Evaluation of the comfort of sportswear

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Abstract: Sportswear comfort is a very important content in the evaluation of sportswear design and development. By reading relevant research literature at home and abroad, it is concluded that the commonly used evaluation methods in the study of sportswear comfort are subjective feeling evaluation method, objective evaluation method and subjective and objective comprehensive evaluation method, etc., and the implementation requirements, advantages and disadvantages of different evaluation methods are analyzed. Research shows that the actual performance of sportswear in survey research, is usually subjective feelings and objective evaluation method is used in combination, in the experimental study on the design to improve targeting, as far as possible to improve the effectiveness of the test results, comprehensive analysis of the different test results at the same time, to achieve a comprehensive, scientific, appropriate and accurate evaluation conclusion.

1. The introduction
With the continuous improvement of people's living standards and the development of sports, the public has put forward more urgent demands for the health, environmental protection and fashion of clothing. Mass sports have become a very important way of life and entertainment in daily life. Sportswear is no longer just for athletes on the field. Sportswear is no longer just for athletic competition. However, it has realized the constant combination and innovation with daily clothing, and made sportswear tends to be fashionable and popular, thus building its own independent clothing system. In order to perfect the system of sportswear, it is necessary to evaluate the ergonomic test on the comfort of sportswear.

At present, the commonly used clothing ergonomic evaluation methods in the study of sports clothing comfort are mainly subjective feeling evaluation method, objective evaluation method and subjective and objective comprehensive evaluation method. In fact, no matter which kind of evaluation methods have their own advantages and disadvantages, we should choose dialectically.

2. Subjective perception evaluation method

2.1. Evaluation contents and indicators
The subjective evaluation of the comfort of sportswear refers to the evaluation of the comfort of sportswear made by the subjects according to their own psychological feelings. The contents and indicators of subjective evaluation refer to the terms used to describe subjective feelings. Clothing comfort is not only determined by the physical indicators of clothing style and clothing material, but also affected by many psychological factors, which also affect the wearer's feelings and work efficiency. There are many expressions for the subjective feeling of comfort in sportswear, such as: the heat and warmth, humidity, muggy feeling, cool feeling, sticky feeling, sweat flow feeling, non-absorption of sweat, smoothness, etc., as shown in the following table.

Table 1. The subjective feeling evaluation index table of clothing ergonomics
2.2. Evaluation Method

The common methods of subjective evaluation are psychological scale method and comparative sorting method.

2.2.1. Psychological scale method

Psychological scale method uses specific numerical values to quantify the subjective comfort degree. In repeated tests, the comfort degree of clothing is directly judged by the comparison of numerical values. It is usually tested in the form of subjective questionnaire. Psychological scale method can be divided into coefficient method and free coefficient method.

Coefficient method refers to a given subject to be evaluated on the basis of an established reference standard, usually with the odd number as the majority, and the commonly used three levels, five levels, seven levels and nine levels are given as the reference standard.

The free coefficient method means that without a mandatory standard, subjects can give an appropriate value or certain evaluation on the exercise comfort of the clothes they wear according to their subjective feelings. However, this evaluation method requires relatively high requirements on subjects, and the formal test can only be conducted after the calibration test.

The common seven levels of sensation are represented by 3→2→1→0→-1→-2→-3. The value 0 is the middle value, and the values on the left and right sides represent two opposite feelings. For example, the following table, the person's cold and warm feeling level seven intensity description table.

| Level | Hot | Warm | A little warm | Neutral | A little cold | Cool | Cold |
|-------|-----|------|---------------|---------|---------------|------|------|
| 3     |     |      |               |         |               |      |      |
| 2     |     |      |               |         |               |      |      |
| 1     |     |      |               |         |               |      |      |
| 0     |     |      |               |         |               |      |      |
| -1    |     |      |               |         |               |      |      |
| -2    |     |      |               |         |               |      |      |
| -3    |     |      |               |         |               |      |      |

Table 2. The intensity of the cold and warm feeling

There are two ways to describe the five levels of sensation. One is the same as the classification theory of the seven levels of sensation, but the number of levels is reduced. It is represented by 2→1→0→-1→-2. The other is specific to a certain level, such as cold feeling 1→2→3→4→5, where 1 means no cold feeling at all and 5 means unbearable cold feeling. Table 3 description of the five levels of cold sensation.

| Level | 1 | 2 | 3 | 4 | 5 |
|-------|---|---|---|---|---|
| Feeling | There is no feeling of cold at all | A little cold | Cool | Cold | An unbearable cold |

Table 3. Cold sensation five levels of intensity description

2.2.2. Comparative sorting method.

Comparing sorting method to evaluate the sportswear pairwise comparison, to dress comfortable good 1 point, clothing comfort 0 poor, all clothing after comparing two according to the order from big to small, the dress with the highest number of points can be concluded that movement comfort the best and lowest scoring dress comfort is the worst.
The comparison sorting method is intuitive and can reduce the impact of human differences on the test results, with low cost and high repeatability. However, this method can only carry out comparison sorting and cannot quantitatively evaluate the comfort degree of clothing.

