# Design of the “Hygroscopic Clothing” in Medical Protective Clothing

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**Abstract**

To solve the current lack of thermal and humidity comfort in medical protective clothing for workers in high-risk environments, this paper seeks to adopt moisture-absorbing materials in the design of work clothes for medical staff, thus presenting an innovative design framework for hygroscopic workwear. This paper uses hospital staff in high-risk environment, such as nurses who operate within hospital hot zones and community service personnel, as research subjects. Their activities were recorded and subsequently analyzed Then, the MET values of these actions were discovered and listed. After calculation, the average medium-high-intensity work MET value was ≈5.8, and the medium-low-intensity MET value was ≈2.8, with the corresponding speed of 6.3 km/h and 2.8 km/h, respectively. These two speeds were the references for human motion experiments.

In the human motion experiment, the objects wore medical protective clothing, the ambient temperature was set to 26-28 °n, and the motion status was determined to be 2.8 km/h: 5 min-6.3 km/h: 25 min-2.8 km/h: 10 min. The filtering paper method was employed to measure the regional body sweat. Then, the regional body sweat map was obtained. According to the results, the structural scheme for hygroscopic workwear was proposed to further promote the research process of the hygroscopic workwear.

In the human body wearing verification experiment, the experimental group was the subjects wearing hygroscopic clothes, and the control group was the subjects wearing pure cotton clothing. In the process of exercise, the hygroscopic performance of the work clothes was compared by the changes of internal environment humidity and the feelings of subjects. Through data analysis, compared with pure cotton upper and lower garment, the hygroscopic work clothes can effectively maintain the comfortable balance of internal environment humidity.

*Keywords*: Thermal and Humidity Comfort; Clothing Structure; Medical Protective Clothing; Work Intensity; Sweating Amounts

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# 1 Introduction

## 1.1 The Status of Medical Protective Clothing

In 2019-2020, because of COVID-19 pandemic, the medical staff, safety patrol personnel and volunteers, who were required by occupation to interact with potential patients constantly, were at high risk of infection. At the same time, due to the particularity of COVID-19, its infectivity was strong and its propagation speed was fast, which seriously endangered their safety. Medical protective clothing can protect the wearers from germs and viruses, by effectively isolating the wears from dangerous environments and protect their health.

However, although the medical protective clothes protect the safety of staff, they are poor in comfort, difficult to wear, poor recognition, and present low physiological adaptability. As the protective clothing functions as a barrier against liquid and gas, the heat and water vapor inside the protective clothing cannot be discharged, causing the wearers to become deeply uncomfortable. After several hours of high-intensity work, the whole body would have been soaked inswept, rendering it impossible to do high-intensity works for a long time when wearing medical protective clothing [1]. Li Qian [2] and others used surveyed frontline medical staff as the research subjects, and analyzed how their comfort relates to their temperature and humidity within the clothing. The results showed that when the protective clothes were worn for 4-8 h, 55.8% of the users thought that the air and humidity permeability was average, and 43.5% of the users thought that the air and humidity permeability was poor. Medical staff think that the main problem of low work efficiency is due to the poor moisture control. Therefore, for the sake of comfort, it is necessary to develop medical protective clothing with improvements in thermal and humidity control.

At the same time, as the types of medical protective clothing users and their work sites increase, it produces separate factor due to different working hours and safety risks. This context has thus exacerbated the inherent design defects of medical protective clothing with a lack of standardized design that can effectively accommodate everyone's needs. Hou Yu [3] tries to improve the existing disposable medical protective clothing. By considering the general requirements of medical staff based on factors of: comfort, convenience, and protective functions. Yu proposes that the new type of medical protective clothing can be designed with two sets of fabrics: which are internal-using cloths and external-using cloths.

## 1.2 The Status of Relative value of perspiration

Zhang Wei yuan [4] once explored the distribution of local perspiration of human body. The conclusion shows that the relative amount of sweating of the neck, trunk, forehead and back of hand is more; The relative amount of sweating in arms, legs and other limbs is less. In addition, he explored the relative value of local sweating of the human body, as shown in Table 1.

Through experiments, Verde t [5] concluded that the amount and state of sweating in various parts of the human body are symmetrically distributed, and the axis of symmetry is the central axis of the human body. At present, the commonly used experimental methods to measure the amount of local sweat are: filter paper method, ventilated sweat bag collection method, ethylene bag method, sweat absorbing patch collection method and so on. Zhang Shuo [6] and others used the filter paper method to measure the sweating volume of the sweat concentration part when

Table 1: Relative value of perspiration in various parts of human body

| Body parts | Relative value of perspiration |
|---|---|
| head | 12.8-12.9 |
| chest | 14.6-15.0 |
| back | 9.9-10.2 |
| abdomen | 13.6-13.9 |
| waist | 12.2-12.6 |
| upper arm | 4.1-4.5 |
| forearm | 4.0-4.3 |
| hand | 4.5-5.0 |
| thigh | 4.2-15.6 |
| shin | 4.5-4.9 |
| foot | 3.6-3.9 |

studying the sweating volume and health status of young athletes after regularly supplementing sports drinks in the specified sports state.

