist-to-hip height	hip-waist circumference difference
1	847	1.3	180	130
2	670	1.5	202	246
3	694	1.5	177	196
4	724	1.3	191	203

Standardizing variables eliminates the effects of the scale and the variable's own variation. This article uses the standard deviation standardization method to standardize categorical variables for each category. In this method, the observed value of a variable is subtracted from the mean value of the variable and then divided by the standard deviation of the variable.

Radar plots is drawn based on the standardized values to more intuitively analyze and compare the differences among the four waist-hip body type clustering categories, as shown in Figure 2.

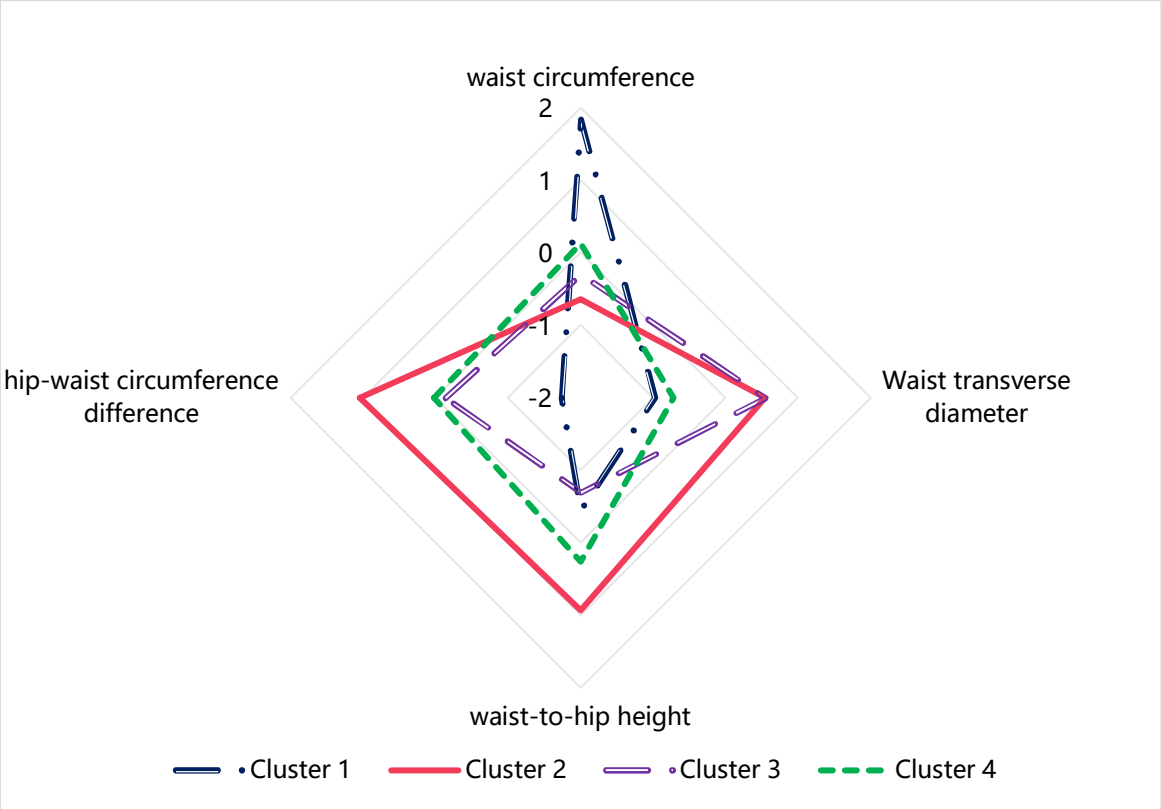

Fig. 2. Radar plots based on the standardized values

From the radar chart, it can be seen that category 1 has the largest overall circumference of the waist and hips, the smallest transverse sagittal diameter of the waist, and the rounded waist and hips; the distance between the waist and hip circumference is small, and it is a short rounded body type.
Category 2 has a small waist circumference, the largest difference of the hip and waist, and the transverse sagittal diameter of the waist is large and it is flat; the distance between the waist and hips is large, and it is a high flat body type.
Category 3 has a medium waist circumference, a medium difference of the hip and waist, a large transverse sagittal diameter of the waist and it is flat in front and behind the waist. The vertical distance between waist and hip circumference is medium, and the body is short flat type.
Category 4 has medium waist circumference, hip-waist difference, and distance between waist and hip circumference, with a small transverse sagittal diameter of the waist, and rounded waist and hip; the distance between waist and hip circumference is small and slightly large, and the body is a high rounded body type.

6. Conclusion

1) After descriptive statistical analysis and comparison of waist and hip body shape variables, there is a significant difference between young women and middle-aged and old women in terms of waist and hip body shape characteristics.
2) Factor analysis was applied to obtain four principal component factors affecting waist-hip body shape characteristics, namely, horizontal circumference factor, height factor,ratio factor, and circumference difference factor.
3) Using the two-step clustering method, the waist and hip body types of young Chinese women were divided into four categories, with the proportion of each category being 11.3%, 23.3%, 35.2%, and 30.3%, respectively; the differences in waist and hip features among the four categories were relatively obvious.
This study is of reference significance for the design and production of women's clothing size specifications.

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