Classification of young males' shoulder shapes based on cross-sectional morphological characteristics

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Abstract. This paper focused on the different characteristics of the shoulder cross-section curves closely related to the shape to subdivide the shoulder shapes. In this paper, 213 young college male students aged 18-26 were selected to measure the shoulder data with three-dimensional body scanner. With the help of imageware12.0 and matlab2012b software, the cross-section curves which could be used to classify the shoulder shapes were extracted, and the method of subdividing the shoulder shapes with the curvature radius of the characteristic points of the cross-section curve and the ratio of sagittal to frontal diameter was established. K-means clustering method was used through dynamic clustering, the optimal classification number of shoulder shapes was determined to be 4 categories by variance analysis, and the shape differences of each shoulder shape were quantified; by comparing the curve shape of shoulder section, the curve change characteristics of 4 categories of shoulder section were further qualitatively described.

1. Introduction

In recent years, three-dimensional anthropometry has gradually become an important tool to obtain human body data [1], providing necessary conditions for the study of human body shape. The high-speed processing ability and accurate algorithm of computer also provide technical support for human body image and shape analysis [2]. There are differences in body shapes, although people with the same size wear the same clothes, because of different body shapes, the wearing comfort is often different. Therefore, somatotype analysis has always been a research hotspot [1]. In order to explore the body shape differences of various human bodies, Yong L C focused on the side contour of human body, put forward to use the side angle to represent the body shape characteristics of human body, and used the mathematical statistics method to divide the side shape into four categories [3]; Yang Y C introduced the body volume index (TVI), and divided the human body into four types: X, H, A and V [4].

The body shape analysis of shoulder, neck, chest, hip[5][6] and other local features has always been the focus of research. Zhang J H used three-dimensional measurement and mathematical statistics method to extract two typical shoulder indicators, subdivided the shoulder shape of young women into four categories [7]; Huang C Y extracted four typical neck indicators, subdivided the neck shape of male college students in school by K-means clustering method [8]. However, the body shape change can be divided into two directions:

length (shoulder width, chest, waist, hip circumference) and girth (shape change of cross-section curve). Gu L proposed the method of body shape classification by parts (chest, waist, hip) based on the difference of body shape of cross-section curve, using the ratio index of characteristic point data [9].

The radius of curvature can be used to describe the degree of curvature change of the curve, and it is applied as a body type classification index. Lee H Y used reverse engineering software to extract the curvature radius of the feature points of the breast bottom contour and subdivide the breast shape [10].

This paper focused on the differences of the shape characteristics of the shoulder cross-section curves to subdivide the young males' shoulder shapes. With the help of three-dimensional anthropometry, reverse engineering software and MATLAB software, the ratio of sagittal to frontal diameter of shoulder section and curvature radius of curve feature points were extracted, and a method of subdivision of young males' shoulder shapes based on the shape indices of section curve is established.

2. Experiment

2.1 Subjects and instruments

In order to make the subdivision of shoulder shapes more targeted, 213 male college students were selected, aged 18-26 years old, height 165cm-185cm, weight 50-90kg, healthy. Three dimensional anthropometer [TC]², calibrated anthropometer and weight meter were used.

The ambient temperature was $(27 \pm 3) ^\circ\text{C}$ and relative humidity was $(60 \pm 10) \%$, which accorded with the naked environment.

2.2 Extraction of section curve

The human body is composed of multiple parallel cross-section layered structure models, which can not only

describe the overall shape of the human body through the characteristic curve of each cross-section, but also reflect the size and shape information of the local human body, as shown in Figure 1. Therefore, the cross-section curve of the end point of the shoulder is selected to analyze the shape characteristics of the male shoulder.

Figure 1. Cross-sections of human body.

Figure 2. Point cloud data of shoulder section curve.

Figure 3. MER algorithm diagram.

Figure 4. Fitting curve of shoulder section.