## 1.3 The Status of High Intensity Workers

During the beginning and midst of the COVID outbreak, the inpatient nursing department and the inspection department were the departments whose staff had high probability of direct contact with the virus. According to the risk level, nurses in charge of the hospitalization of new patients were generally divided into three categories: green area nurses, yellow nurses and red area nurses. The red area nurses were mainly in charge of the arrangement of discharges, ward checks, treatments, basic nursing, vital signs measurements and other work. Among the nurses, red area nurses are mostly likely to be in direct frequent contacts' with new crown patient, and are the most likely to be infected by virus spray. Generally, they require the most protection, but are also required to take on the most intense workloads and require very strong physical and psychological qualities [7][8].

According to the New Coronavirus pneumonia diagnosis and treatment plan (trial version 8) [9], doctors and nurses need to give different degrees of treatment for COVID patients, including antiviral therapy, immunotherapy, hormone therapy, etc. most of them are clinical treatment methods: injection and drip. ICU emergency rescue takes a long time, high intensity nursing work, which is generally completed by doctors. The working cycle is $4 \sim 6$ h, and one round of rest.

Liu Suzhen [10] pointed out that the community prevention and control personnel (such as community medical personnel, neighborhood committees and village committee staff, police, property management personnel), who are infected with the pneumonia prevention and control network of New Coronavirus, undertake community fever clinic screening, follow-up, referral, traffic road point screening, door-to-door registration, and investigation.

Community volunteers also play an important role in community service. From the "community volunteer service action guide", we can see that they have certain physical labor services: help to buy materials, transport support materials, and deliver goods needed for daily life.

In the article "Analysis of joint prevention and control mechanism in the capital metropolitan area" [11], it pointed out that in the early stage of the outbreak, nucleic acid samples were collected on a large scale in high-risk areas with communities as the unit.

Novel coronavirus pneumonia joint control mechanisms at Beijing airport port [12] pointed out that the initial working mode of joint prevention and control mechanism has been formed in the inspection and quarantine of entry passengers. Other methods that were used include entry management, personnel diversion, information notification, identity registration, health monitoring, and emergency treatment, etc. Four flights within 24 hours, subject to flight schedule allocation. According to the time and shift, each person on duty for a single time will split their attention between 6-12 flights [13].

### 1.4 Research Direction

This paper aims to solve the problem of poor thermal and humidity comfort of medical protective clothing under high intensity labor. Through investigation of the workers in different occasions and different needs, we improved the thermal and wet properties of the internal environment of medical protective clothing. In view of the hot and wet problems in the design of medical protective clothing exposed to the epidemic, it is necessary to put forward new design ideas from the perspective of the wearer. The core of medical protective clothing design is safety, so the protection grade and parameter index are still the basis of its design. In order to improve the thermal and wet comfort of the inner environment of medical protective clothing, a functional innovative design of the work clothes is proposed in this paper. This paper aims to change the design concept based on CUBA [14] design principles, so that the clothing of protection workers should not only achieve protection, but also consider comfort, beauty and versatility in multiple occasions.

In summary, the methods in this paper include analytical the research, experiments conducted with human subjects and verification experiments.

## 2 Research Methodology

### 2.1 The Calculation Methods of Work Intensity (MET)

Through the literature survey of the 1.3 part, we identified the study subjects as well as their representative activities. The research object is the high-intensity workers, which is the high demand population of protective clothes. The research objects are the high-intensity workers in the red area, the high-intensity workers in the early and mid-term outbreak of the epidemic, the high-intensity workers such as community prevention and control workers and volunteers, and the high-intensity workers of protective security personnel (Airport as an example), who need safety protection most and whose comfort needs to be improved urgently.

The daily work content of high-intensity workers with protection needs is compartmentalized into simple repetitive work or action. The comprehensive heating degree and activity intensity of human body can be roughly measured by monitoring their cardiopulmonary function indexes, and the perspiration rate per unit area can be predicted, by drawing a positive correlation between activity intensity and perspiration volume of the human body [15].

The following table is the compartmentalization of working action taken by subsection of research subjects, and the corresponding MET values in the physical activity compendium are listed one by one.

Table 2: Working action decomposition and MET table

| Content | Specific activities | Major heading | Code | METS |
|---|---|---|---|---|
| Buy supplies Delivery of supplies | Walking: Round-trip outhouse, purposeful | Volunteers' activity | 17280 | 2.5 |
| | Stand and walk back and forth in a multi-item integrated motion | miscellaneous | 09071 | 2.5 |
| | Walking: 5.6 km/h, fast, carrying objects less than 11.3 kg | occupation | 11810 | 4.8 |
| | Weight 0.5-6.8 kg: up the stairs, down the stairs, shuttle back and forth | walking | 17026 | 5.0 |
| | Truck driving: loading and unloading trucks, bundling loads, standing, walking, and carrying heavy loads | occupation | 11766 | 6.5 |

Through the literature survey of the 1.3 part, we selected 23 representative activities, such as purchasing materials, transporting materials, guiding diversion, station temperature measurement, etc., and divided them into 144 activities, including 39 kinds of activities through the activity category table of the body activity compilation.

## 2.2 Measurement of the Regional Body Sweat Amount While Wearing Medical Protective Clothing

### 2.2.1 Preliminary Preparation of Experiments

Under regulated temperature and humidity under laboratory conditions, the experimenters worn medical protective clothing. By simulating activities of different intensity on treadmills, we used filter paper to collect the sweat from 13 parts of the subject's body. The analysis was efficiently carried out by Atlas and provides a reference for the structure and materials of the internal-using hygroscopic workwear.

