Study on Comfortability Design of Heart Rate Monitoring Vest for Elderly Women

Wang Shi, Xu Zhi
Dalian Polytechnic University, Institute of Clothing Technology, Dalian, Liaoning
wangshi@dlpu.edu.cn

Abstract. In order to promote healthy aging and care for the heart health of elderly women, the authors carry out a design for the heart rate monitoring vest sold in the market for its “suitability for the elderly” and “comfortability”. Based on the requirement of flexible heart rate monitoring, this paper analyzes the functional requirements of physiological function and morphological changes of elderly women, selects eight kinds of high-elastic nylon and spandex interwoven fabrics with different composition ratios on the market to test the two basic properties—tensile property and thermo-wet comfort property, and optimizes the fabric partition design of elderly heart rate monitoring vests by referring to the test results of fabric comfortability. To a certain extent, the study improves the comfortability and stability of heart rate monitoring vest of elderly women, and provides multiple choices for the maintenance of heart health of elderly women.

1. Introduction
With the aggravation of the aging process in the world, the concept of healthy aging has reached a consensus in the world, and heart disease is an important factor endangering the life, health and safety of the elderly. According to the literature, more women die from heart disease than men, and postmenopausal women have an increased risk of heart disease. The average age of the first heart attack in women is 72 years. Therefore, postmenopausal elderly women are at high risk of heart disease. [1] At present, the clothing with heart rate monitoring function on the market is mainly designed for young sports consumers, and little attention is paid to the health needs of elderly women. Therefore, it is imperative to modify the heart rate monitoring vest for its suitability for the elderly and its comfortability. Based on the present situation of humanistic care and medical care demand for elderly women, this paper combines fabric with structural improvement to enable clothing to own the function of body-fitting comfort and stable structure, so as to meet the needs of daily health maintenance of elderly women.

2. Methods
Based on the analysis of functional requirements of heart rate monitoring vests of elderly women, eight kinds of fabrics containing both nylon and spandex with different structural parameters are tested. According to the national standard GB/T 3820 - 1997 Determination of Thickness of Textiles and Textile Products, FZ/T 70006 - 2004 Test Method of Tensile Elastic Recovery of Knitted Fabrics, GB/T5453 - 1997 Textile-Determination of the Permeability of Fabrics to Air, GB/T6503 - 2017 Man-Made Fibres—Test method of Moisture Regain, FZ/T01071 - 2008 Textiles—Test Method for Capillary Effect, the authors complete tensile elasticity test, air permeability test, moisture absorption...
test, and wet permeability test of the fabrics. The authors adopt YG141LA fabric thickness gauge in the thickness test, Instron universal electronic strength machine in the tensile elastic test, YG461Z automatic air permeability gauge in the air permeability test, Y801A constant temperature oven, balance, sample container and dryer in the moisture absorption test, and YG871L capillary effect gauge in the wet permeability test. All the tested samples are static for 24 hours in the standard environment, and the test conditions are as follows: The temperature is (20 ± 2) °C and the relative humidity is (65 ± 2)%. The comfortability design of fabric and structure is studied by the comprehensive evaluation obtained by Grey System Theory.

3. Analysis of Functional Requirements

With the decline of physiological function of elderly women, the somatotype characteristics of elderly women have changed greatly. The skin of elderly women is thin and crisp, thus some skin problems happen such as skin laxity, wrinkling, dry and desquamation and so on. At the same time, the ability of their body temperature regulation becomes worse, the sweating function of body surface is weakened, and the ability of skin to lock water and moisturize is decreased, all of which lead to the decrease of skin defense ability to the outside world, and may cause skin pruritus and other skin diseases. More seriously, the sensitivity of elderly women in vision, touch, and especially cold, hot, pain and other irritating reactions decreases, and the flexibility of their body becomes worse, which put forward higher requirements for the fabric selection and structure design of heart rate monitoring vest of elderly women.