With the help of three-dimensional anthropometer, obtained the point cloud data of human body; used the reverse engineering software imageware12.0 to process the original point cloud data and extracted the section curve data that could represent the shape characteristics of shoulder, as shown in Figure 2; used MATLAB R2012b software to transform polar coordinates and used the minimum closing rectangle (MER) [11] to adjust the section axis of shoulder, as shown in Figure3, with symmetrical treatment, curve fitting of shoulder section was carried out by using the least square method [12], and a curve mathematical model with high goodness of fit was established to effectively characterize the shape characteristics of human shoulder, as shown in Figure 4.

2.3 Experimental data parameters

2.3.1. Shoulder sagittal frontal diameter ratio

In human orientation, the ratio of sagittal diameter to frontal diameter refers to the ratio of the short axis to the long axis. The ratio of sagittal to frontal diameter R of the cross section is the ratio of thickness a to width b of the cross section, that is, $R = a / b$, as shown in Figure 5. This characteristic value represents the degree of oblateness of the cross section. For the same section circumference, if the ratio of vector to frontal diameter is larger, it means that the ratio of vector to frontal diameter is larger, and the ratio of frontal diameter to frontal diameter is smaller, which means that the shoulder section is thicker.

Figure 5. Schematic diagram of shoulder sagittal frontal diameter ratio.

Figure 6. Extraction of radius curvature of each point of section curve.

2.3.2. Curvature radius of shoulder section curve

Curvature refers to the degree of curvature of a curve. Curvature of a plane curve refers to the rate of rotation of the tangent direction angle of a point on the curve to the arc length. The greater the curvature is, the greater the degree of curvature of the curve is, and the greater the degree of deviation of the curve from the straight line is. The curvature formula of the curve [13] is as follows:

$$K = \frac{|y''|}{(1+y'^2)^{3/2}}$$

where y' is the first derivative of the fitting curve and y'' is the second derivative of the fitting curve.

The radius of curvature is equal to the reciprocal of curvature, that is, the radius of the circle formed when this arc is part of a circle. Because the curvature value of fitting curve of shoulder section was relatively small and there were many decimal places after the decimal point, it was not convenient for subsequent analysis, so curvature radius was selected to evaluate the curve bending degree. The larger the radius of curvature, the smoother the arc, the smaller the radius of curvature and the steeper the arc, so the radius of curvature could accurately reflect the shape characteristics of shoulder section.

Figure 7. Mean distribution of curvature radius of shoulder.

Figure 8. Characteristic points of section curve.

It could be seen from Figure 7 that the radius of curvature fluctuates continuously from -90° to 90° , among which the radius of curvature at -50° , -35° , 0° , 50° and 90° were the local minimum values, and the curve in the local range had the largest bending degree, which could accurately reflect the local shape of the section curve and the overall change of the section shape. Therefore, the radius of curvature at these five angles, namely RC_{-50° , RC_{-35° , RC_{0° , RC_{50° and RC_{90° , were selected as the follow-up according to the classification of shoulder shape features, the corresponding position of shoulder section curve is shown in Figure 8.

3.2 Shoulder shape subdivision

The human body is approximately symmetrical to the left and right, so the left half of the cross-section curve of the male shoulder was analyzed, and the curvature radius was extracted with 5° as the interval angle [14][15], a total of 36 curvature radii were extracted to reflect the shape characteristics of the cross-section curve, as shown in Figure 6.

3. Data processing and analysis

3.1 Feature points extraction and analysis of shoulder section curve

In order to ensure the accuracy and reliability of the curvature radius of each feature point, it was necessary to preprocess it before data was analyzed, so as to eliminate the influence of singular value and wrong data on the experimental results. Spss19.0 was used to preprocess the data obtained by box chart, extracted useful information by eliminating the existing "abnormal data", and analyzed the data of 200 reserved experimental samples to get the change of mean curvature radius, as shown in Figure 7.

In order to find the characteristics of the shoulder data, the k-means method was used to cluster the acquired shoulder data dynamically according to the six shape indexes of the cross-section curve, which were the curvature radius of the five characteristic points of the cross-section curve and the ratio of the section vector to the frontal diameter.

