

Pattern-Making for Y-Body Types of Young Females' Pants in China Based on 3D Virtual Technologies

Haina Shen^{1*}, Xiaofen Ji¹

¹ Zhejiang Sci-Tech University, NO. 928, 2nd Street,
Xiasha High Education Park Hangzhou, Zhejiang, China 310018

* Corresponding author. E-mail: shenhn@zstu.edu.cn

Abstract

This paper aims to introduce an innovative pattern-making technique to enhance the fit of pants for young females. Utilizing a 3D scanning system, seventy-one sets of detailed body data were collected to create a Y-body type mannequin. A raw pant pattern was crafted by unfolding the surfaces of the research mannequin in CLO3D. Through comprehensive assessments conducted by participants and experts for fit, movement adaptability, silhouette, and body shape correction, adjustments were made to the ease allowance and silhouette, culminating in the development of the pant pattern and final pant specification sheet that achieved a high level of satisfaction.

Keywords

3D virtual technology, pant pattern-making, fit analysis, Y-body shape, Chinese National Standard Size system.

1. Introduction

For female consumers, factors such as age and childbearing status significantly influence the shape of the lower limbs. Research by Goldsberry, Shim, and Reich, as well as Rosenblad-Wallin and Karlsson [1], has highlighted that mature females typically exhibit characteristics such as shorter stature, thicker waists, more pronounced abdomens, and flatter buttocks compared to young females.

Schewe [2] observed that with increasing age, measures like the sitting height, trunk height, muscle mass, arm span, thorax size, and bone density decrease, while the percentage of body fat and the pelvic breadth increase, indicating fundamental changes in the body anthropometry between young and mature females. It is a widespread issue that young women are often dissatisfied with the fit of pants available in the market. LaBat and DeLong [3] discovered that young women express the highest level of dissatisfaction with the fit of their pants, particularly around the waist, hip, and thigh areas. To address this issue, this study explores a new pattern-making method aimed at enhancing pant fit through 3D virtual fitting.

2. Literature Review

2.1. Standard size system

Garment pattern-making, also known as garment plane structure design, involves creating garments based on human engineering principles, considering both the fabric and the wearer's fit. The current National Standard Size system for women's clothing in China (GB/1335.2-2008) categorizes body types into four groups: Y (chest-waist difference > 19 cm), A (14 cm < chest-waist difference < 18 cm), B (9 cm < chest-waist difference < 13 cm), and C (chest-waist difference < 8 cm), representing 14.8%, 44.1%, 33.7%, and 6.5% of the population, respectively. These categories are based on a comprehensive national body measurement survey conducted between 1985 and 1987 [4-5].

However, the system has limitations, as it does not account for lifestyle changes in China that are leading to a gradual shift in body shapes and sizes. Studies have shown that there has been a reduction in the width gap between the upper and lower trunks and an elongation of lower limbs over the past two decades. Tu et al. [6] reported an increase of 1.5 cm in the Acromio-cristal Index and 1.2 cm in the Manou Riers Skelic Index for females. This was determined by comparing

anthropometric data from urban residents in China from the years 1979 and 2013, highlighting a significant shift in body dimensions over time. Additionally, the system, which spans the age range of 13 to 60 years old, fails to distinguish between young and mature women. This broad categorization can lead to fitting problems for young women whose body shapes slightly deviate from the standard sizes.

2.2. Body shape analysis of young females in China

With the global trend of slimming down, women increasingly prefer a more petite physique [7]. Physical exercise has been shown to alter body measurements related to aesthetics and reduce dissatisfaction with the body image [8]. A significant portion of Chinese college students are engaged in regular physical exercise, with 61.5% of female students specifically identifying the maintenance of fitness as their primary reason for working out [9].

Research analyzing the BMI distribution among Chinese college students has revealed that over 25% of female college students are underweight [10]. Furthermore, the Y-body type is more common in this population than the

current national standard suggests. He et al. [11] discovered that 30.8% of the 110 female students surveyed in north China had a Y-body shape, as identified through the application of the K-means clustering algorithm. Additionally, Niu et al. [12] reported that 26.4% of young women in Henan province were underweight, with over 20% of whom categorized as having the Y-body type.

Female college students in China are typically aged between 18 and 25 and are unlikely to be married or have children. Data from 2015 showed that only 25.5% of individuals aged 19 to 24 were married, with this figure dropping to less than 1% specifically among college students [13]. Consequently, there exists a marked distinction in the body shape between female college students and the general adult female population. Numerous studies have highlighted that the waist and hip shapes differ the most prominently between younger and mature females. For instance, research by Zhang, Guo, and Liu [14] observed that middle-aged women tend to have thicker waists, flatter posterior waist curves, and smaller hip convex angles compared to younger women. This study compared the body sizes of women aged 18-25 and 30-45 from Zhejiang and Jiangsu provinces in southeastern China.