In order to get close to practical conditions, 25 women with height of (165±5) cm, age of $22 \sim 35$ and weight of $50 \sim 60$ kg were selected in the experiment. In the constant temperature and humidity laboratory, the temperature is set at $(28 \pm 2)$ °m, and the relative humidity is $(40 \pm 10)\%$. The main experimental equipment used are: Keep treadmill K2, stopwatch. According to the results of the work intensity (MET), the speed and time were set as 3.8 km/h-5 minutes, 6.3 km/h-25 minutes and 3.8 km/h-10 minutes respectively. The total exercise time was 40 minutes.

It was determined that the perspiratory positions of various parts of the human body are symmetrical, that is, the s perspiration rate of the right hand and the left hand, the right thigh and the left thigh are symmetrical. In order to simplify the test process and make it operable, the left part of the body was selected for the test [16].

In this experiment, we marked the neckline, front midline, chest line, waist line, armpit line and back midline by black marking line on the bodies of objects, to divide and determine the accurate position of the tested parts. 13 different parts of the left side of the body were tested. The position of the filter paper patch is shown in the Fig. 1 and Table 3.

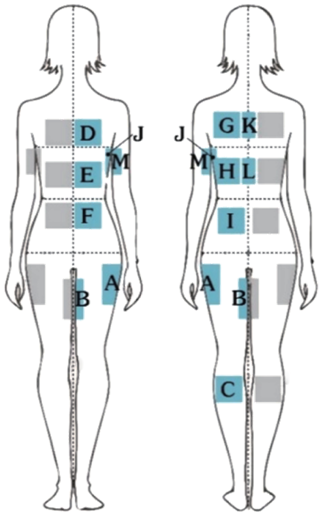


Fig. 1: Location diagram

Table 3: Positions

| CODE | MAME |
|---|---|
| A | Inner thigh |
| B | Lateral thigh |
| C | Under the leg socket |
| D | On the chest |
| E | In the belly |
| F | Intraabdominal |
| G | On the back |
| H | In the back |
| I | Under the back |
| J | Under the armpit |
| K | On the spine |
| L | Under the spine |
| M | Under the left arm |

### 2.2.2 Calculation of Sweating per unit area

The self-sealing bag was pre marked with the corresponding movement speed and the position of filter paper to differentiate against each other. Finally, put each self-sealing bag with filter paper on the electronic scale and weigh it twice. After recording the data, the average value was recorded is according to the weight M of filter paper corresponding to their respective body part before the experiment. According to the position determined in 2.2, the filter paper is pasted in the corresponding self-sealing bag, and then quickly put on the pure cotton T-shirt and medical protective clothing. After 40 minutes of exercise, the filter paper attached to each part was torn off from the skin surface one by one and put them into the corresponding self-sealing bags.

After sealing, the bag is weighed immediately. The weighing method is the same as that of filter paper weighing before exercise. The time is controlled within 3 minutes. Finally, the average value of two weighing data is obtained and recorded as N.

The perspiration rate of the human body is larger in the front and back midline, while the perspiration rate of the area on the side of the human body is smaller.[17] Considering that there must be a certain margin in the moisture absorption ability, in the area division of sweat, the higher perspiration in the area was taken as the main test subject. And the sweating area was divided according to the perspiration of the main test subject. The weight gain of filter paper before and after exercise was the sweating amount Z in this period.

$$\mathrm{Z = N - M} \tag{1}$$

And The amount of sweating per unit area Zs ($\mathrm{g} \times 10^{-2}/\mathrm{cm}^2$) was

$$\mathrm{Zs = Z/S} \tag{2}$$

## 2.3 Methodology of the Fabric Experiment

In this paper, eight kinds of knitted fabrics suitable for work clothes are selected, including plain knitted fabrics, pick hole knitted fabrics and knitted mesh fabrics.

The purpose is to select the fabrics with excellent performance as the main fabric of moisture absorbing work clothes by testing their moisture permeability. Test the moisture permeability of the selected fabric according to GB/T 12704.2-2009. The positive cup method is used to measure the moisture permeability and moisture permeability of 8 kinds of fabrics. The fabric number is as follows (Table 4).

In order to ensure the accuracy of the experimental data, before the test, take three fabric samples with a diameter of 8.5 cm, and reasonably place them in the moisture permeable cup containing water. Adjust the constant temperature and humidity test chamber and set the temperature $(38 \pm 2)\,^{\circ}\mathrm{C}$ and relative humidity $(50 \pm 2)\%$. After the test chamber is stable, put 24 moisture permeable cups into the stable test chamber for balance for 1.5 h. During the experiment, electronic balance (accuracy 0.001 g), standard disc punching knife and measuring cylinder (measuring range 50 ml) are also required.

In order to ensure the accuracy of the data, the moisture permeability of the sample shall be expressed as the average value of three samples, and the experimental data shall retain 3 significant figures. Calculate the moisture permeability WVT ($\mathrm{g/m^2/h}$) of 8 samples:

$$\mathrm{WVT = (m - m1)/(A * T)} \tag{3}$$

WVT – moisture permeability of fabric, unit: g/(M2) $\times$ h;

M – the first weighing mass of the sample, unit: G;

Table 4: Fabric information

| Fabric number | Fabric name | Weight (g/$m^2$) |
|---|---|---|
| 1# | Plain knitted fabric 1 | 243.16±3.55 |
| 2# | Plain knitted fabric 2 | 206.02±3.17 |
| 3# | Plain knitted fabric 3 | 192.36±2.52 |
| 4# | Plain knitted fabric 4 | 225.20±1.25 |
| 5# | Hole picking fabric 1 | 190.05±1.15 |
| 6# | Hole picking fabric 2 | 170.05±1.15 |
| 7# | Mesh fabric 1 | 150.05±1.05 |
| 8# | Mesh fabric 2 | 148.05±1.05 |

