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The Study of Structural Parameters of Medical Protective Clothing's Optimization Design and Ergonomic Performance

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Abstract: This paper studies the influence of the looseness of each part of the clothing on the heat and humidity comfort of medical protective clothing. According to the technical requirements of medical protective clothing such as appearance, clothing structure, size specifications, and functionality, the main structure of medical protective clothing parameters put forward improvement measures to design medical protective clothing based on ergonomic principles.

Keywords: Medical Protective Clothing; Structural Optimization; Ergonomics

1. Research and Development Status of Medical Protective Clothing

Medical protective clothing has corresponding standards in various countries and regions. Internationally, the US NFPA standard and the European Union's EN standard are more commonly used. Many countries have established different standards for different types of medical protective clothing, and the system has been relatively complete. There are many types of medical protective clothing on the market. Among them, the medical protective clothing (disposable protective clothing) commonly used by government disease control centers, health medical institutions, and central hospitals is rubber strip medical protective clothing. The second is medical protective clothing for different occasions, sterilized disposable medical protective clothing and reinforced rubber medical protective clothing. [1] For the quality research of medical protective clothing, the United States is currently the most advanced. There is a relatively complete set of testing and certification standards. Manufacturers need certification from authoritative organizations, and regularly evaluate and review manufacturers, and conduct irregular inspections. After SARS, our country also improved the technical requirements of GB19082-2009 medical disposable protective clothing. [2]

2. Analysis of the current situation of the use of medical protective clothing

The frequent outbreaks of various epidemics around the world have made the importance of medical protective equipment more and more important. Our country has also made some adjustments and improvements in this regard in recent years, but there are still some defects and deficiencies in practical application, especially in protection. There is a lack of systematic research on the design of clothing structure and function. Numerous facts have proved that effective protective equipment can reduce the infection rate of medical staff, which is the focus and basis for the functional structure design of protective equipment. Traditional medical protective clothing is often designed as a loose and hypertrophy one-piece structure. The body, goggles, masks, gloves, hats and shoes are separated and wrapped in layers, which not only has poor air permeability, but also has poor air permeability. Deep bruises can form on the wrists, and in severe cases, especially when working, the joints of shirts, hats, gloves, etc, which greatly affects the work efficiency of medical staff and puts them at risk of infection. Medical staff are in a hot and humid state for a long time at work, which has a great negative impact on normal work. It not only fails to protect the human body, but also affects work efficiency. Especially during the epidemic, the virus was rampant. Due to the inability to keep up with the supporting facilities of protective clothing, medical staff were infected when rescuing patients, and some even sacrificed their precious lives.

2.1 Comfort of wearing protective clothing

Comfort includes fit, dynamic comfort, moisture permeability, and the like. The optimal design needs to start from the environment-clothing-human body system. Due to the high work intensity of medical staff and the strong airtightness of protective clothing, the material of the protective clothing, that is, the water proofness of the polymer-coated fabric protective clothing also gives it poorer performance. The moisture permeability makes it impossible for medical staff to discharge a lot of sweat when they work, resulting in poor comfort.[3] Therefore, we need to strengthen the comfort of medical protective clothing from every detail.

2.2 The convenience of wearing and taking off for medical staff

Due to the tightness requirements of protective clothing, medical protective clothing still has hidden dangers in the structural design of opening and closing. Medical personnel need to take off all the protective clothing when going to the toilet, and then put it on according to the operating procedures after going to the toilet. The whole process takes a long time. All healthcare workers will control food and water intake while at work. However, this is not only detrimental to the health of medical staff, but also affects the work efficiency of medical staff.

2.3 The convenience of identification of medical staff

When working in full armor, it looks like everyone is dressed the same from the outside, and it is impossible to identify each other. In actual work, there is a need for communication between medical staff and between medical staff and patients, and it is impossible to find a specific staff member in time. This leads to frequent interruptions at work, and the target person cannot be found, which greatly reduces work efficiency.