The majority of garment companies design their products based on A and B body types, which make up 77.8% of the national standard [15]. As a result, a substantial number of young female consumers with a Y-body type frequently encounter issues with fit and comfort [16].

2.3. Automatic pattern making technology

A garment prototype serves as a fundamental sample crucial for examining garment fit. However, in practical production, prototypes are often used in the general garment structure drawing, a process that can be limited by empirical formulas and may fail to capture the contemporary population's body shape characteristics. This can lead to shortcomings in both the overall and local fit. Consequently, it is

essential to investigate the principles of prototype generation that are tailored to the specific contours of the human body to achieve a more fitting pattern. Since clothing is affected by the form and movement of the body, the advent of 3D measurement technology has sparked interest among scholars in the automated creation of 3D samples using curved surface technology. This technique employs the principle of curved surface flattening to derive a 2D pattern from the 3D surface of the human body.

Shimada et al. [17] employed a surface partitioning algorithm to flatten the clothing surface. Thomassey [18], on the other hand, established and flattened surfaces by connecting body contours, which were defined based on human anatomical landmarks and clothing structure baselines. Cichocka et al. [19] explored the direct parametric modeling of clothing on a 3D human body mannequin and simulated various fabrics for design and development. Utilizing 3D point cloud data, Gu et al. [20] investigated the characteristics and generation rules of neck girth lines, creating a neck girth model for a 3D virtual female upper body mannequin. A system for generating women's suit patterns was subsequently developed, capable of automatically producing patterns based on 2D measurement data from the human body. This curved surface flattening method preserves more detailed human surface information, making it ideal for creating personalized patterns. Hong [21] extended the application of this personalized clothing pattern generation system by implementing 3D clothing design for individuals with disabilities, based on the transition from a 3D human mannequin to a 2D pattern.

Currently, a variety of sophisticated 3D fashion design systems are available, including CLO3D, Style3d, and VStitcher. These systems facilitate the creation of integrated 2D clothing patterns from 3D virtual human mannequins, enabling an automated transition from 3D designs to 2D patterns [22]. Researchers have begun to implement these systems in pattern design. For instance, Jian and Kai [23] utilized 3D software to design well-fitted underwear

by calculating the ease of movement around the virtual mannequin. Dong [13] leveraged 3D software to enhance suit patterns for middle-aged women. For the garment industry, 3D fashion design systems have become indispensable, as noted by Lagè [24]. These systems can significantly cut down the time and costs associated with prototyping by enabling rapid pattern adjustments through precise fit simulations. Moreover, they serve as a potential tool for lowering garment development expenses by streamlining production processes within the supply chain [25-26].

3. Research methods

To explore the pattern-making method of form-fitting pants for young women with the Y-body type, this study adopted a mixed-method approach to find the issues and variables. The research is structured into four primary steps: (1) Initially, extensive research on the body type classification of young women was conducted to confirm the considerable prevalence of the Y-body type. Concurrently, a comfort survey for Y-shaped body women's pants was implemented to identify the main areas of fitting dissatisfaction. (2) Secondly, anthropometric data of young women with a Y-body type were collected using 3D body scanning technology, which allowed for the creation of an accurate digital Y-shaped female body mannequin. (3) Subsequently, the 3D human body mannequin's surface was developed into a two-dimensional pattern using 3D design software, and a raw pant pattern was produced through preliminary adjustments. (4) Lastly, by integrating feedback from participants and pattern-making experts, the ultimate pattern and pattern-making method were refined through multiple iterations.

3.1. Survey of young females with the Y-body type and pant fit problems

To determine the prevalence of the Y-body type among young females, a questionnaire was distributed face-to-

face in the university town of Hangzhou, China. There were three parts to the questionnaire. The first section contained six items regarding age, gender, height, weight, chest girth and waist girth. Adopted to filter valid samples were underweight (BMI<18.5) and Y-type body (chest-waist difference>19 cm). The second section focused on wear preferences for pants, assessing preferences for looseness, waist positioning, and overall pant shape. The final section inquired about specific fit issues with pants, asking participants to rate the most problematic areas for fitted pants, including the waist, hip, crotch, thigh, calf, ankle, and length. Additionally, an open-ended question was posed: “What was the most significant fit issue with the pants you recently purchased?” to elicit further insights.

The study's participants were 258 female college students, aged 18 to 25 years, from Hangzhou, China. The survey results indicated that 36.4% of the respondents were underweight, and 24.8% had a Y-body type. Among these respondents, 65.5% showed a strong preference for buying form-fitting pants, such as high-waisted straight-leg or skinny pants. Over 70% expressed concerns about the fit around the waist and hips, while less than 15% were worried about the calf and ankle fit. This suggests that the shape and circumference of the abdomen and waist are significant factors affecting the overall fit of pants.

The open-ended question revealed that the primary fit issues with pants were excessive looseness in the waist and thigh and tightness in the hip area. Additionally, to achieve a better waist fit, respondents often opt for pants one size smaller than their standard size. In conclusion, the subsequent study should focus on optimizing the fit of the waist, hip, and thigh in the pant pattern to address these common concerns.