3. **Objective evaluation method**

Objective evaluation method belongs to quantitative analysis method, also known as physiological index measurement of human body. It usually standardizes the working environment and conditions, and then evaluates the sports comfort of sportswear by measuring direct or indirect quantitative indexes. The objective evaluation method needs to be carried out in the laboratory environment, which can be subdivided into physical evaluation method and physiological evaluation method according to the different properties of evaluation indexes.

The physical evaluation method mainly measures the changes presented by the dressed human body or the sportswear itself in the physical space of its movement, such as the range and Angle of the human joint movement, the human activity efficiency bound by the sportswear, the pressure generated by the sportswear in the process of human activity, and the deformation characteristics of the sportswear during exercise. Physiological evaluation method is to measure the changes of a series of physiological indicators (such as human body temperature, heart rate, sweat volume, blood flow, oxygen consumption, blood lactate concentration, brain wave, etc.) caused by the restriction of sportswear during exercise.

3.1 **Thermal and wet comfort test**

The testing instruments for thermal comfort of clothing are mainly warming-body dummies, which can be divided into three types: constant temperature dummies, variable temperature dummies and sweating dummies. Constant temperature dummies and variable temperature dummies can be used to measure the thermal resistance of sportswear. The sweaty dummy was used to evaluate the thermal and humidity performance of the sportswear by using the dummy simulation method. The method has good repeatability and can exclude the influence of psychological and physiological factors. The main evaluation indexes are moisture permeability index and moisture resistance. Currently in clothing thermal comfort evaluation, representative is one of the world's first USES the water cycle and high strength "can breathe fabrics made of sweat" dummy "Walter", it consists of the Hong Kong polytechnic university professor jin-tu fan research and development, can be used to simulate the temperature distribution of the body and the body's latent sweat, can also be by changing the different permeability of skin to adjust sweating rate. The Walter can simultaneously measure dry heat transfer, evaporation heat, thermal resistance and moisture resistance. In addition, the limbs can simulate human walking activities.

3.2 **Body core temperature**

Human body temperature is a common physiological index to measure the comfort and physiological load of sportswear. The physiological term "body temperature" refers to the core temperature, which is the average temperature deep in the body. Because the metabolic level of each organ inside the body is different, their temperature is also slightly different, but because blood circulates ceaselessly along the body, often make the temperature of each organ inside the body tends to be consistent. Therefore, the blood temperature inside the body can represent the average temperature of the vital organs inside the body, namely the body core temperature.
Table 4. The meaning of eight physiological indexes

| Name of the temperature | Method of measurement | Represented body part |
|-------------------------|-----------------------|-----------------------|
| Oral temperature        | Place the temperature sensor at the sublingual branch of the deep artery | Affect the temperature regulation of the central blood temperature |
| The temperature of the esophagus | Place the temperature sensor 5-7cm in the lower middle part of the esophagus | The anterior wall of the left atrium and the inferior aorta |
| Intraperitoneal temperature | Swallow the warm capsule sensor | The wall of the great artery or a locally metabolized organ or abdominal wall |
| The rectal temperature | The temperature sensor is inserted 6cm above the rectum | Deep blood temperature |
| Periosteal temperature | Position the temperature sensor as close to the eardrum as possible | Brain tissue temperature |
| Listen to the Temperature | Place the temperature sensor on the auditory canal wall near the eardrum | The blood temperature of the heart arteries and the skin around the ears and near the head |
| Urine temperature | Determine the temperature of fresh urine output | Bladder |
| The axillary temperature | Place the temperature sensor under your armpit | Your armpit |

Strictly speaking, the temperature of the body core should be measured to measure the temperature of the blood inside the body. In practical operation, the temperature of the blood is more troublesome. The temperature of the body core can be expressed by measuring the temperature of the 8 parts of the body, because the temperature of the 8 parts of the body is closest to the temperature of the body core. The above table can indicate that the measurement of different parts represents the body part of the body core temperature.

3.3 Skin temperature

Skin temperature is the temperature of the most superficial layer of the human body. Because of the differences in skin fat thickness, muscle strength, blood flow supply, and skin surface geometry, skin temperature varies greatly among different parts of the body. Skin temperature, on the one hand, to human body thermal intensity, on the other hand can to investigate the relationship between the human body through the heat exchange between clothing and the environment, also said that skin temperature can reflect the body to the surface, the heat flow between the surface of the skin can also be reflected in a track state of dynamic balance between the heat or heat.