M1 – the second weighing mass of the sample after 2 h, unit: G;

A – sample area, 0.00283m2;

T – interval time, 2 h;

## 2.4 Hygroscopic Materials Properties

The special hygroscopic product in this garment is a composite hygroscopic material. Its liquid absorption rate (deionized water) can reach 136.45 g/g and the liquid absorption rate can reach 51.14 g/min. The lower layer of the composite absorbent material is water repellent non-woven fabric, its upper layer is wood pulp paper, and the middle layer is sodium polyacrylate. The lower layer material is bonded with the upper layer material, the sodium polyacrylate particles are embedded in the middle, and the thickness of the upper layer material and the lower layer material can be equal. Sodium polyacrylate is a strong absorbent material, which can absorb water molecules hundreds of times its own weight, and has excellent absorption capacity for artificial sweat.

The hygroscopic products also include the wood pulp paper. It has fast water absorption rate and excellent water extension ability on its surface. Therefore, it is suitable to be attached to the surface of the production sheet for rapid water absorption and water conduction, and the sodium polyacrylate in the inner layer can achieve the function of water storage.

## 2.5 Preparation of Verification Experiment

The same test subjects were wearing hygroscopic work clothes with pure cotton upper and lower clothes, and they were wearing medical protective clothing under the same experimental conditions as the perspiration experiment. The efficiency of these hygroscopic work clothes was verified by comparing the initial humidity, the turning point of humidity increase, the humidity growth rate, and the highest humidity of the internal environment humidity curve, and through the analysis and comparison of the subjective comfort of the wearer (stuffy, wet, hot, cold, itchy), benign modification suggestions to the design scheme [18].


Fig. 2: Hygroscopic material

# 3 Experimental Results and Data Analysis

## 3.1 Analysis of Sweating Amount while Wearing Medical Protective Clothing

According to the principle of metabolism counting, 4.5-9 is medium and high intensity work in professional activities or sports. From the Fig. 3 below, in the medium and high intensity areas, MET $\approx 5$ is the most frequent, and after weighted average statistical calculation, the maximum met value is about 5.8, i.e., running: 6.3 km/h (105.3 m/min). It can be seen from the Fig. 1 that in the low intensity area, met is the maximum strength of 2.5, and the maximum met value is about 2.8, namely walking (fast walking): 3.8 km/h.

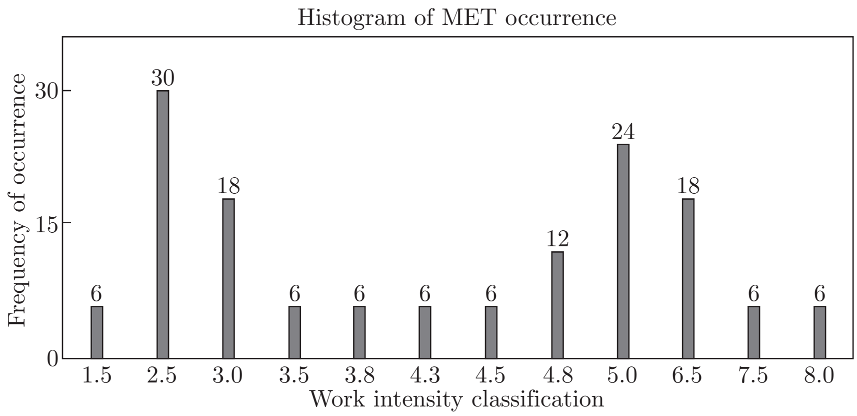


Fig. 3: Histogram of MET occurrence

## 3.2 Analysis of Sweating Amount while Wearing Medical Protective Clothing

Fig. 4 is the final data of sweating per unit area of 25 people, and the histogram of perspiration per unit area of A$\sim$M is calculated by the average method. To ensure the accuracy of the experimental data, each fabric is measured three times, and the final data is the average of the three data. Fig. 5 is the perspiration per unit area of divided areas by color according to the value. "Red" refers to areas with more sweating, "yellow" refers to areas with less perspiration.