3.2. Human body data collection and 3D modelling

Seventy-one female college students, aged 18 to 25, from various universities

Measurement categories	Measurement items
Length item	Length of upper arm and lower arm
Height item	Height, waist height, chest height, hip height, crotch height, thigh height, knee height, and back neck height
Circumference item	Neck girth, shoulder length, and circumference of the chest, waist, hip, abdominal, thigh, knee, calf, and ankle
Width item	Depth of waist, hip, and abdomen

Table 1. Twenty-three measurement items for the human body

in Hangzhou, China, participated in a 3D scanning research study. Utilizing a BOSS-21 body scanning system, the study captured over 50 body measurements within 40 seconds for each participant. All participants identified as having a Y-body type. The research incorporated twenty-three measurement items that are closely related to the body shape, comprising two length measurements, eight height measurements, ten circumference measurements, and three width measurements, as detailed in Table 1. The measurements were conducted in accordance with the Chinese national standard for Basic Human Body Measurements for Technological Design (GB/T 5703-2010).

For the acquisition of precise body data, participants were required to stand naturally in their bare feet and don form-fitting attire, devoid of any additional accessories. The collected data exhibited a normal distribution. Correlation and linear regression analyses were employed to identify significant relationships between the various measured items. The findings indicated a strong correlation between the height and seven other height-related measurements ($P<0.01$). Furthermore, the chest circumference, lower arm length, and upper arm length were significantly correlated with the shoulder length, neck girth, hip girth, and waist circumference ($P<0.01$). Additionally, the waist circumference showed a strong association with the majority of the circumference and width measurements, including the abdominal circumference, hip circumference, thigh circumference, knee circumference, calf circumference, ankle circumference, as well as the waist depth, hip depth, and abdominal depth.

Factor analysis was adopted to discover the main factors influencing the body shape

of young women in this study. The KMO measure of sampling adequacy of 0.769 and Bartlett's test of sphericity (χ^2 value 858.341, $df = 190$, $p = 0.000$) indicated that the factor analysis was possible. It classified all the body measurement items into seven factors by factor analysis, including the circumference (girth of chest, waist, hip, and abdomen, thigh), height (chest, waist, hip, crotch, and back neck height), shoulder (shoulder length), thickness (depth of waist, hip, and abdomen), lower limb (thigh height, knee height, circumference of the knee, calf, and ankle), upper limb (length of upper arm and lower arm), and neck (neck girth). Among the factors, the circumference was the most critical factor, which could better indicate the characteristics of samples in this study, followed by the height, shoulder, thickness, lower limb, upper limb, and neck. Thus, the factor concerning the pant fit of young women with a Y-body type was the circumference of the lower body (girth of waist, hip, abdominal and thigh).

A linear multiple regression model of the body measurement items' relationship was obtained by multiple linear regression analysis. It would be used to build the mannequin in the following study. Height, chest circumference, and waist circumference were regarded as independent variables, and other measurement items as dependent variables, when we performed the multiple linear regression analysis. Then, 20 regression equations were found, such as the following:

$$\text{Hip circumference} = 0.603 \times \text{waist circumference} + 0.224 \times \text{height} + 13.119 \quad (1)$$

$$\text{Waist height} = 0.665 \times \text{height} - 0.280 \times \text{chest circumference} + 13.544 \quad (2)$$

	Measurement items	Data (cm)		Measurement items	Data (cm)
Height	Height	160	Length	Length of upper arm	25.3
	Waist height	97.4		Length of lower arm	23.0
	Chest height	115.1	Circumference	Neck girth	24.5
	Hip height	79.4		Shoulder length	33.4
	Crotch height	71.2		Chest circumference	80.5
	Thigh height	68.6		Waist circumference	60.5
	Knee height	45.4		Hip circumference	85.4
	Back neck height	139.3		Abdominal circumference	73.3
Depth	Waist depth	14.3		Thigh circumference	48.4
	Hip depth	16.1		Knee circumference	29.8
	Abdomen depth	18.0		Calf circumference	32.1
				Ankle circumference	19.7

Table 2. Body data of the virtual mannequin

A series of body data of typical young women with a Y-body type could be obtained after applying the mean values of height (160 cm), chest girth (80.5 cm), and waist circumference (60.5 cm) of 71 samples to the regression equations. Table 2 provides the body data of typical young female with a Y-body type.

Finally, a mannequin of a young female with a Y-body type was built according to the data in Table 2 by CLO 3D.