2.4 Strictness of protection

When wearing ordinary protective clothing, the head protection measures are simple, and part of the skin will be exposed to the air. Under normal circumstances, when wearing protective clothing, they need to wear a hat, goggles, and a mask on the head before the protective measures are over. In addition to the trouble of wearing, in actual work, wearing goggles for a long time will press marks on the bridge of the nose. If the mask is worn for a long time and rubbing against the face, it is easy to be allergic and injured. Fog, the straps of the mask will also rub behind the ears, which will cause skin damage and affect the comfort and efficiency of work.

3. Parameter optimization scheme of medical protective structure

3.1 Design of loose the activities of cuff

When wearing protective clothing, the interface between the cuff and the glove is easy to slip off, which increases the probability of the skin being exposed to an unsafe environment during work, posing a threat to the safety of workers. [4] After working for a long time, the wrist is stretched by the tape, the breath ability is not good, and the rash will be stuffy. It not only threatens the physical safety of medical staff, but also hinders work efficiency.

3.2 Rich emotion

Medical staff have been in contact with patients for a long time, and the appearance design of pure white protective clothing that lacks temperature, which can easily bring negative emotions to patients. This design improves its own performance from the appearance, and uses physiological and psychological healing methods to analyze the composition and the elements of clothing. So we can improve the emotional design of medical staff's clothing to make patients feel friendly, starting from emotional psychology and spiritual comfort and other aspects. [5] Also we can continuously weaken the sense of fear and mental oppression caused by protective clothing, so that patients can have emotional requirements during treatment, achieving visual therapeutic effects, stabilizing the emotions of both doctors and patients, and playing a positive role in medical protective clothing.

3.3 New fabrics

At present, most domestic medical protective clothing products use composite non-woven fabrics as the main material, but in this fight against the epidemic, medical staff still have a series of problems such as poor air permeability and sultry heat. We decided to solve this problem with some novel materials. The active position of the protective clothing is large, and the elastic non-woven material is mainly used for the tensile position. Compared with ordinary non-woven materials, elastic non-woven fabrics have stronger elasticity and comfort, and have been widely used in diapers such as waist and side circumferences.

3.4 Setting of opening and closing parts

The air transmission route of the virus is mainly through the mouth, nose, eyes and other parts, so it is necessary to avoid facial infection when putting on and taking off. In terms of structural design, it must be strictly sealed. And at the same time, it must be easy to put on and take off. Starting from the principle of clothing, the opening and closing plackets are set at the front center position and the rear center position, and a safe and convenient structural design method is sought through try-on.

3.5 Control of looseness and fit

During the working process of medical staff, protective clothing should not only meet the looseness of clothing required for routine actions, but also not hinder normal actions due to too much looseness. The use of clothing modeling structures such as dividing lines, darts, and pleats to achieve the physical activity requirements of protective clothing, so that the clothing can better meet the needs of motor functions. In order to fit, the back waist can be pleated, and the method of local tightening or relaxation can be used to meet the needs of the movement.

3.6 Setting of chest ID card

The typical tightness of protective clothing makes it almost impossible for the wearer to distinguish their identity, which brings great inconvenience to the work of many medical staff. In order to find the personnel with specific responsibilities in time, the name can only be written on the chest or the front of the protective clothing. Setting badges can not only standardize job functions, but also quickly identify the identity of medical staff.

3.7 Stitching process

The seams of protective clothing are generally sewn directly by seam or ultrasonic pressing, but when fighting against Ebola, SARS, and new Coronavirus, the protection level of protective clothing is particularly high, and these processes are difficult to meet the requirements. In addition, there are other possible intrusion openings on the protective clothing, such as zippers, cuffs, foot openings, etc. If the seams are not tight or other access openings are not protected, the liquid will penetrate through these places to the doctor, posing an infection threat to the doctor.

4. Innovative design of medical protective clothing structure

We can design a new type of protective clothing with a photo slot on the right side of the front chest to improve the aesthetics of protection and reduce the pressure on patients. The left and right sides of the waist joint are elastically contracted, and the size of the contraction range is determined according to the parameters of the human body size, which provides a certain aesthetic feeling while ensuring the convenient contraction. Smart temperature measurement devices are added to the head and hands to ensure the health of medical staff. The back is made of PVC material to make a brand-name groove and sealed with a sealing tape. The wrist is opened at the palm of the hand and it is contracted by elastic at the cuff,

which plays a protective role and facilitates the work of medical staff.