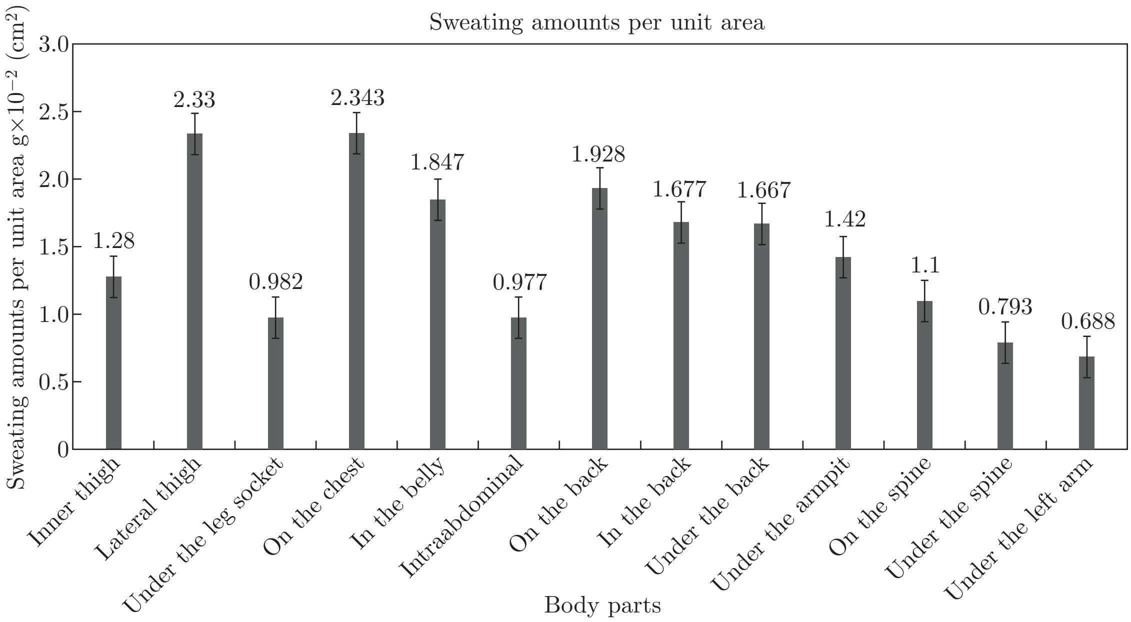


Fig. 4: Sweating amounts per unit area

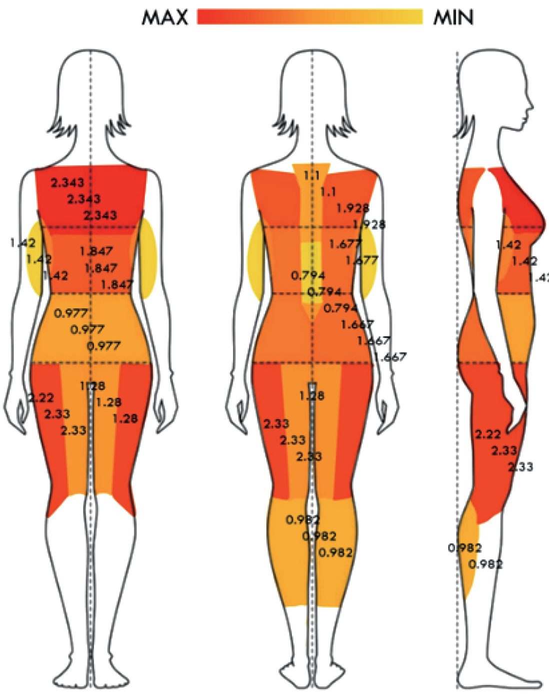


Fig. 5: Regional body sweat map

## 3.3 Analysis of Structural Design

According to the experimental data and the regional perspiratory patterns of wearing medical protective clothing, the structural design principles of the internal-using hygroscopic workwear are detailed as follows.

1) Positions of the patch pockets; more sweat absorbing material patch pockets were set in the area with more sweat (red areas); the place with large expansion and contraction of human skin surface were avoided during exercise.

2) Pattern design. Through reasonable segmentation, the work clothes were made to be as form-fitting as possible. Since the form-fitting tracksuit is convenient for wearers to work, it can also make sweat-absorbing materials play a full role simultaneously.

3) Patch pockets' shape. According to the regional sweating data, moisture absorption materials were selected, and the amount of each patch bag was scientifically controlled, to achieve efficient moisture absorption. For this purpose, the patch bags were designed as a uniform rectangle, convenient for inserting moisture absorption materials (flakes) and subsequent production.

4) Patch pockets directions. Axillary hygroscopic material (flakes) insertion direction was changed to side oblique insertion to avoid falling when performing demanding movements.

The Fig. 6 illustrates the front and back structure of the hygroscopic work clothes. The direction of the arrow indicates the direction of the material inserted into the patch pockets.

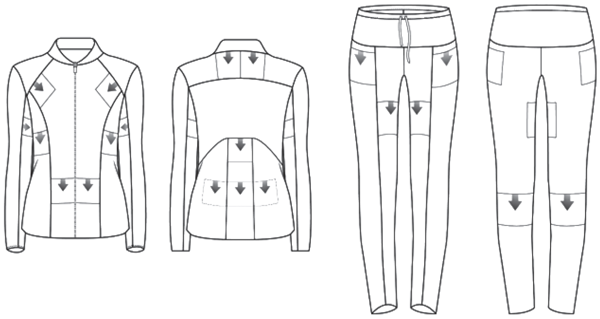

Fig. 6: The structure of internal-using hygroscopic workwear

## 3.4 Moisture Permeability Analysis of Fabric

After calculation, the test results are shown in the table:

To ensure the accuracy of the experimental data, each fabric is measured three times, and the final data is the average of the three data. The moisture permeability results of the fabric are shown in the table 5. In general, the moisture permeability is 4#> 7#> 8#> 1#> 2#> 3#> 5#> 6#, and the moisture permeability range of the fabric is 115.43-281.51 g/(m$^2$)× h). Among them, 4# and 1# have strong moisture permeability, the gram weight of 1# is heavier than 4#, so it is suitable for making the main body fabric of the garment. 4# fabric is light, thin, slightly transparent and elastic, and is suitable for splicing parts with more sweat on the skin surface; Because most of the hole fabrics are artificial cotton and are small holes with loose dispersion, the moisture permeability of the hole fabric is not excellent; The excellent moisture permeability of mesh fabric is related to its large mesh gap. The mesh of 7# is much larger than that of 8#,