3.3. Pattern development from the 3D mannequin

The surface extension tool in CLO3D software facilitates the transformation of the virtual mannequin's surface into 2D patterns. First, to ensure the precision of resulting patterns after the 3D mannequin is flattened, the lower limb surface of the mannequin is segmented into 16 sections using 12 cutting lines, as depicted in Figure 1. The three horizontal cutting lines represent the waistline, crotch line, and bottom line. The auxiliary lines include the abdomen bulge line, hip circumference line, thigh midline, knee circumference line, and calf circumference line. The three horizontal cutting lines bifurcate the mannequin's lower limbs into two sections at the crotch line: abdominal-buttocks section and leg section. In the vertical direction, based on the surface contours of the mannequin's abdomen and buttocks, the front and back circumferences are divided into four equal parts, creating eight distinct areas.

Secondly, the mannequin's lower limb was unfolded into 16 individual 2D pattern pieces following the 12 predefined cutting lines, ensuring that the auxiliary lines remained aligned. Thirdly, the hip circumference line was maintained level, and the midpoint between the hip circumference line and the bottom line was designated as the warp direction, allowing the patterns to be seamlessly pieced together.

Subsequently, the ease of each pant section was fine-tuned. Measurements revealed that the front waist ease of 2.62 was appropriate, while the back waist ease of 7.08 was excessively loose. To address this, the pattern above the crotch line was rotated clockwise, using points A and B as pivots, to reduce the distance between pattern sections 1, 2, and 3 at the waistline to 0.5 cm and 1.3 cm, as illustrated in Figure 1. This adjustment slightly warped the hip circumference line, resulting in a more accurate alignment with the mannequin's surface contour. To prevent tightness at the crotch, which could restrict the limb movement, the crotch line was lowered by 1 cm to ensure comfortable mobility. As shown in Figure 1, the back pattern was rotated clockwise with points C and D as pivots, and the crotch point was lowered onto the adjusted crotch line to form the back rise line. Similarly, the front pattern was rotated counterclockwise around point E to create the front rise line.

Next, the pant pattern's contour was refined. Considering that the back crotch rise stretches more than the front when walking, 4 cm was transferred from the

front crotch to the back. Additionally, to accommodate the significant stretching of the knee area, when the leg is bent, an extra 6 cm of ease was added to the knee circumference based on the mannequin's measurements. For comfortable wear, the circumference of the human heel in a relaxed state was used as the reference for the pants' bottom line, with an additional 7 cm ease added to the slack bottom.

Finally, waist darts were established. A single front waist dart was drawn between front pattern sections 5 and 6, while two back darts were created at the three equally spaced points on the back pattern. After several iterations and adjustments to the pattern's design lines, the preliminary pattern for the research pants tailored to young females with a Y-body type was completed.

3.4. Pant pattern development and wearing evaluation

To assess the raw pant pattern's viability, three representative participants donned the raw research pants and conducted a wearing evaluation. These participants were young females around 20 years of age, with body sizes akin to those of the Y-body type young females studied. Table 3 details the primary body measurements of those participants. To enhance the evaluation's precision, a movement adaptability assessment was also carried out, encompassing three lower limb movements: sitting, leg lifting, and crouching, as shown in Figure 2. The wearing and movement adaptability