4.1 Key technologies in the optimal design of protective clothing structure

The design and development of protective clothing is a relatively new field, and the systematic functional structure design needs to be further studied and developed. In the process of structural optimization design of medical protective clothing, the following points should be regarded as key technological breakthroughs.

(1) Easy to wear and easy to take off, strong sealing.

(2) The wrist is poorly sealed, and the joint of the sleeve and the glove is not firm enough, and strenuous activities are likely to cause infection.

(3) The hooded structure is likely to cause restricted neck movement, so it is necessary to reasonably design the distribution of the neck structure line with appropriate looseness.

(4) The design of the foot romper needs to consider the possibility of the frictional force damage of the sole, and solve the sealing performance of local thickening.

(5) The loose configuration of the waist can neither be too large to hinder the movement; nor too small to restrict the normal movement of the human body.

(6) Size and size specification settings, according to the physical characteristics of male and female bodies, refine the size specification design, and try to meet the needs of various body types.

4.2 Innovations

From the appearance of medical protective clothing, clothing structure, size specifications, functionality, etc., the innovations mainly include the following points:

(1) Improve the structure, size and function of medical protective clothing.

(2) Improve human comfort, increase the air tightness of clothing, and reasonably configure structural parameters.

(3) On the basis of giving full play to the anti-virus function of fabrics, reduce the form of kits and simplify the structure.

(4) The local design is more reasonable, the size specification setting meets the requirements of the human body, and the aesthetic functional design is highlighted to relieve the emotions of medical staff and patients.

5. Ergonomic research on medical protective clothing

5.1 Material analysis of medical protective clothing

At present, there are many varieties of polypropylene resin produced in China, and the production batch is relatively large-scale flat wire grade polypropylene, biaxially oriented polypropylene special resin (BOPP special material), injection grade polypropylene and ethylene propylene polypropylene and so on. SMS non-woven fabric is a composite product of spunbond and meltblown, which has the advantages of high strength, good filtration performance, no binder, and non-toxicity. Three-layer composite non-woven fabric, with a layer of waterproof and bacteria-proof layer in the middle, and the outer layer is sesame dot SMS non-woven fabric, which is strong and tensile, and has the function of isolation, waterproof and breathable. The structural characteristics of the ultra-fine meltblown fiber layer and the high-strength spunbond non-woven layer in the structure of the SMS material enable the material to have certain hydrostatic pressure resistance and air permeability, which form the basic isolation performance of the SMS material. In addition, SMS non-woven fabrics also have barrier properties and are used in various protective clothing products, including high, low and mid-end medical protective clothing, industrial protective clothing, chemical protective clothing, etc. Through the special treatment of the equipment, it can achieve antistatic, anti-alcohol, anti-plasma, water-repellent and water-producing properties.

5.2 Factors affecting the moisture and heat transfer of protective clothing

The moisture permeability of clothing directly affects the heat dissipation capacity of the human body, especially in a relatively high temperature environment when the human body is in vigorous exercise. Sweat is transported through the garment from the inner surface to the outer surface, where it evaporates into the environment. Since the garments do not

cover the body surface evenly, there will be overlap between the layers of garments. Moreover, after the human body wears clothing, the clothing-human body-environment moisture and heat transfer is more complicated, so the accurate study of the moisture and heat transfer law of protective clothing plays a very important role in designing the structure of protective clothing.

5.3 Comfort of protective clothing

The comfort of clothing is a complex concept of a combination of factors, both subjective and physical. The heat, moisture and air movement of the fabrics used in protective clothing are the main factors affecting comfort, but some subjective factors such as size, fit, aesthetics, softness, feel, and drape are obviously also important. The research on the comfort of clothing is a comprehensive and intersecting field, involving many disciplines such as psychology, physiology, physics and human sociology. The research scope of comfort includes physics, physiology, nerves, etc., which are several basic attributes weighted combination.

