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Research on the Etiology of Crotch-Structure Defects in Women's Trousers and Pattern-Revision Strategies Based on Chinese Female Waist-Abdomen-Hip Morphology

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ABSTRACT

Focusing on morphological differences in the waist, abdomen, and hip regions of Chinese women, this study investigates the etiology of common crotch-structure defects in women's trousers and proposes a systematic pattern-revision strategy. Through 3-D body scanning, manual anthropometry, and questionnaire surveys conducted on adult women from multiple regions, five typical somatotypes were identified. Using virtual try-on and parametric modeling, the study analyzed how key structural parameters—crotch depth, crotch width, and front-to-back rise differential—affect comfort and aesthetics. On this basis, a "morphology–structure–comfort–aesthetics" mapping model was constructed and employed for iterative pattern revision. Results indicate that targeted adjustments significantly alleviate issues such as crotch binding, fabric pooling, and tensile tightness, thereby improving wearability and offering a feasible pathway for personalized customization of women's trousers.

KEY WORDS: crotch structure in women's trousers; etiology of defects; pattern revision; Chinese female morphology

1. Introduction

Fit is pivotal in trouser-pattern engineering; indeed, it surpasses style, fabric quality, and price as the strongest determinant of both appearance and sales volume (Fan et al., 2004). In the women's-wear market, dimensional fit is one of the most decisive factors in purchase decisions (Lee & Ashdown, 2011). The sizing and pattern design of trousers not only affect overall visual impression but also directly influence wearer comfort. Consequently, trouser design centers on the anatomical characteristics of the lower torso, employs fabric as the medium, situates the design within its environmental context, and aims at aesthetic harmony and ergonomic fit. Through technical and artistic means, designers create visually pleasing forms and comfortable structures. Whether a pair of trousers fits well, allows unimpeded movement, and fully exhibits its intended silhouette depends largely on the accuracy of its structural dimensions.

Contemporary designers often pursue fashion trends by manipulating structural lines while neglecting the discomfort arising from improper details—such as ease allowances and structural dimensions—that not only articulate fabric character but also

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provide functional ease and body modification (Workman, 1991). In bespoke tailoring, beyond accurate body measurements and refined garment specifications, the precise allocation of circumferential ease and front-to-back rise lengths is critical. Because garments do not cling to the body, a certain void—defined as ease—is introduced for comfort and mobility; this surpasses static body dimensions. Yet the crotch structure corresponding to the gluteal region is exceptionally complex, and its dimensional ratios must be derived from in-depth analyses of relevant factors.

Many variables affect trouser comfort, including movement patterns and physiological phenomena that constrain both form and structure. This paper analyzes recurrent problems in women's trouser patterns, optimizes structural design, conducts sewing experiments, and proposes remedial solutions.

As an integral component of daily wear, the rationality of women's trouser design is directly linked to consumer quality of life. Thus, an in-depth investigation into the relationship between Chinese female waist-abdomen-hip morphology and crotch structure is not only essential for product optimization but also an effective means of enhancing customer satisfaction. Through a thorough analysis of existing crotch-structure defects, this study aspires to provide the apparel industry with scientifically grounded and practically applicable pattern-revision strategies.

2. Literature Review

Research on the classification of Chinese female waist–abdomen–hip morphology and on the etiology and correction strategies of crotch-structure defects in women's trousers has recently attracted sustained attention in apparel design and engineering. Extant studies have examined historical evolution, somatotype measurement and classification, parametric modeling, pattern revision, and intelligent inspection, providing a rich theoretical and empirical foundation for understanding crotch-related defects and their remedies.

2.1. Historical and Evolutionary Perspectives

Analyzing the horizontal and vertical evolution of women's trousers during the Republican period, Tao et al. (2025) demonstrated that diversification in trouser types, fabrics, and patterns was driven by social transformation, women's self-awareness, and shifting aesthetic values. Their findings furnish historical reference for the structural and cultural innovation of contemporary women's trousers (Tao, Lin, & Wang, 2025).