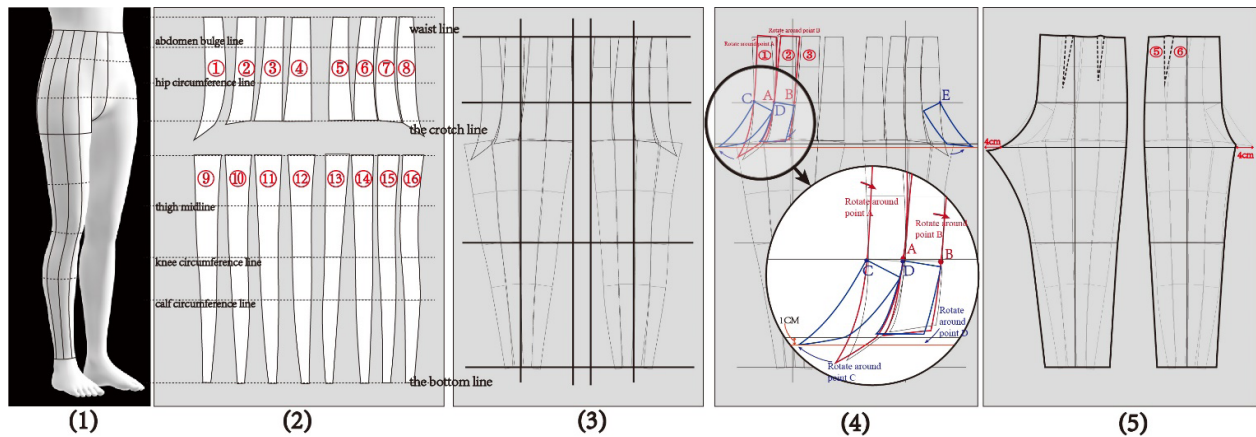


Fig. 1. Steps to form a raw pant pattern

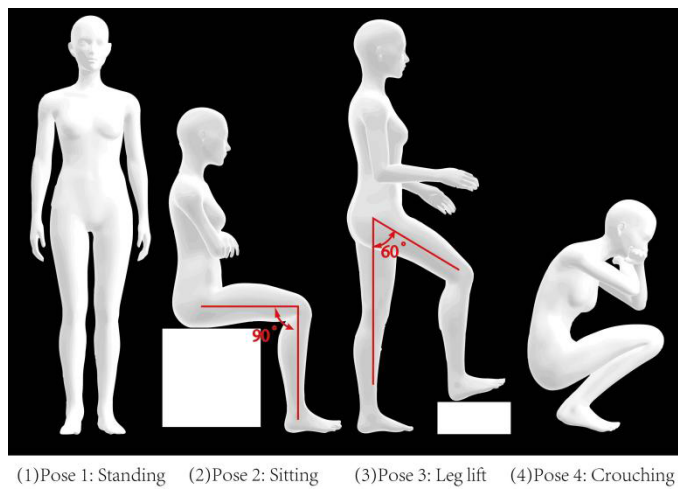


Fig. 2. Pose of wearing evaluation and movement adaptability evaluation

Items	Mean (cm)	SD	Items	Mean (cm)	SD
Height	159.9	0.33	Length of upper arm	25.4	0.33
Waist height	97.3	0.36	Length of lower arm	23.1	0.33
Chest height	115.1	0.29	Neck girth	24.5	0.33
Hip height	79.1	0.29	Shoulder length	33.4	0.33
Crotch height	71.1	0.33	Chest circumference	80.5	0.25
Thigh height	68.5	0.29	Waist circumference	60.6	0.37
Knee height	45.3	0.17	Hip circumference	85.4	0.33
Back neck height	139.1	0.29	Abdominal circumference	73.4	0.49
Waist depth	14.2	0.21	Thigh circumference	48.3	0.17
Hip depth	15.1	0.29	Knee circumference	29.8	0.29
Abdomen depth	18.1	0.33	Calf circumference	32.1	0.21
			Ankle circumference	19.7	0.21

Table 3. Body measurements of the participants

evaluations focused on the fit of six lower limb areas—waist, hip, crotch, thigh, knee, and calf. Additionally, three pattern-making experts were invited to provide feedback and suggestions on the

silhouette and body shape correction. The silhouette evaluation concentrated on the wearability of the waistline, side seam, and crotch, while the body shape correction evaluation emphasized the

effectiveness in adjusting the waist, hip, abdomen, thigh, and calf. Evaluations were scored on a seven-point Likert scale, ranging from 1 (extremely poor) to 7 (excellent). Incorporating the participants' and experts' recommendations, the pant patterns underwent progressive refinements.

4. Result and discussion

4.1. Raw pattern and development

A raw pattern for the research pants was crafted based on the 3D mannequin of a young female with a Y-body type. After several iterations and adjustments to the pattern's design lines, the final pant pattern was established. To confirm any discrepancies in sizing between the raw pattern and the research mannequin, a comparison of waist, hip, thigh, knee, calf, and slack bottom measurements was conducted, as detailed in Table 4. Notable differences were observed, particularly in the knee and pant bottom areas. These variations are primarily attributed to the addition of ease during pattern corrections to ensure optimal wearing comfort.

4.2. Wearing evaluation and pattern development

Following the outcomes of the raw pant pattern's wearing evaluation, a revised version of the pant pattern was created. Results of the wearing evaluation for the raw pattern are presented in Table 5.

For the raw pattern, the average score for the fitting items was 4.78, while those for the silhouette and body shape correction evaluations were 4.41. During the static wear assessment, the comfort evaluation scores for the hip, crotch, and thigh areas were all below 4.50, with the crotch comfort score being the lowest at 4.00. This indicated that participants experienced discomfort in the hip, crotch, and thigh areas of the raw pant pattern. In the movement adaptability evaluation, comfort scores in these areas also fell below 4.50, with further decreases in certain postures. Specifically, during sitting and crouching, the waist and knee comfort scores dropped from 5.00 to 4.67 and 4.33, respectively. This suggested that the pants were not well-

suited for extensive motor activities, as the pattern lacked adequate ease. Additionally, participants unanimously noted that while the initial pants closely followed the body's contours, the crotch was uncomfortably tight, particularly during movement. When sitting or crouching, the back rise stretched, causing significant discomfort in the small of back. Likewise, the insufficient ease in the thigh area resulted in a slight tightness around the knee, when seated or in a crouched position.

In the assessments of silhouette and the body shape correction, the three experts expressed a dissatisfaction with the crotch lines, noting they did not effectively enhance the silhouette. It was suggested

that further refining the waistline and side seam curves would help maintain the garment's overall shape and create a more streamlined look. Based on discussions with both participants and experts, four key adjustments were made to the initial pants pattern:

- (1) Increasing the slope of the back rise and deepening the curve to facilitate better forward hip flexion.
- (2) Lowering the front waistline and raising the back waistlines, then smoothing out the curves for a continuous waistline.
- (3) Lengthening the front darts and repositioning the dart points to address the abdominal protrusion, and add additional ease to the waistline.
- (4) Modifying the curves of the inseam and outseam to accommodate more ease around the thigh area.

