Stretch elasticity and garment pressure of shaping-underwear fabric

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Abstract. In recent years, the relationship between corsets and human health has been widely concerned. In order to explore the relationship between body shaping fabric and garment pressure, this paper starts from the reasons for the formation of body-dressing clothes, discusses the comfort range of human body wear and summarizes the principles, advantages and disadvantages of various methods of testing body-dressing clothes. At the same time, five elastic fabrics are selected to test their tensile properties. The garment pressures produced by the human calf diameter of 9 cm are also tested. The relationship between the tensile properties of the fabric and the garment pressure is analyzed, which lays the foundation for designing the intelligent corset that can meet the health requirements of people and realize the shaping of the body.

1. Introduction
Shaping-underwear, also known as tight garment, include bras, waist-nipper, split type shaping-underwear, toning pants, etc., mainly by applying pressure to the wearer to help people transfer excess meat from various parts of the body to the desired position. In this way, it can straighten the chest, lift the buttocks, slim the legs and correct the hunchback, so as to correct the body curve and shape the perfect figure for modern women [1, 2]. However, too much clothing pressure will not only cause the wearer's bone deformation, internal organs movement, but also bring them a series of physiological problems, and even cause diseases [3, 4]. Therefore, studying the pressure comfort of shaping-underwear is of great significance for optimizing its structural design and improving its fit and health.

2. Garment pressure produced by shaping-underwear
The garment pressure produced by the corset is mainly composed of weight pressure, surface pressure and restraint pressure. Weight pressure is formed by the weight of the body-shaping garment itself. Surface pressure is caused by the elasticity of the fabric and the looseness of the clothing or the excessive frictional resistance of the fabric when the human body is in dynamic contact with the garment. The restraint pressure is produced when the body is wrapped tightly in the body during exercise. The impact of the three on the human body depends on the specific situation. Generally, there are at most two of them in the plane of the human body, and sometimes only one kind of pressure exists. In the curved part of the human body, there may be two or three kinds of pressures. In addition, the cause of the corset garment pressure is also related to the psychological factors of the human body.

A large number of studies have shown that the pressure comfort on clothing required by the human body under normal exercise conditions is about 0.49 to 2.6 kPa. However, due to the different wearers
and wear parts, the degree of discomfort will vary [5]. In 1995, Pratt proved through a large number of experiments that the blood pressure of the capillaries on the human body surface is close to 1.96~3.92 kPa. When the garment pressure reaches 5.88~9.8 kPa, people will feel uncomfortable. When the garment pressure exceeds 9.8 kPa, the human body is not able to withstand it [6]. When wearing a tight garment such as toning pants, if the leggings clothing pressure is less than 1.47 kPa, the human body basically does not feel the pressure. When the clothing is pressed at 1.47~2.46 kPa, the human body feels comfortable pressure. At this time, the exercise can be strengthened. When the clothes of the pants are pressed at 2.46~3.92 kPa, people begin to feel the pressure, but it is not enough to cause physiological harm. If the uncomfortable clothing pressure threshold reaches between 3.92 and 7.85 kPa, the wearer will feel extremely uncomfortable [7,8].

3. Test method for pressure of shaping-underwear

3.1. Subjective testing method

The evaluation of garment pressure produced by corsets has special characteristics. Shapewear will wrap the body tightly, so the comfort level is directly perceived by the body itself. Therefore, the subjective evaluation method is often used to study the clothing pressure. In order to quantify subjective feelings, psychological scales are often used in trials to assign different levels of sensation to different values, allowing the wearer to mark the scale based on their wearing sensation. At the end of the test, the tester estimates the size of the value based on the marker. However, due to the large difference in subjective evaluation of individual feelings, simple subjective test cannot accurately describe the comfort performance of clothing. So, it is necessary to use instruments to obtain more objective results [9].

3.2. Objective testing method

Objective tests include direct measurement and indirect measurement. The direct test method is to place the sensor in some parts of the corset and the wearer in the dressing state, and directly measure the pressure value of the specific part. The direct test method is divided into many types, as shown in table 1 [10, 11].

Table 1. Several direct garment pressure testing methods.

| Test Methods          | Principle                                                                 | Advantages                                          | Disadvantages                                             |
|-----------------------|---------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------|
| Fluid pressure test   | Measuring the garment pressure value by reading the height change          | Simple operation, light weight and small size.       | Low data reliability, without continuous dynamic measurement. |
|                       | of the mercury column in the single tube or the height difference          |                                                     |                                                           |
|                       | of the liquid level in the U-tube.                                         |                                                     |                                                           |
| Sensor measurement    | Including piezo-resistive type, capacitive strain type,                   | Light weight, small size, high precision, stable    | Easy to be affected by factors such as radius of curvature, |
|                       | piezoelectric type and pressure change detected by voltage or resistance  | results, real-time measurement of continuous        | hardness, and elastic elongation of the fabric.           |
|                       | value change.                                                             | pressure distribution.                              |                                                           |
| Air bag pressure      | By applying pressure to the airbag filled with a certain amount of air,    | Good applicability, small error and good flexibility.| Only point measurement can be performed, and local        |
| tester                | the pressure sensing member transmits the pressure to the input end of the |                                                     | pressure distribution law cannot be predicted.            |
|                       | strain gauge pressure                                                    |                                                     |                                                           |
sensor, and the change in pressure is detected as a change in voltage. The incident light is generated by the He-Ne laser generator, enters the optical fiber and is reflected back to the core from beginning to end. The elastic fiber is deformed by force to change the number of rays transmitted in the core layer. And the external force value of the elastic fiber can be obtained by the amount of light.