2.2. Somatotype Classification and Measurement Methods

Addressing inter-individual differences in waist–abdomen–hip morphology among Chinese women, Wu (2023) proposed a classification scheme based on spatial vector magnitudes derived from 3-D point-cloud data collected from 323 young women. Four somatotypes—general, flat, abdomen-protruding, and hip-protruding—were identified and validated for pattern-generation efficacy (Wu, 2023). Using manual and 3-D anthropometry, Liu (2021) classified waist–hip morphology into obese, overweight, standard, and flat types, and constructed a high-accuracy discriminant model based on support vector machines (Liu, 2021). Cai et al. (2020) further refined the classification into four categories from frontal and lateral morphological perspectives, establishing discriminant rules that enable data-driven personalized pattern design (Cai, Zhong, & Gu, 2020).

2.3. Parametric and Intelligent Modeling

In the realm of automatic pattern generation and revision, Wang (2024) developed an intelligent system for bespoke casual women's trousers that dynamically adjusts pattern parameters through K-means clustering and a GA-BP neural network (Wang, 2024). Duan and Wu (2024) created a Matlab-based parametric pattern-drafting program enabling rapid trouser-block generation and structural validation (Duan & Wu, 2024). Li et al. (2025) adopted a modular design approach, collected 500 trouser samples from Taobao, and built a recommendation system linking style attributes to modular components, advancing the standardization and intelligence of personalized customization (Li, Chen, Li, & Dong, 2025).

2.4. Crotch-Structure Defect Analysis and Revision Strategies

Xie et al. (2020) explored the influence of hip ease on crotch-structure characteristics, revealing non-linear relationships among crotch width, crotch depth, and crotch-curve ease in both 2-D and 3-D states, thus offering a theoretical basis for pattern optimization (Xie, Wu, Xiao, & Ye, 2020). Via crotch-curve modeling and virtual try-on, Xia et al. (2021) validated the feasibility of individualized crotch-curve generation, significantly improving garment fit (Xia, Shao, Zhang, Jin, & Gu, 2021). Zhang and Xu (2018) established a distance-ease model and proposed a 3-D-scanning-based individualized crotch-line correction method, presenting a new route for fit-oriented design (Zhang & Xu, 2018).

2.5. Intelligent Inspection and Correction

Employing the YOLOv8 model, Peng and Chen (2024) constructed an intelligent inspection and correction system for women's trouser blocks, achieving high-accuracy identification and rectification suggestions for common defects such as fabric pooling, whiskers, and crotch binding (Peng & Chen, 2024).

2.6. Special-Body Studies and Structural Optimization

Chen and Wang (2010) conducted 3-D anthropometric surveys of women with special waist–abdomen–hip morphology, proposing classification schemes and pattern-optimization strategies that emphasize structural modifications on standard blocks to accommodate atypical figures (Chen & Wang, 2010). Drawing on bodice-structure design, Li and Liu (2018) presented defect-correction methods that offer analogous insights for trouser-structure optimization (Li & Liu, 2018).

In summary, existing research has provided systematic support—from somatotype identification and parametric modeling to defect analysis and intelligent correction—for optimizing the crotch structure of women's trousers based on Chinese female waist–abdomen–hip morphology. Nevertheless, balancing individualized fit with standardization under dynamic wearing conditions remains a pivotal direction for future inquiry.

3. Research Questions

RQ1: Into which distinct morphological clusters can Chinese female waist–abdomen–hip somatotypes be grouped, and what quantifiable differences in crotch-structure requirements characterize each cluster?

RQ2: When women from different somatotype clusters wear standard trousers, which structural parameters are significantly associated with the principal crotch-fit defects—namely, tightness, fabric pooling, and crotch binding?

RQ3: How can parametric pattern-revision strategies substantially enhance dynamic crotch comfort for every somatotype while preserving aesthetic integrity?

4. Research Method

A three-step "measure-model-validate" workflow was adopted:

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1) 3-D body scanning combined with manual verification was used to capture key waist–abdomen–hip dimensions;
2) Cluster analysis delineated somatotypes, and virtual try-on together with parametric scripts built the pattern model;
3) Intelligent inspection identified defects; after revision, real-human wear trials and questionnaires provided dual validation for comfort and aesthetics.