Table 5: Moisture permeability of fabric(Mean+STD)

| Fabric number | Fabric name | Moisture permeability (g/($m^2$×h)) |
|---|---|---|
| 0# | Standard knitted fabric | 103.5∼190±0.67 |
| 1# | Plain knitted fabric 1 | 157.83±0.18 |
| 2# | Plain knitted fabric 2 | 146.64±0.5 |
| 3# | Plain knitted fabric 3 | 135.16±0.12 |
| 4# | Plain knitted fabric 4 | 281.51±0.2 |
| 5# | Hole picking fabric 1 | 117.79±0.6 |
| 6# | Hole picking fabric 2 | 115.43±0.17 |
| 0'# | Standard Mesh fabric | 120∼411.8±0.17 |
| 7# | Mesh fabric 1 | 276.80±0.65±0.92 |
| 8# | Mesh fabric 2 | 246.71±0.44 |

so its moisture permeability is better.

The pictures 7 below show the final designs.

Fig. 7: The final looks

## 3.5 Comparative Analysis of Relative Humidity Change Curve of Internal Environment

During the recording process of the humidity recorder, there will be a sudden increase in humidity data. This is because a small amount of sweat will occupy the tester during human movement. In order to avoid the impact of abnormal data on the curve, the curve will be corrected. In order to ensure the accuracy of the experimental data, we selected the average of three experimental data of one experimenter. After the specified movement state, the maximum humidity of the internal environment is quite different. The maximum humidity of the group wearing hygroscopic work clothes is about 68.2%, while that of the control group is 86.8%. Therefore, the hygroscopic tablets can effectively reduce humidity.

In the follow-up development and production stage, different humidity regulatory levels of hygroscopic work clothes can be analyzed. Based on the field investigation of work intensity

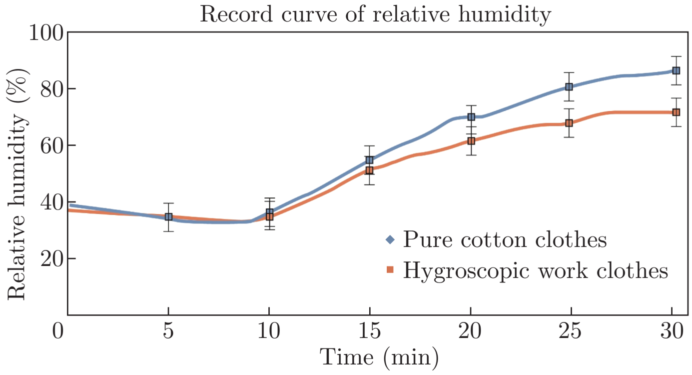


Fig. 8: Record curve of relative humidity

and the analysis of low, medium, and high work intensity as well as the extent of actions taken, personalized hygroscopic work clothes for different types of work can be developed.

### 3.6 Comparative analysis of subjective evaluation

In the subjective feeling part of this experiment, the five-level sensory rating method is used to express the subjective feeling during the exercise, that is, 1-2-3-4-5. Taking heat as an example, 1 means no heat and 5 means the strongest heat. The test indicators include: heat, cold, wet, stuffy, sticky, and itchy. Exercise timing is 40 min and recorded every 10 min. In order to get the subjective feeling of the evaluators more accurately, the representative parts with more sweating, namely chest, abdomen, waist, back, arms and legs, were selected for the experiment, and the average subjective feeling level of the six parts of the three experimenters was recorded, as shown in Figure 9.

Table 6: The statistical significance of subjective feeling level with the p value(cottern clothing-sticky)

| P value | Chest | Abdomen | Back | Waist | Arm | Leg |
|---|---|---|---|---|---|---|
| Chest | 1 | / | / | / | / | / |
| Abdomen | 0.005,2 | 1 | / | / | / | / |
| Back | 0.072 | 0.190 | 1 | / | / | / |
| Waist | 0.077 8 | 0.2 | 0.467* | 1 | / | / |
| Arm | 0.206 | 0.03 | −0.30 | 0.011,7 | 1 | / |
| Leg | 0.2 | −0.062 | 0.02 | −0.096 | −0.02 | 1 |

Note: * indicates significant correlation at 0.05 level (two sides).

Through the analysis of variance (P = 0.05), the subjective comfort of cold sense was significantly correlated, so it can not be used as a standard to compare the comfort of the clothing supervisor. (The table only shows the subjective comfort correlation analysis of thermal sensation.) With the increase of exercise time, the heat feeling grade, moisture feeling grade and stuffy feeling grade of hygroscopic overalls (experimental group) and pure cotton clothes (control group) increased first and then decreased, increased slowly in the period of 0-10 min, reached the highest in 20 min-30 min, and finally decreased. The reason is related to the state of exercise.