Items	Research mannequin (cm)	Raw pants (cm)	Ease(cm)
Waist circumference(W)	60.5	61.2	0.7
Hip circumference(H)	85.4	86.3	0.9
Thigh circumference	48.4	51.4	3.0
Knee circumference(KL)	29.8	35.8	6.0
Calf circumference	32.1	35.6	3.5
Slack bottom(SB)	19.7	26.7	7.0
Trousers length(TL)	92.9	93.8	0.9
Crotch length(CL)	26.2	27.3	1.1
Trousers length(TL)=Waist height -Ankle height (3.5 cm)			
Crotch length(CL)=Waist height-Crotch height			

Table 4. Size difference between the raw pant pattern and research mannequin

Items			Mean		Items			Mean	
			Raw	Secondary				Raw	Secondary
Wearing evaluation	Standing (static state)	Waist	5.00	6.33	Movement adaptability evaluation	Sitting	Waist	4.67	6.00
		Hip	4.33	6.00			Hip	4.00	5.67
		Crotch	4.00	6.00			Crotch	3.33	5.33
		Thigh	4.67	5.67			Thigh	4.33	5.67
		Knee	5.00	6.33			Knee	4.67	6.33
		Calf	5.67	6.33			Calf	5.33	6.33
Mean		4.78	6.11	Leg lift		Waist	5.00	6.33	
Silhouette evaluation	Waist-line	5.33	6.00			Hip	4.33	6.00	
		Side seam	5.33			6.00	Crotch	3.67	5.67
	Crotch	4.00	5.67			Thigh	4.67	5.67	
		Knee	5.00			6.33	Calf	5.33	6.33
Mean		4.89	5.89			Crouching	Waist	4.33	5.67
Body shape correction evaluation	Waist	5.00	6.00	Hip			3.67	5.67	
		Hip	4.67	5.67			Crotch	3.33	5.33
		Abdomen	4.33	5.67			Thigh	4.00	5.67
		Thigh	4.67	6.00			Knee	4.33	6.00
		Calf	5.33	6.33			Calf	5.33	6.33
Mean		4.80	5.93	Mean			4.41	5.91	

Table 5. Result of the wearing evaluation for the raw pattern and secondary pattern

Figure 3 illustrates the modifications made to the raw pant pattern.

4.3. Secondary pattern development and wearing evaluation

The measurements for the revised pant pattern are detailed in Table 6. For this version, the waist circumference was

Items	Research mannequin (cm)	Secondary pants		Final pant specification	
		Measurement (cm)	Ease (cm)	Measurement (cm)	Ease (cm)
Waist circumference(W)	60.5	64.48	3.98	64.5	4.0
Hip circumference(H)	85.4	88.45	3.05	88.5	3.1
Thigh circumference	48.4	52.82	4.42	/	/
Knee circumference(KL)	29.8	36.03	6.23	36.0	6.2
Calf circumference	32.1	35.67	3.57	/	/
Slack bottom(SB)	19.7	28.02	8.32	28.0	8.3
Trousers length(TL)	92.9	93.50	0.60	93.0	0.1
Crotch Length(CL)	26.2	27.46	1.26	27.5	1.3

Table 6. Size difference between the secondary pant pattern and research mannequin

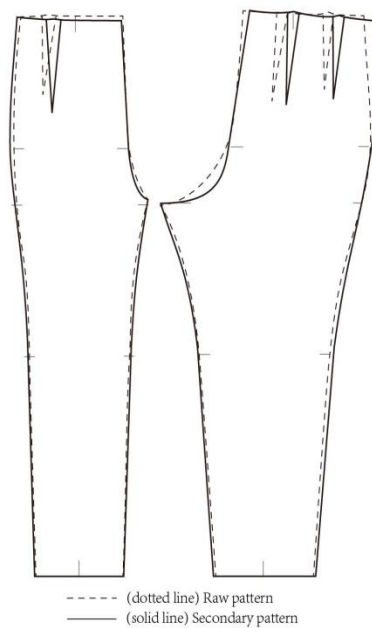


Fig. 3. Modifications of the raw pant pattern

set at 64.48 cm, which is an increase of 3.28 cm from the raw pattern, to enhance comfort and movement. The hip and thigh circumferences were also increased by 2.15 cm and 1.42 cm, respectively, to ensure better compatibility with movement. Most other measurements remained consistent with the raw pattern, except for the slack bottom, which was extended by 1.32 cm to improve the overall appearance.