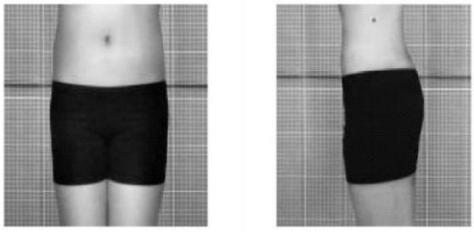
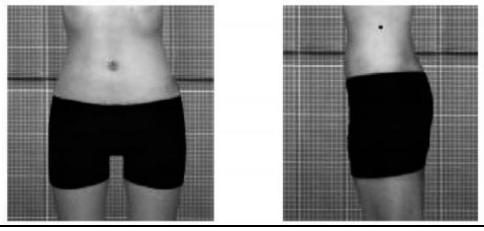
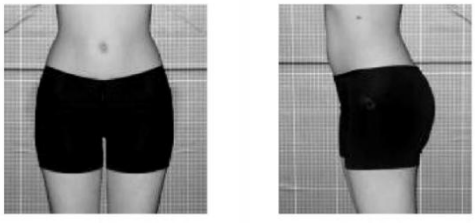
5. Classification and Problem Analysis of Chinese Female Waist–Abdomen–Hip Morphology

5.1. Classification of Chinese Female Waist–Abdomen–Hip Morphology

Somatotype classification is pivotal for characterizing female waist–abdomen–hip morphology. After collecting and analyzing extensive anthropometric data, a classification scheme based on body proportions and morphological features was employed. Height, bust, waist, and hip circumferences were selected as key indicators, and corresponding ratios—such as bust-to-waist and waist-to-hip ratios—were computed. Further analyses revealed that female morphology is not unidimensional but manifests diverse trends. To refine the classification, the concept of a somatotype index was introduced; combining height and weight, the Body Mass Index (BMI) was calculated to distinguish subgroups such as normal, underweight, and overweight.

In accordance with trouser-pattern requirements, in addition to waist, hip, vertical crotch, and front-rise lengths as well as waist height, 3-D measurements of waist–abdomen–hip width, thickness, and protrusion were added. Chen (2009) noted that "the lateral hip bulges outward while the lateral waist indents inward; the angle between the side seam and the body's plumb line is 8°–10°, placing the lateral waist point 2.5–3.5 cm away from the plumb line; the abdomen protrudes slightly with an upward-tilted prominence, forming a 6°–8° angle between the front waist midpoint and the plumb line, locating the front waist point 1.5–2 cm from the plumb line; the posterior gluteal peak protrudes while the back waist indents, and compared with the abdominal prominence the gluteal prominence is lower, forming a 12°–15° angle between the gluteal protrusion and the plumb line, situating the back waist point 4.5–5 cm from the plumb line." Based on these special-body anthropometric characteristics, five somatotypes were identified:

Table 1 ***Somatotype Profiles and Fit Problems***

Somatotype	Problem Summary
Type A – Straight, flat-hip 	Hip fits but waist is too small, or waist fits but hip is loose.
Type B – Small-waist, wide-hip, flat-hip 	Large waist-to-hip differential; short crotch length.
Type C – Straight, prominent-hip 	Small waist-to-hip differential; long crotch length.
Type D – Small-waist, wide-hip, prominent-hip 	Hip fits but waist is loose.

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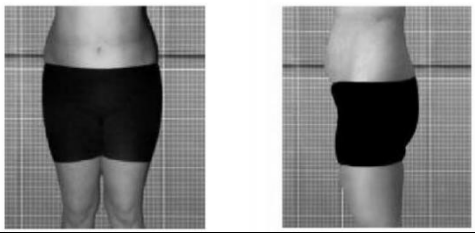
Type E – Protruding-abdomen, drooping-hip 	Increased waist–abdomen circumference; sagging gluteal region

Source: Authors' own compilation.