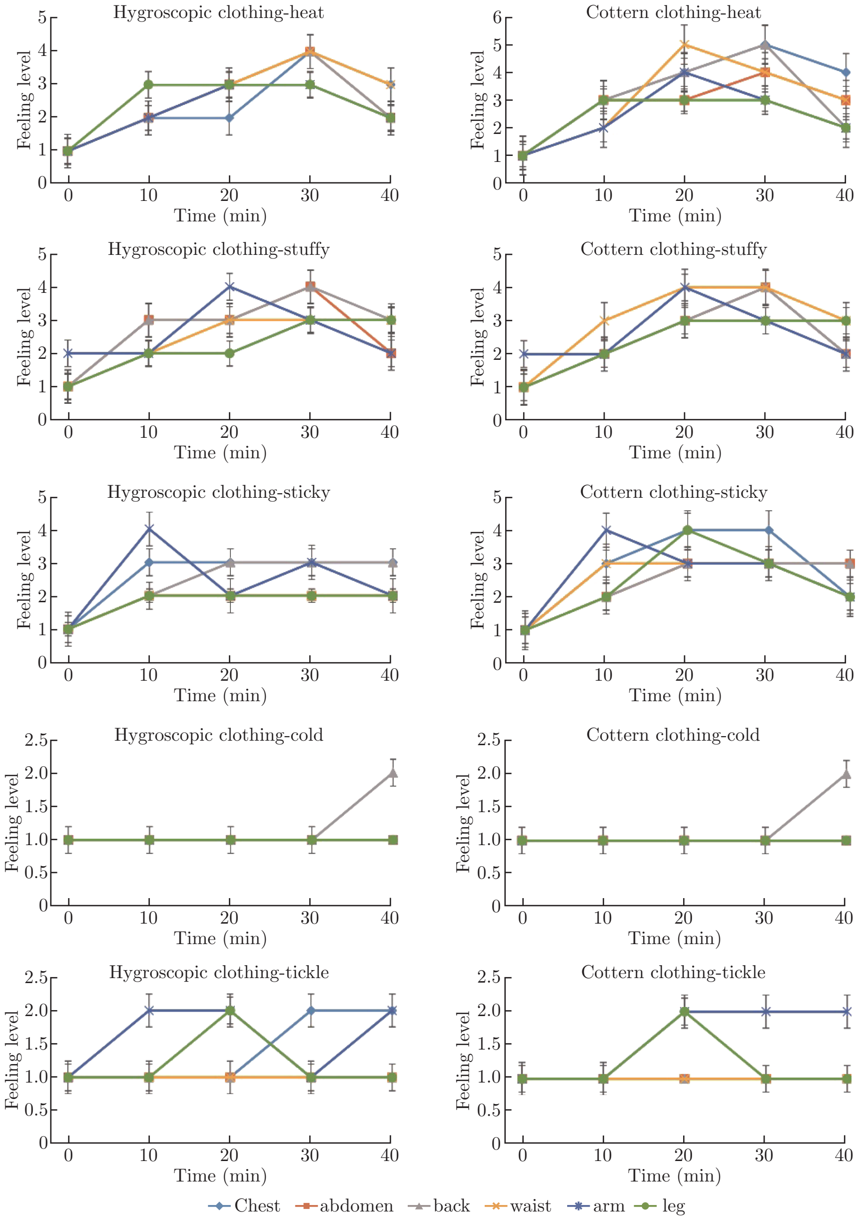


Fig. 9: The average subjective feeling level of the six parts

At the same time, the increase of sweating also takes away heat, and the heat sensation will decrease after reaching the highest point. With the decrease of exercise intensity, the amount of sweating is stable, so the feeling of tightness and humidity will decrease in a small range. For the itching feeling, the subjective feeling level fluctuates little, but the itching feeling occurs in the legs and arms of the experimental group and the control group, which may be related to the movement state of the experiment. The experimental clothes are more fit clothes. Due to the large movement range of the legs and arms during running, sweat is easy to be adsorbed on the surface of the fabric, The wet fabric surface causes a slight itching in this area.

## 3.7 Comparison analysis of subjective feeling evaluation at 20 min

At the starting point of exercise (0 min-10 min), there is little difference in subjective feeling evaluation between the experimental group and the control group. After exercise for 5 min, the exercise intensity increases. At about 10 min, the subjective feeling value of all parts has a slight upward trend, but the difference is not obvious. Through p value analysis, at 20 min, the difference of subjective feelings between the experimental group and the control group becomes larger. Therefore, the subjective feelings of 20 minutes can be used as a basis for comparing the two products.