The wear evaluation results for the secondary pant pattern are presented in Table 5. The average score for the fitting items of the revised pattern improved to 6.11, and those for the movement adaptability increased to 5.91. Participants unanimously noted significant enhancements in the pants' adaptability for movement. In terms of

silhouette and body shape correction, the average scores reached 5.89 and 5.93, respectively. The pattern-making experts expressed a high level of satisfaction with the revised pant pattern. Based on these outcomes, the secondary pant pattern was designated as the final one for this study.

4.4. Final pattern-making and discussion

The final specifications for the pants are detailed in Table 6, which lists six essential measurements: the waist, hip and knee circumferences, pant length, crotch depth, and the width of the slack bottom. The measurements provided were utilized to establish objective mathematical formulas and assign specific values, which greatly simplifies the process of creating a pant pattern and facilitates the automation of pattern drafting for trousers. Figure 4 illustrates the pattern-making method for well-fitting pants tailored to young females with a Y-body type as proposed in this study. Notably, this method accounts for differences in hip and knee circumferences between the front and back patterns, with the back pattern's measurements being 4.0 cm and 5.0 cm larger, respectively. Additionally, the back pattern's pant bottom is 2.0 cm wider than the front's to accommodate the posterior shape of the hips and calves, ensuring the side seam aligns with the body's side. Furthermore, given that the abdominal protrusion is less pronounced than the hip, the front waist dart is 2.4 cm smaller than the back waist dart. In the light of the less pronounced abdominal bulge among young females, the front waist dart in this pattern extends to 10.0 cm. These refinements ensure

that the pattern caters to the specific body shape characteristics of the target demographic.

The pant pattern-making method introduced in this research takes into account the physiological attributes of young females exhibiting the Y-body type. Through the collection and analysis of anthropometric data from that population, a virtual mannequin encapsulating the physical characteristics of such individuals is created. The raw pant pattern is crafted using the surface development techniques, followed by a series of fitting assessments and expert reviews to further refine the design. Consequently, the resulting pant pattern for young females is formulated on empirical anthropometric measurements and expert feedback, transcending the reliance on the subjective expertise of the pattern maker.

5. Conclusion

This research introduces a pattern-making approach aimed at crafting form-fitting pants specifically designed for young females characterized by the Y-body type. The methodology leverages human body scanning and 3D ergonomic mapping to ensure the pants cater to the comfort needs of that demographic.

The investigation began with an examination of pant fit among young female university students in Hangzhou, China, who possess a Y-body type. The findings revealed that the percentage of the Y-body type among this group exceeded that reflected in the Chinese National Standard Size system.

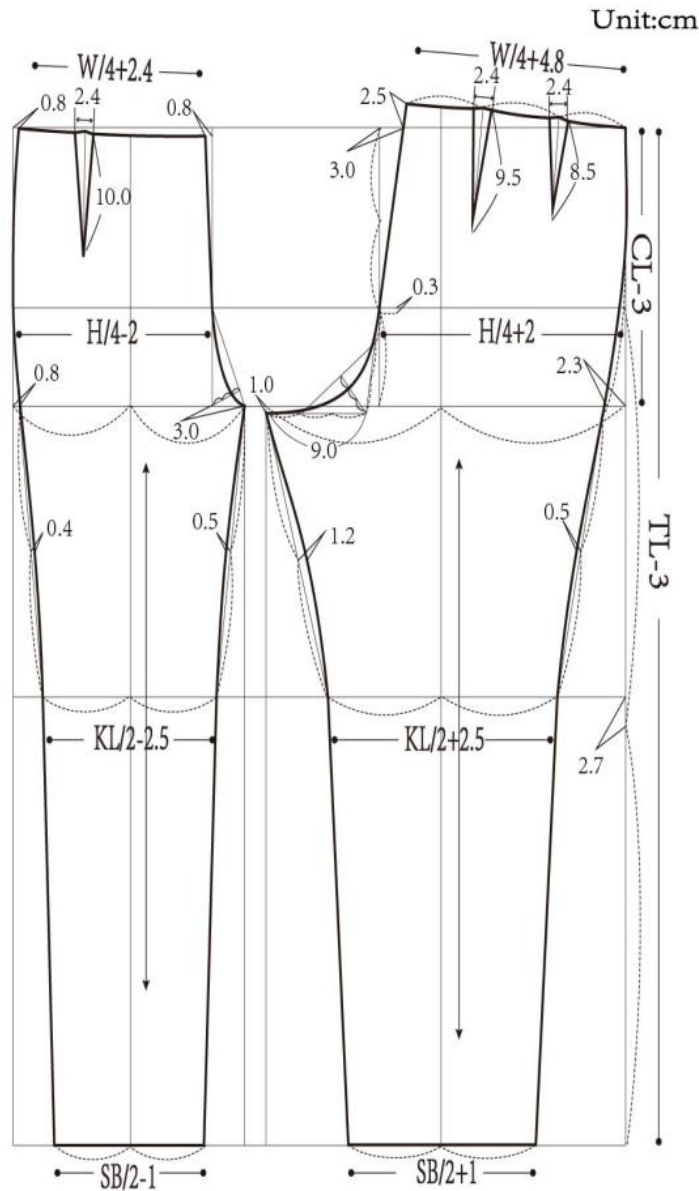


Fig. 4. Proposal of the pattern-making method for Y-body type young females' pants

Additionally, it was noted that fit issues concerning the waist, thigh, and crotch areas were particularly pronounced. For young females with a Y-body type, it is imperative for fashion brands to explore innovative pattern optimization strategies to satisfy the evolving demands of their consumers.