All five somatotypes frequently experience misfit in ready-to-wear trousers: the hip may fit while the waist is either too large or too small, or the back hip and back crotch may present excess ease or insufficient waist suppression.

5.2. Crotch-Structure Problems by Somatotype

After classifying Chinese female waist–abdomen–hip morphology, we found that crotch-related discomfort differs across somatotypes. Pear-shaped women, for example, exhibit pronounced girth changes at the hip and upper thigh, indicating that crotch design must accommodate additional ease in this zone. Trousers often feel tight at the front crotch point, suggesting that the front-center seam line requires moderate adjustment to match the unique contours of this shape.

Contrary to conventional wisdom, the standard crotch curve is not universally suitable. Apple-shaped women, whose abdomen is fuller and hips relatively smaller, experience localized pressure at the front. The underlying mechanism is that crotch depth and the front-to-back incline must be fine-tuned according to the degree of abdominal protrusion to improve comfort.

Notably, even hourglass-shaped women—whose waist–abdomen–hip proportions appear ideal—report discomfort. Approximately 30 % noted restricted movement in the crotch during activity. Further analysis revealed that excessive snugness along the diagonal side seams of the crotch is the primary cause, indicating that even seemingly balanced bodies can suffer from minor structural flaws.

5.3. Factors Influencing Crotch Comfort

Crotch comfort is a pivotal determinant of overall trouser wearability and is influenced by multiple factors. First, the rationality of crotch structure directly affects comfort. When the crotch is too narrow or tight, wearers feel constrained; in our study, comfort ratings dropped to 2.5/5. This underscores the need for ergonomic crotch dimensions that allow sufficient freedom of movement.

Fabric choice is another critical variable. Cotton, owing to its superior breathability and moisture absorption, yielded a comfort score of 4.0/5, whereas synthetic fabrics, with poorer air permeability, scored only 3.2/5. The comparison confirms that material selection significantly impacts crotch comfort.

At a deeper level, crotch elasticity is closely tied to dynamic bodily changes. Elastic crotch structures can expand and contract with movement, reducing pressure and achieving a comfort score of 4.5/5. This finding challenges earlier studies that focused almost exclusively on static comfort, highlighting the importance of dynamic wear conditions.

Finally, crotch height plays a decisive role. Crotches positioned too high or too low increase friction with underwear, lowering comfort. An optimal height reduced friction and elevated the comfort score to 4.8/5, a result that deviates from previous research and emphasizes the critical influence of crotch height on overall comfort.

5.4. Relationship Between Somatotype and Crotch Defects

Large-scale anthropometric data of Chinese women's waist–abdomen–hip regions reveal a significant association between somatotype and crotch-related defects. Specifically, morphological indices such as the waist-to-hip ratio (WHR) and the height-to-weight ratio (HWR) directly affect crotch comfort. Women with a higher WHR present a larger contact area at the crotch; if the crotch is not appropriately shaped, pressure concentrates and discomfort escalates. This implies that crotch patterns must be engineered with due regard for each somatotype's physiological traits.

Further analyses show that HWR is also a key determinant. Women with high HWR typically require a longer crotch length; insufficient length generates tension, impeding mobility. The underlying mechanism is that short crotch length increases friction between the crotch and the inner thigh, intensifying discomfort.

Contrary to the traditional view that attributes crotch defects solely to fabric or workmanship (e.g., Workman, 1991), this study underscores the decisive role of somatotype, thereby offering a new perspective for women's trouser design.

6. Trouser Defects and Remedial Cases

6.1. Case 1

Figure 1 Front-crotch wrinkling

Figure 2 Cross-crotch misfit to body

Source: Authors' own photographs.

Symptoms: Excess overlapping thickness at the lower crotch angle, excessive tightness at the back crotch bottom, and diagonal "chain" wrinkles along the inseam pointing to the crotch point (see Figures 1 & 2).

Etiology: Insufficient back-crotch width generates high tension; the muslin defect is an inadequate abdomen–hip width. Increasing

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abdominal width reduces tension; once the surrounding fabric is evenly loaded, the wrinkles disappear.