With the increase of age, the height of elderly women gradually becomes shorter, while the circumference of their body increases significantly. The body shape of elderly women is mainly on the heavy side (type B) [3], which refers to the body size of women with thoracolumbar difference between 9 cm and 13 cm in GB/T 1335.2–2008 Size Designation of Clothes—Women. The external manifestations of morphological changes are as follows: Their breast atrophies and droops, bust point moves downward and even vertically points to the ground, fat of their anterior axillary line and waist abdomen accumulates, neck forward tilts with round back and hump shoulder, etc. In view of garment plate making, the upper body pattern of elderly women is as follows: The width of front chest becomes smaller while the width of back chest increases, the length of front waist shortens while the length of back waist increases, and the armhole line decreases, etc. According to Qi Qian, the basic morphological changes of chest in elderly women are as shown in figure 1: The transverse diameter of breast (IJ) is the largest, and the width of breast position (HI) and breast spacing (BP1BP2) also show an increasing trend; the mastoid volume L becomes smaller, and the distance from front neck point to bust point (BP1D), shoulder midpoint to bust point (BP1A), side neck point to bust point (BP1C) are larger; the bust top (EG) is the smallest, the lower cup arc length (BP1F) and breast depth K are relatively small, etc. [4] Based on the skin characteristics, perceptual impairment and limb flexibility of elderly women and according to the selected heart rate monitoring system, the study designs only upper garment for most elderly women who are on the heavy side (type B) with reference to the clothing size standard.
4. Fabric Basic Property Test

In the experiment, nine kinds of fabric containing nylon and spandex which are commonly used in the heart rate monitoring clothing on the market are tested. The structure parameters of the fabric used in this experiment are shown in Table 1.

| Fabric Number | Fabric Composition | Gram Weight/g/m² | Thickness/mm |
|---------------|--------------------|------------------|--------------|
| 1#            | 86%nylon+14%spandex | 160              | 0.20         |
| 2#            | 85%nylon+15%spandex | 200              | 0.28         |
| 3#            | 84%nylon+16%spandex | 190              | 0.40         |
| 4#            | 82%nylon+18%spandex | 180              | 0.36         |
| 5#            | 63%nylon+37%spandex | 200              | 0.30         |
| 6#            | 92%nylon+8%spandex  | 160              | 0.16         |
| 7#            | 78%nylon+22%spandex | 160              | 0.25         |
| 8#            | 72%nylon+28%spandex | 230              | 0.40         |

4.1. Tensile Elasticity

The experiment tests the elongation percentage of the fabric in warp and weft direction under 15N tension. The test results are shown in Table 2. From Table 2, it can be seen that fabric 8 and 5 have the maximum elongation percentage and the best tensile property at a constant force. The elongation percentage of fabric 4 in warp direction is obviously greater than that in weft direction, while fabric 8 is on the contrary, which can be used according to their characteristics. The elongation percentage in warp direction under 15N tension ranks 4>3>5>8>7>2>1>6 in descending order, while in weft direction 8>5>2>4>1>7>6>3.

| Fabric Number | Elongation Percentage under 15N Tension/% |
|---------------|------------------------------------------|
|               | Warp Direction                           | Weft Direction |
| 1#            | 66.7                                     | 90.9           |
| 2#            | 88.9                                     | 121.5          |
| 3#            | 109.4                                    | 68.8           |
| 4#            | 141.3                                    | 95.4           |
| 5#            | 106.2                                    | 122.2          |
| 6#            | 64.1                                     | 87.3           |
| 7#            | 103.0                                    | 89.0           |
4.2. **Air Permeability**

Test results of air permeability are shown in Figure 2, from which it can be seen that the air permeability of different fabrics ranks 4>3>1>6>8>7>5>2 in descending order.

![Fig.2 Test Results of Air Permeability](image)

4.3. **Moisture Absorption**

The moisture regain test results are shown in Figure 3, from which it can be concluded that the moisture regain of fabric 6 is the largest and thus its moisture absorption is the best, while fabric 5 has the lowest moisture regain and the worst moisture absorption property. The descending order of the tested fabrics in view of moisture regain is 6>4>3>1>7>8>2>5.