Table 1 showed the variance analysis results of curvature radius value and vector frontal diameter ratio of characteristic points obtained when the shoulder data were clustered into 3, 4 and 5 categories according to 6 section curve shape indices. It could be seen from table 1 that when the shoulder shape was divided into four categories, the probability of F test was less than 0.05,

so four categories were the best choice for shoulder shape classification. When the shoulder shape was divided into four categories, the first category contained 49 samples, the second category contained 25 samples,

the third category contained 106 samples, and the fourth category contained 20 samples.

Table 1. Analysis of variance about shape types of shoulder

Clusters	Indices	Mean square		F	Sig.
		Between groups	Within group		
3	<i>R</i>	0.093	0.103	3.124	0.001
	<i>RC</i> _{50°}	135827.660	3525.145	49.852	0.000
	<i>RC</i> _{-50°}	1105.480	421.218	8.526	0.000
	<i>RC</i> _{-35°}	110376.109	258.187	601.938	0.410
	<i>RC</i> _{0°}	175.311	119.275	2.133	0.008
	<i>RC</i> _{90°}	201831.257	5088.021	112.038	0.000
4	<i>R</i>	0.198	0.015	3.395	0.037
	<i>RC</i> _{50°}	143156.257	2375.692	53.818	0.000
	<i>RC</i> _{-50°}	2651.428	380.726	6.284	0.000
	<i>RC</i> _{-35°}	125347.166	221.462	535.372	0.000
	<i>RC</i> _{0°}	287.163	74.420	3.426	0.005
	<i>RC</i> _{90°}	263963.845	5007.271	52.893	0.000
5	<i>R</i>	0.248	0.031	7.407	0.025
	<i>RC</i> _{50°}	131050.837	2964.435	51.342	0.000
	<i>RC</i> _{-50°}	3274.242	371.161	5.598	0.000
	<i>RC</i> _{-35°}	163591.510	200.344	580.225	0.081
	<i>RC</i> _{0°}	386.528	54.484	2.753	0.000
	<i>RC</i> _{90°}	419124.721	5011.225	150.148	0.000

Figure 9 was the cross-sectional curve of each type of shoulder shape, which clearly and intuitively showed

that there were significant differences among the four types of shoulder shape.

Type 1: moderate thickness of shoulder, obvious curve at both ends and middle part of shoulder, sharp angle at both ends of shoulder, smooth curve at back shoulder, obvious concave convex curve at front shoulder.

Type 2: thick thickness, the shoulder curve is relatively smooth, generally symmetrical, the two ends of the shoulder are round, the arc of the front and rear shoulders is smooth, the back is concave and convex, and the front shoulder is round.

Type 3: the shoulder curve is clear, the arc of the front and rear shoulders is concave and convex, and the two sides are prominent.

Type 4: the back is thick, the arc of the front and rear shoulders is gentle, and the two ends of the shoulders are slightly forward.

4. Conclusions

By analyzing the change of the mean value of curvature radius, the five characteristic point angles of shoulder section curve, namely - 50 °, - 35 °, 0 °, 50 ° and 90 °, were determined.

In this paper, a method was established to subdivide the body shapes of the male shoulder by using the curvature radius of the characteristic points of the section curve and the ratio of the sagittal diameter to the frontal diameter. By using k-means clustering method and variance analysis, the body shapes of the shoulder were divided into four categories, and the shape differences of the section curve were quantitatively distinguished, and the amount of samples was obtained. By comparing and analyzing the shape of the section curve of the shoulder, the curve change characteristics of the four categories of the shoulder section curve are qualitatively described.

Acknowledgments

This research was financially supported by the Program of Fuzhou Science and Technology Bureau (No.2018-G-97), the Open Project Program of Fujian Clothing Industry Technology Development Base, Minjiang University, China (No. MJXY-KF-201907), the Open Project Program of Fujian Province University Engineering Research Center of Textile and Clothing, Minjiang University, China (No. MJXY-KF-201902), the Rector Fund (No.103952019141), the Science and Technology Pre-research Program of Minjiang University (No. 31404305), and was supported by the corresponding author Doctor Juan Feng Jin, who can be contacted at jjf6859@163.com.

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