**FlexiForce Stress Test**
Through the FlexiForce pressure sensor, the measured physical signal is converted into an electrical signal by the amplifying circuit, and then converted into a computer by the data acquisition system, and finally processed, analyzed and displayed by the computer. Excellent technical characteristics and easy to use with continuous measurement and analysis. It is suitable for static measurement and the cost is high. Dynamic test can also be carried out when the measurement accuracy is not high.

**Virtual instrument based pressure test system**
The signal collected by the sensor is processed and sent to the PC through the signal conditioning device and the data acquisition card. Finally, the data is analyzed by the Labview program. It improves the measuring efficiency, realizes multi-point simultaneous measurement and real-time observation of pressure changes. When measuring, the sample content is large, and it is necessary to master high theoretical knowledge of computer, physics, mathematics etc.

Differences in the laboratory environment, temperature, humidity, and the physiological condition of the wearer will have a certain impact on the direct test results. In order to effectively avoid these interference factors, indirect measurement methods can be used. It is also divided into many types, as shown in table 2 [12, 13, 14].

| Test Methods                  | Principle                                                                 | Advantages                                        | Disadvantages                                    |
|-------------------------------|---------------------------------------------------------------------------|---------------------------------------------------|--------------------------------------------------|
| Theoretical calculation method| Based on the establishment of the three-dimensional human body model, the garment pressure is theoretically calculated from the elongation deformation and curvature in all directions. | Various effects can be simulated to predict the pressure distribution. | Pressure calculation results have large errors. |
Plaster method
Gypsum or synthetic resin is used to form a convex model that simulates the elbow, knee, etc. Holes are punched in the arch, and a pressure sensor is attached to measure the pressure on the raised part of the clothes.

The natural garment pressure can be measured at the time of dressing.

The gypsum model material is hard and far from the softness of the human body.

Soft dummy method
The shape of the soft dummy is digitally scanned by a humanoid scan. And it has a special skeleton, soft tissue, smooth skin and a pair of easily changing artificial breasts.

The modulus of elasticity is similar to that of a real person, with a wide range of applications, saving time and cost.

Ignoring the effects of physical and psychological reactions on the body's stress.

4. The relationship between fabric and garment pressure
As a kind of clothing with adjustment function, the corset is generally made of elastic fabric. Compared with ordinary fabric, elastic fabric has the mechanical characteristics of easy elongation, easy recovery and good elasticity. The elasticity of the fabric depends on the stretching of the fabric, while the garment pressure is caused by the compression of the fabric into the body. Therefore, the garment pressure must be related to the elongation of the fabric.

4.1. Basic parameters of the fabric
In order to make the test results representative, five representative corset fabrics were purchased from the market, and their parameters are shown in Table 3.

| Table 3. Fabric parameters. |
|-----------------------------|
| Fabric number   | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
| Composition and content | 5% spandex + 95% polyester | 8% spandex + 92% polyester | 12% spandex + 88% nylon | 15% spandex + 85% nylon | 18% spandex + 82% nylon |
| Gram (g m⁻³)     | 180      | 176      | 198      | 192      | 170      |

4.2. Fabric extension performance test
When the human skin is in motion, the maximum elongation of the longitudinal and transverse skin is 45 % and 34 %, respectively. Therefore, during normal wearing, the elongation of the garment material is similar to the skin elongation and will not exceed 50 %. In this paper, the longitudinal and transverse
tensile properties of elastic fabrics were tested using an electronic universal testing machine. The tensile curves of the five fabrics are shown in figure 1 and figure 2.

![Figure 1. Longitudinal tensile curve of the fabric.](image1)
![Figure 2. Transverse tensile curve of the fabric.](image2)

During the stretching process of the five fabrics, the tensile forces in both longitudinal and transverse directions increased with the increase of the elongation. Moreover, in the initial stage of stretching, the sample can produce a large elongation deformation under the action of a small tensile force.

4.3. Research on garment pressure of body shaping fabric

In this paper, the pressure of the garment with a diameter of 9 cm on the human calf was measured with a sensor. Through curve fitting, the relationship between the garment pressure generated and the fabric elongation within the range of 50% was obtained, as shown in figure 3 and figure 4.

![Figure 3. Longitudinal elongation and pressure curve of fabric.](image3)
![Figure 4. Transverse elongation and pressure curve of fabric.](image4)

Except for sample 1, during the longitudinal stretching of the fabric, the garment pressure increases linearly with the tensile elongation, which may be caused by either the different spandex content of the fabric or the different fabric structure. Compared with the transverse stretching, the longitudinal stretching has a greater impact on the garment pressure generated by the human body, which may be because the garment pressure is mainly caused by the longitudinal stretching of the fabric.
5. Concluding remarks

The paper starts with the reasons for the garment pressure on the body moulding underwear and summarizes the principles, advantages and disadvantages of various methods of testing body shaping clothes. At the same time, this paper also focuses on the relationship between the extension of some elastic fabrics and the garment pressure. This kind of discussion is limited to the surface. It is also necessary to experiment with more elastic fabrics to study the specific relationship between fabric and garment pressure.

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