Consequently, utilizing three-dimensional body scanning technology, this study amassed an extensive dataset comprising 23 distinct body measurements from 71 young females, all identified as having the Y-body type and aged between 18 to 25 years, residing in the Hangzhou

region. Through a factor analysis process, these measurements were distilled into seven key dimensions: the circumference, height, shoulder, thickness, lower limbs, upper limbs, and neck. Building upon this foundation, multiple linear regression analysis was engaged to explore and model the interrelations between the various body dimensions and three critical anthropometric metrics: the height, chest, and waist circumference. This analysis was instrumental in extracting the fundamental body data necessary for understanding the physique of young females with the Y-body type, who stand at a height of 160 cm.

In the final phase of this preparatory research, CLO3D 3D design software was employed to construct a virtual mannequin representing a young female with a Y-body type and height of 160 cm, serving as the foundation for following pattern-making research.

In the process of designing the pant pattern, a 3D ergonomic mapping technique was implemented within the CLO3D design software. The waistline, crotch line, and bottom line were selected as the horizontal reference points, with each girth being evenly segmented into eight parts. The 3D surface of the lower limbs of the research mannequin was then transformed into a series of 16 two-dimensional pattern pieces. A raw pant pattern was crafted by integrating these patterns and adjusting the design lines accordingly.

To enhance the precision of the pant pattern and confirm its practicality, a wearing evaluation was conducted with three participants whose body measurements closely resembled those of the research mannequin. They assessed the pants' fit and adaptability to movement through four key actions: standing, sitting, lifting legs, and crouching. Furthermore, three seasoned pattern-making experts critiqued the pattern, focusing on the silhouette and its ability to correct the body shape, offering valuable feedback and suggestions. During the raw wearing evaluation, the scores for the hip, crotch, and thigh areas were below 4.50, indicating a need for improvement. These areas also restricted the full range of motion to a certain degree. The pattern-making experts similarly conveyed concerns regarding the shapes of the crotch, abdomen, and side seams, highlighting the necessity for further refinements to achieve a more comfortable and functional fit.

Following the detailed feedback received from both participants and experts, targeted enhancements were made to the raw pant pattern. These improvements targeted four key areas, focusing on ease allowance adjustments and silhouette refinements, to better suit the form-fitting requirements of the garment.

Upon conducting the second wearing evaluations, the results were notably positive, with all scores surpassing a threshold of 5.5. This indicated a substantial improvement in the comfort aspects of the pattern, addressing the issues identified in the raw pattern. With these successful modifications, the final pant specification sheet was established. This comprehensive document included objective formulas and values that were instrumental in creating a pattern-making method specifically designed for young females exhibiting the Y-body type.

This research holds substantial value as it offers a comprehensive guide for crafting patterns for form-fitting pants specifically designed for young females exhibiting the Y-body type. The study introduces a pattern-making approach that leverages 3D body scanning data to generate foundational patterns, thereby anchoring the method in empirical data and fitting assessments rather than relying solely on the pattern maker's experience and intuition. Furthermore, the exploration of 3D virtual fitting technology marks

an innovative step in the realm of pattern-making. This technology allows for a visual representation of fitting outcomes and simulates both static and dynamic wear scenarios, providing a more comprehensive understanding of a garment's performance. For apparel companies, the adoption of 3D virtual fitting technology can expedite the design process and significantly lower the costs associated with product development. Grounded in model definition theory, the 3D garment model serves as a digital twin, encapsulating detailed information about the pattern, manufacturing processes, and materials used. This model can be seamlessly integrated into product lifecycle management, offering valuable insights to guide future garment design and production. By embracing these advanced technologies and methodologies, the fashion industry can achieve a higher level of precision, efficiency, and innovation in creating garments that perfectly match the form and function required by the modern consumer.

This study acknowledges two primary limitations. The first pertains to the scope of the Y-body type human body data, which was collected from a sample of 71 females in the Hangzhou area and may not be representative of the entire female population. The second limitation is that the form-fitting pant design developed in this research is grounded in a basic style pattern, and its adaptability to a broader range of styles has yet to be confirmed. Despite these limitations, the approach taken in this study to translate 3D body data into two-dimensional pattern pieces offers a valuable reference for future research endeavors in the realm of personalized and small-batch clothing customization within the fashion industry. This methodology has the potential to revolutionize the way garments are designed and produced, catering to individual body shapes and preferences, and ultimately enhancing the fit and satisfaction of consumers.

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