The way of measuring skin temperature can be divided into contact and non-contact. The non-contact measurement method, as the name implies, does not touch the subject. The infrared radiation sensor is used to keep a certain distance from the subject to measure the skin temperature at a certain point on the body. Another method is to fix a temperature sensor to the skin surface to measure the temperature of the skin surface.

3.4 Cardiopulmonary function test

By monitoring the human respiratory rate, oxygen uptake, exhalation, relative oxygen uptake, metabolic equivalent, tidal volume, ventilation per minute and other cardiopulmonary function data, the energy
metabolism of the human body can be assessed, and the comprehensive heat exposure degree and activity intensity of the human body can be roughly described. The oxygen consumption and other physiological indexes of human body during exercise, the specific meaning of each physiological index is shown in the chart.

| The index name             | abbreviation | unit       | define                                          |
|----------------------------|--------------|------------|------------------------------------------------|
| Oxygen consumption         | vCO2         | L/min      | Oxygen intake per minute                        |
| Breathing rate             | RF           | L/min      | Breaths per minute                             |
| Tidal volume               | VT           | L          | The amount of air that is breathed in or out each time |
| Ventilation per minute     | VE           | L/min      | The amount of gas exchanged per minute while breathing |
| Respiratory quotient       | RQ           | ——         | The ratio of carbon dioxide exhalation to intake |
| Oxygen equivalent          | VE/VO2       | ——         | The ratio of ventilation to oxygen uptake per minute |
| Carbon dioxide equivalent  | VE/VCO2      | ——         | The ratio of the amount of air per minute to the amount of CO2 exhaled |
| Relative oxygen uptake     | VO2/ kg      | mL/min/kg  | Oxygen uptake per kilogram of body weight per minute |
| Metabolic equivalent       | METS         | ——         | A multiple of the metabolic rate during exercise to that at rest |

It can be seen from the chart that there is a close relationship between each physiological index, wherein respiration quotient, also known as respiration exchange rate, is the ratio of the amount produced by the oxidation of various nutrients in the body to the consumption at the same time, expressed by the formula: RQ = VCO2/VO2; Ventilation per minute is the product of tidal volume and respiratory rate, expressed by the formula: VE = VT/RF; 1 Metabolic equivalent is equivalent to VO2 × 3.5mL/(min.kg), etc. Therefore, VCO2, VO2, VT and RF are the basis of these 10 physiological indicators, and other indicators can be converted from these four data.

3.5 Skin stretch rate
In the process of exercise, the skin on the surface of the human body will flex and deform. If the tight sportswear cannot change with the wearer's skin, it will have a sense of pressure on the corresponding body parts, which will affect the human sports comfort after wearing. Human body skin stretching rate with symbol ΔL said that calculation formula is: ΔL = (LM - L0)/L0 x100%, including LM said skin elongation after exercise; L0 represents the amount of skin elongation before exercise. Current research shows that human skin shape variables vary greatly and are complex. Different parts of the body have different skin shape variables, and different types of movement have different movement dynamics and movements, thus producing different skin shape variables. The sportswear designed based on skin shape variable should be designed and developed in accordance with the tensile properties of fabrics.

3.6 Clothing pressure
Clothing pressure refers to the pressure caused by the shape, size, weight and other factors of clothing on the human body after dressing. In other words, the skin elongation caused by exercise after wearing clothes requires the elastic elongation of clothing fabric to compensate. This kind of stretching force produces partial force to restrain the human body in the direction, and the vertical load formed by the clothing weight makes the human body feel a sense of oppression and restraint, which is called clothing pressure. Clothing pressure can be divided into static clothing pressure and dynamic clothing pressure.
Objective measurement methods of clothing pressure include direct measurement and indirect measurement. Direct measurement method needs to use clothing pressure measuring device to directly measure the clothing pressure value. Direct measurement is easy to operate, simple and intuitive, but it is easily affected by external factors. Indirect measurement methods include arch compression method (complex model method), soft dummy method and theoretical calculation method. In the study of clothing pressure comfort, the direct measurement method and the indirect measurement method should be combined to provide more effective research methods and more accurate and reliable experimental data for the study of clothing pressure comfort.

4. Conclusion
From the perspective of clothing ergonomics, sports comfort is a comprehensive balance among environment, clothing and human body, which can meet the physiological and psychological needs of human body. Because there are a lot of evaluation index of sports clothes and sports work efficiency, the evaluation of oneness is one-sided, should optimize the evaluation index, determining the reasonable scale, through the precise measurement of the objective instruments, make the subjective and objective complement each other, mutual combination, establish a subjective and objective comprehensive evaluation scheme, form a comprehensive evaluation of sports clothes and sports efficiency of scientific evaluation method.

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