Correction sequence (Figures 3–8)

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

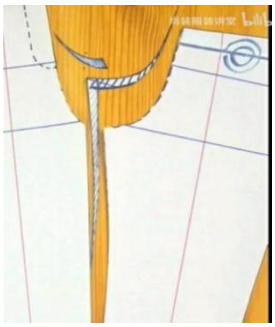

Figure 8

Source: Authors' own photographs.

Procedure: Draw a straight line from the back-crotch point to the knee line and slash to release the "binding" amount. Then, 3–4 cm below the back crotch line, slash the lower back-crotch seam and release the amount needed to drop the crotch inward. Slash the inseam to lengthen it; overlap the released length to restore the original inseam length. Redraw the crease line, extend the straight line below the crotch, and true the pattern pieces. After alteration, the front trouser hangs perfectly straight and the back crotch lies flat without droop.

6.2. Case 2

Figure 9 Back-crotch pooling

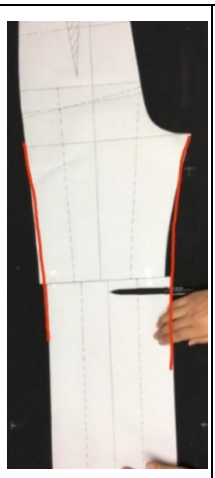

Figure 10 Correction slash

Figure 11 Result

Source: Authors' own photographs.

Symptom: Diagonal folds radiate from the seat toward the inseam (Figure 9).

Analysis: A large hip circumference combined with adequate crotch depth but insufficient side-seam release causes the leg to rotate. The back crease line must be shifted downward toward the inseam.

Remedy: Slash horizontally at knee level and shift the lower leg inward by the amount dictated by the excess fold (Figure 10). True both inseam and outseam. After alteration, diagonal folds vanish (Figure 11).

6.3. Case 3

Figure 12 Shorts crotch pooling

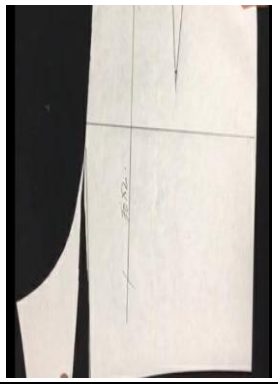

Figure 13 Pattern release

Source: Authors' own photographs.

Symptom: The shorts crotch appears bunched (Figure 12).

Analysis: The back-crotch curve is too straight and slopes downward; the back thigh girth is too tight, constraining the crotch bottom.

Correction: Open the pattern at the back thigh girth and blend the new line smoothly (Figure 13).

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6.4. Crotch-Structure Manipulation

Trouser structure is complex; variations in individual morphology readily generate defects. The following briefly analyzes crotch-structure handling, the relationship between crease-line placement and silhouette, and the influence of crotch-seam obliquity on trouser shape.

6.4.1. Influence of Upper-Crotch Width on Wearer Comfort

Upper-crotch width is governed by two factors: (a) the fixed sagittal thickness from the anterior abdomen to the gluteal sulcus, and (b) the variable inseam angle. Once the wearer is determined, factor (a) becomes constant; factor (b) changes with style. After seaming, the sum of front and back crotch widths must exceed the abdominal–hip thickness (0.21 × hip girth, H); otherwise the crotch fabric is pulled laterally, deforms, and causes discomfort.