![Fig.3 Test Results of Moisture Regain](image)

4.4. **Wet Permeability**

The test results of the wicking height in warp and weft direction are shown in Figure 4. As shown in Figure 4, except fabric 2 and 3, the wicking height in weft direction is higher than that in warp direction. The overall wicking height of fabric 6 is the largest so that the wet permeability of it is the best. The wicking heights of fabric 1 and 2 are similar and so do their wet permeability. Fabric 5, 7 and 4 have the lowest wicking height and the worst wet permeability. In addition, the wicking height of all other fabrics increase steadily except fabric 8. At 30min, the descending order of the wicking height in warp direction is 2 > 3 = 6 > 1 > 8 > 5 > 7 > 4, while in weft direction 1=6>8>2>3>5>7>4.
4.5. Overall Evaluation

Properties of the eight fabrics containing nylon and spandex are evaluated by use of grey system theory. The results are as follows:

| Fabric Number | Tensile Elasticity (%) | Air Permeability (mm/s) | Moisture Regain (%) | Wicking Height (mm) |
|---------------|------------------------|-------------------------|---------------------|-------------------|
| 1#            | 90.9                   | 65.09                   | 5.56                | 149               |
| 2#            | 121.5                  | 12.70                   | 4.78                | 158               |
| 3#            | 109.4                  | 77.79                   | 5.59                | 126               |
| 4#            | 140.3                  | 100.80                  | 5.60                | 9                 |
| 5#            | 122.2                  | 17.91                   | 4.46                | 43                |
| 6#            | 87.3                   | 41.03                   | 5.80                | 149               |
| 7#            | 103                    | 21.94                   | 5.19                | 18                |
| 8#            | 146.3                  | 31.64                   | 4.87                | 146               |

A cluster matrix can be concluded by use of MATLAB programming.

$$\begin{bmatrix}
0.6088 & 0.2979 & 0.5 \\
0.5572 & 0.4365 & 0.5931 \\
0.6974 & 0.4885 & 0.4833 \\
0.6066 & 0.4292 & 0.5171 \\
0.3466 & 0.4852 & 0.8944 \\
0.5659 & 0.1778 & 0.5 \\
0.3479 & 0.3921 & 0.8156 \\
0.6811 & 0.4304 & 0.4156 \\
\end{bmatrix}$$

The eight lines of the matrix represent the clustering results of eight kinds of fabrics. It can be seen that the comprehensive evaluation of the wearability of the 8 kinds of fabrics is all of middle grade, and the descending order is 3> 8> 1> 4> 1> 4> 6> 2> 7> 5. The comprehensive evaluation of the third fabric is better, and its tensile property in weft direction is the worst. The comprehensive evaluation of the eighth is well but its moisture absorption property is poor. With a meshwork structure, the first fabric has good thermo-wet comfort property but poor tensile property. The fourth fabric has excellent tensile elasticity, air permeability and moisture absorption, but its wet permeability is the worst. The sixth fabric has the best wet permeability but the worst tensile elasticity. The wet permeability of the second fabric is the best, but its air permeability and moisture absorption properties are poor. The worse comprehensive evaluation belongs to the seventh fabric. The fifth fabric has good tensile property but poor thermo-wet comfort property. To sum up, in practice it is difficult to create a kind of
fabric that performs excellent in all aspects\cite{5}, but fabric partition design for various areas can be achieved according to the characteristics of different fabrics.

5. Fabric Partition Design

With reference to the style and structure of the women’s intelligent sports vest sold on the market, the study designs a type of intelligent heart rate monitoring vest with bralette for elderly women as shown in Figure 5.