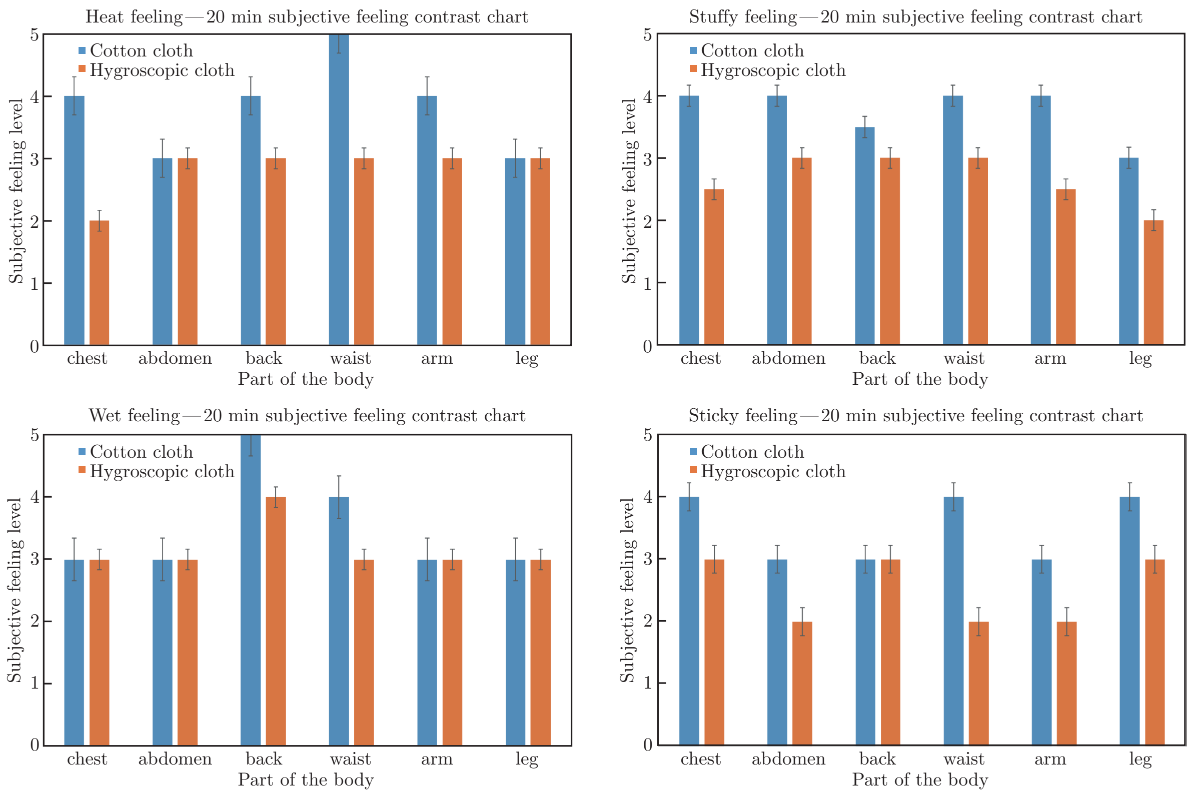


Fig. 10: Subjective feeling evaluation at 20 min

Table 7: The statistical significance of subjective feeling level with the p value (Time)

| P value | H-0 min | H-10 min | H-20 min | H-30 min | H-40 min |
|---|---|---|---|---|---|
| C-0 min | 0.907* | / | / | / | / |
| C-10 min | / | 0.602 4* | / | / | / |
| C-20 min | / | / | 0.026 | / | / |
| C-30 min | / | / | / | 0.996* | / |
| C-40 min | / | / | / | / | 0.12 |

Note: * indicates significant correlation at 0.05 level (two sides).

Because the difference between itching and cooling is small in 20 minutes, and the differences of heat, tightness, humidity, and viscosity at 20 minutes are analyzed. It can be seen from the figure that there is a gap between the four subjective feelings of heat, tightness, humidity, and viscosity at 20 min.

Among them, there are great differences in chest and waist, followed by legs and abdomen, and finally back and legs. There is little difference in subjective feeling level between the back and legs, and there is little difference in the viscosity and tightness of the back, which is also related to the setting position of the moisture absorbing sheet of the moisture absorbing overalls in the experimental group. Due to the strong tensile property of the back skin surface during human movement, the moisture absorbing sheet position is not set at the shoulder blade position, but light and thin breathable elastic knitted fabrics are spliced. Therefore, the back has no moisture absorption function design, but the light and breathable fabric is also conducive to the evaporation and diffusion of sweat, which reduces the heat and humidity to a certain extent. Therefore, compared with the control group, the heat and humidity levels are lower. For the legs, the experimental group only improved the viscosity, which also shows that the hygroscopic film also alleviates the phenomenon of sweat adhering to the skin, which is drier than pure cotton clothing (control group).

# 4 Conclusion

1) Workers operating in high-risk environments, such as nurses and community service personnel in the red area of the hospital, that require protective wear were selected as the research subject. Their work movements were compartmentalized and subsequently analyzed, corresponding to the types of activities in the physical experiments. The MET values were listed and analyzed. The average value for medium and high work intensity (MET) was $\approx 5.8$, the medium and low intensity (MET) was $\approx 2.8$, and the corresponding running speeds were 6.3 km/h and 2.8 km/h. These results can provide a reference for the motion status in the experiment.

2) In the experiment that measures the regional perspiration of the human body while wearing medical protective clothing, the amount of perspiration per unit area of 13 parts (including the inner thigh, the outer thigh, the lower leg socket, the upper chest, the middle abdomen, the lower abdomen, the upper back, the middle back, the lower back, the lower armpit, the upper spine, the lower spine, and the lower left arm) were calculated based on the experiment data. The perspiration map demonstrated that the chest, abdomen, thigh lateral, and back presented larger concentrations of perspiration.

3) In the human body wearing experiment, by analyzing and comparing the data of the wearer's subjective comfort (tightness, humidity, heat, cold and itching), the heat level, humidity level and tightness level of hygroscopic work clothes (experimental group) and pure cotton clothes (control group) increased first and then decreased with the increase of exercise time, and increased slowly at 10 minutes, it reached the highest in 20-30 minutes, and then began to fall back. Where there is a large difference in subjective level between the experimental group (hygroscopic work clothes) and the control group (pure cotton clothes), the differences in various feelings of chest, arm, abdomen and waist are that the subjective feeling level of the control group is higher than that of the experimental group. This proves that the hygroscopic work clothes effectively play the hygroscopic function and effectively solve the problem of subjective discomfort to a certain extent.

4) In this study, the hygroscopic materials and work clothes were combined into a complete

protective wear, and the innovative design of hygroscopic workwear in protective clothing was proposed. The research results provided experiences for humidity treatment in the fully enclosed clothing environment, as well as new ideas for the improvement of thermal and moisture comfort of medical protective clothing.

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