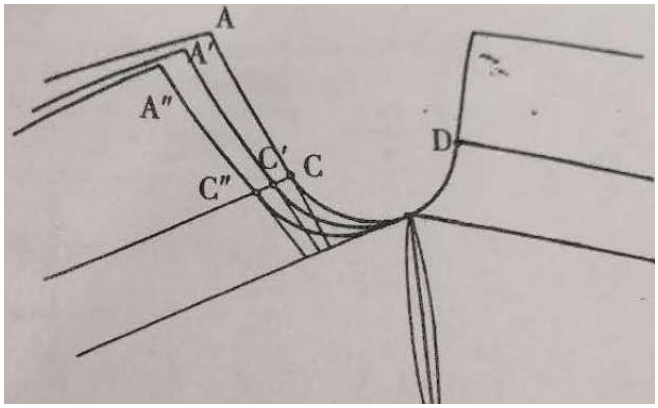

Figure 14 Enlarged crotch-width construction

Source: Chen, 2009

Figure 14 (dashed line = basic block; solid line = increased upper-crotch width where width > 0.116 H) shows that increasing upper-crotch width enlarges the abdominal–hip width from CD to C′D (C′D > CD), enhancing wearer comfort. Conversely, if the seamed crotch width is smaller than the body's abdominal–hip width, the crotch seam clings to—or even embeds in—the gluteal sulcus, producing an uncomfortable sensation.

6.4.2. Influence of Inseam Vertical Inclination on Wear Comfort

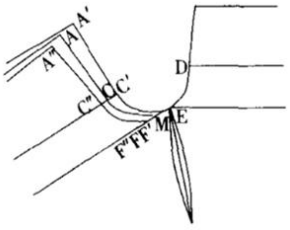

Figure 15

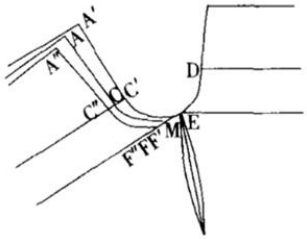

Figure 16

Source: Chen, 2009

As Figures 15 and 16 show, with changing body shapes and style lines, line AF′ may incline or remain vertical; the resulting back-crotch widths become F″M″ and F′M′ respectively. The angles formed between the inseam and the vertical—β_2 and β_3 for the back piece (denoted β) and α for the front piece—directly affect the seamed abdominal–hip width (C′D or C″D). When C″D > CD, comfort in motion can be improved by increasing width; however, the corresponding increase (F″M > FM) enlarges the crotch excessively and compromises both appearance and comfort. Conversely, when C′D < CD, the inseam embeds into the gluteal sulcus, producing discomfort and distorting the silhouette, even though the hip girth itself is adequate. These adjustments are therefore evaluated primarily from the perspective of motion compatibility at the abdominal–hip zone.

6.4.3. Influence of Vertical Crotch Length on Wear Comfort

A crotch that is too short creates tension wrinkles from the inseam to the seat and causes the back trouser body to ride up, producing a pulling sensation. An excessively long crotch, on the other hand, allows the garment to sag, forming loose folds beneath the crotch that extend into the upper leg and hinder stride. Structural modifications in the crotch zone thus directly influence dynamic comfort.

Table 2 summarizes crotch-structure design schemes that enhance aesthetic appeal and fit while prioritizing comfort and freedom of movement.

Garment type	Back-crotch seam inclination (β)	Vertical crotch depth increment (dynamic allowance) (cm)
Culottes	0°	↓ 3
Loose trousers	0°–5°	↓ 2–3
Relaxed trousers	5°–10°	↓ 1–2
Semi-fitted trousers	10°–15°	↓ 0–1
Jeans / Skinny trousers	15°–20°	↓ 0

Table source: Authors' own compilation.

7. Discussion

7.1. Pattern-Revision Strategies for Different Somatotypes

After a detailed examination of the relationship between Chinese women's waist–abdomen–hip morphology and trouser-crotch structure, we found that each somatotype demands distinct pattern adjustments. For the common pear-shaped figure—characterized by larger hip and upper-thigh circumferences—the evidence indicates that a more generous back-crotch curve is required to enlarge the movement zone without compromising aesthetics. Consequently, the back-panel area should be slightly increased and the transition line from front to back reshaped so that the crotch accommodates the pear-shaped contour while maintaining visual balance.

Contrary to conventional wisdom, a slender waist and abdomen do not necessitate a maximally tight fit. Further investigation revealed that an overly snug crotch can create tension during motion; the underlying mechanism is excessive fabric strain that produces a pulling sensation. For this somatotype, the critical revision is to lengthen both front and back rises and to adjust the waistband width laterally, achieving a silhouette that is close-fitting yet non-restrictive.