![Fig.5 Design Drawing for Structure Optimization of Intelligent Heart Rate Monitoring Vest](image)

In Figure 5, area 1 forms a new segmentation method by combining wide shoulder strap with higher side panel at the midpoint of clavicle to disperse shoulder pressure and enhance stability while covering anterior axillary line fat to avoid discomfort caused by extrusion. Area 2 applies interlacing design to increase lateral support to provide restraint for loose skin of elderly women and apportion part of chest droop. The outline of the center front in area 3 is an outer arc, which accords with the morphological change of the width of breast position of the elderly female human body, and reduces the sense of compression. Generally speaking, the higher the center front is, the better stability of the vest has, and the narrower, the better agglomeration effect.\cite{6} As the demand for breast aggregation and shaping of elderly women reduces,\cite{7} the width of center front should not be too narrow in this design. Area 4 and 5 are the lower cup area, adopting multi-slice segmentation in four directions to fit the body more, in which the T shape of the lower half of the cup (area 5) provides support force and upward thrust for the breast droop, while the upper part of the cup (area 4) becomes a separate surface directed towards the small mastoid volume and the flat drooping shape of the breast, which helps the lower half to raise and stabilize the drooping breast. Area 6 is the main functional area with fabric electrode fixed on the left and right sides under the cup, and the microprocessor is connected by buckle in the middle. In order to prevent breast sloshing and displacement from affecting fabric electrode signal acquisition, the bottom circumference can be widened, and the upper end of the bottom circumference can be fully adapted to the human body in order to reduce unnecessary interference. Area 7 and 14 are designed to increase friction so as to improve stability. The middle triangle segmentation of area 7 is helpful to alleviate the center pressure of the bottom circumference (area 6) to improve comfortability.

In view of the characteristics of the round, wide and sunken back of the elderly women, area 8 adopts an anti-skid X-shaped back modeling design, which is connected by circular cutting pieces in area 9 to disperse the pressure of the central part and fit the bow shape of the back. The outer arc outline design of area 10 provides active space for the hunchback protruding position. Area 11 and 12 are designed to conform to the muscle texture of U-shaped back panel to increase the stability, which is beneficial to the stretching movement in low intensity of the elderly women. Area 1 and 13 have buckles in the front side and shoulder, convenient for the elderly women to wear and take off flexibly according to their own condition.

Combined with the characteristics of the tested fabrics, fabric 8 is selected as the main fabric of the vest. The comprehensive evaluation of fabric 8 is excellent, especially its tensile property, so it is suitable for the moisture permeable area (area 1, 3 and 10) and the hump area (area 8, 9). As the elderly women mainly do low intensive exercise and their skin should not be too dry or too wet, the
ability of moisture absorption and perspiration can be improved by using fabric 8 in area 1, 3 and 10, and the posture needs of elderly women with round shoulder and hunchback can be satisfied to improve the stability of clothing structure by using fabric 8 in area 8. 9. Fabric 3 is a spliced fabric, and has better comprehensive wearability and better tensile property in warp direction. Area 2 and 4 need strong longitudinal tension, so fabric 3 is suitable for them. In addition, high elastic rubber bands are used in areas 6, 7, 12 and 14 to enhance stability and friction.

6. Conclusion
Based on the changing parameters of physiological function and physical characteristics of elderly women, the wearability of eight kinds of fabrics containing nylon and spandex commonly used in heart rate monitoring clothing are tested in this study. According to the wearability properties of the fabrics, the fabric layout and structure of the heart rate monitoring vest of the elderly women are designed to realize the best suitability and practicability in order to meet the wearing needs of elderly women and make up for the consumer limitation of the heart rate monitoring clothing on the market, so as to provide a reference for the clothing production of enterprises. However, the deficiency of the study is that the antibacterial properties and treatment technology of the fabrics have not been studied. In the later research, the comprehensive consideration of the structure and fabric improvement design will be focused on in order to achieve the application of industrialization.

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Author: Wang Shi (1981-), female, associate professor, master, mainly engaged in the research of molding knitted garments
Xu Zhi (1997-), female, design science, master

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