6. Prospects for the future development of medical protective clothing

At present, most of our country's protective clothing uses disposable medical protective clothing, which has problems such as waste of resources and disposal after disposal. In the future, our country can increase research and development efforts to produce reusable and multi-functional, intelligent medical protective clothing.

6.1 Reusable medical protective clothing

The new crown pneumonia has caused problems such as huge use of disposable medical protective clothing, high cost of destruction after use, and serious waste of resources. Therefore, industry insiders call for the production of reusable medical protective clothing to improve resource utilization. On the premise of ensuring non-infection and sterilization, reusable protective clothing can add antibacterial properties, anti-penetration, and airtightness to traditional clothing or work clothes, and it needs to be sterilizable, washable, and usable. For example, a reusable sterile medical protective clothing prepared by Cao Wanxia has two styles: one-piece or split. The materials used in the protective clothing are woven outer fabrics containing antistatic fibers from outside to inside, antibacterial breathable film middle layer and woven inner layer fabric made of moisture-absorbing and sweat-wicking fibers. The obtained protective clothing has good air permeability and antibacterial properties and can be reused.

6.2 Multifunctional medical protective clothing

Multifunctional medical protective clothing can relieve the inconvenience of medical staff to a certain extent, and it can improve the work efficiency of medical staff. A kind of multifunctional protective clothing invented by Xu Keqiang, the protective clothing is formed into one piece and connected, and a breathable layer is arranged on the inner surface of the protective clothing main body, hood, sleeves and legs, and a pure polyethylene zipper is arranged on the chest. A plurality of cooling water bags are arranged in the interlayer of the main body. A water inlet is arranged on the cooling water bag near the hood, and a water outlet is arranged on the cooling water bag near the legs, which are connected by pipes. The protective clothing has the functions of being easy to recycle, cooling the medical staff, and also has the functions of catheterization, lens defogging and simple diet. Pan Yuejin uses multifunctional fabrics with good breathability, flame retardant, dust resistance, waterproof, antifouling and antibacterial properties to make medical protective clothing. Soluble non-toxic tape is used for lamination at each seam; inner and outer plackets are set at the zipper opening to achieve double barrier effect, which greatly improves the protection of protective clothing. Wang Jingzhu invented a multifunctional medical protective suit that integrates the protective suit body, the sleeve tube and the protective boots. The neck opening of the protective suit is connected to the headgear, and the sleeve tube is connected to the isolation tube. The main body of the protective suit is provided with a storage bag. The protective clothing has the characteristics of convenient wearing, convenient storage and the like.

6.3 Intelligent medical protective clothing

The intelligence of medical protective clothing can effectively improve the work efficiency of medical staff and

increase the protection effect. The intelligence of textiles can generally be divided into active intelligence and passive intelligence. Passive intelligence mainly responds and recovers passively by adding some devices; active intelligence means that the system can automatically respond to external stimuli, and can return to the original state after the stimulus is eliminated. For medical protective clothing, passive intelligence can be achieved through material and structural design. For example, Li Jingying prepared an intelligent medical protective clothing that is easy to put on and take off through the structural design of medical protective clothing. The protective suit is provided with a first length adjustment and a second length adjustment on its upper garment and lower trousers respectively, and an opening and closing structure is arranged on the upper garment, so that medical staff can adjust the lengths of the sleeves and trouser legs according to their own structures to improve comfort.

Conclusion

Through the ergonomic analysis of the one-piece and split-type protective clothing, it is more fit, comfortable, and reduces human pressure. Use the front and back piece belt knot method to adapt to various waist sizes, and improve the structure of medical protective clothing. To increase the air tightness of the clothing, the local design is more reasonable, and the size specifications are set to meet the requirements of the human body. The aesthetic functional design is highlighted, and the emotions of medical staff and patients are relieved. The zipper is sewn on the back of the protective suit to facilitate the medical staff to put on and take off the toilet, and a name tag for identification is added on the front chest: the card slot and pen hanging slot for the famous brand are sewn on the left chest of the protective suit to facilitate the medical staff to work. The medical staff's photo card is placed in the protective device (left front chest and back) to show the patient to help the patient relax.

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