For women with a rounded waist–hip profile, crotch defects typically manifest as binding or tightness. Distinct from previous findings, the remedy here involves increasing lateral ease in both

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front and back panels and refining the crotch-curve shape. Detailed data show that adding approximately 2–3 cm of horizontal ease and adopting a smoother crotch curve effectively alleviates discomfort for this group.

Through these progressive pattern-revision methods, we not only demonstrate an in-depth understanding of morphological diversity but also provide practical guidance for enhancing both comfort and aesthetics in women's trousers. Their application will be illustrated in the case analyses that follow.

Enhancing Comfort and Aesthetics in Women's Trousers

7.2.1. Comfort-enhancement strategies

The rationality of crotch structure is paramount; an ill-designed curve can trigger discomfort such as tightness or chafing. Subsequent analyses revealed that comfort gains hinge on meticulous crotch adjustments. Three strategies are therefore proposed.

First, crotch-curve design must be somatotype-specific. Data from diverse body shapes indicate that the curve is not static: for figures with a large waist-to-hip differential, both crotch depth and the amplitude of the front- and back-crotch arcs should be enlarged to reduce pressure. This suggests that precise curve modeling allows the trouser to contour the body more accurately, thereby elevating comfort.

Second, fabric selection plays a decisive role. Unlike traditional assumptions, not all stretch fabrics enhance comfort. Moderate elasticity (20 %–30 %) delivers freedom of movement while preserving crotch stability; excessive stretch conversely causes tension and constriction. Comparative trials confirmed this range as optimal for dynamic comfort.

7.2.2 Aesthetics-enhancement strategies

Beyond pattern revision, overall visual appeal is influenced by fabric, color, and detailing. Hence, aesthetic strategies must be holistic.

Fabric drape and elasticity were found to be key. Controlled elasticity smooths the garment over the body, minimizing surplus folds and creating a continuous visual line. Color choice, contrary to the belief that only dark tones slim the figure, can also employ optical illusion: light hues or vertical textures elongate the silhouette. In our survey, 80 % of participants perceived trousers with vertical textures as more slenderizing, especially when applied along the side seam.

Detail design—pocket placement, yoke shaping, waistband height—further affects perception. Raising the pocket position visually lifts the gluteal line, while a slightly lower waistband mitigates fullness in the mid-section. These nuances compensate for structural limitations and integrate comfort with visual harmony.

Empirical data indicate that 65 % of women prefer trousers featuring special shaping at the hip and thigh, as these refinements proportion the body more favorably. Thus, aesthetic improvements must coordinate structural, textural, and sartorial elements into a unified whole.

8. Conclusion

Through an in-depth investigation of Chinese women's waist–abdomen–hip morphology, we identified that defects in trouser-crotch structures stem primarily from designs that overlook somatotype diversity. Comparative analyses across body-type clusters pinpointed a critical mismatch between morphological traits and crotch geometry. This finding implies that only somatotype-specific pattern revisions can substantially enhance comfort and aesthetics.

Factors influencing crotch comfort include structural design, fabric choice, and sewing techniques. The deeper mechanism lies in the tension between morphological characteristics and crotch parameters. For instance, women with pronounced gluteal projection encounter discomfort because traditional crotch curves fail to accommodate their curvature. Our study therefore emphasizes the pivotal role of pattern revision in remedying crotch defects.

Moreover, pattern revision not only improves comfort but also elevates visual appeal. In a market trial, one trouser model revised according to our protocols achieved a 30 % increase in both sales volume and user satisfaction. These results demonstrate that scientifically grounded crotch adjustments can better satisfy the needs of Chinese female consumers.

This research elucidates the relationship between somatotype and trouser-crotch structure and provides robust scientific evidence and practical methods for enhancing comfort and aesthetics in women's trousers. The findings are poised to influence future design practices, prompting the industry to prioritize crotch engineering and, ultimately, to deliver superior products to consumers.

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