Design of ergonomic hospital clothing based on the morphological transformation principle

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Abstract. The article presents materials on the design of ergonomic hospital clothing for people with temporarily limited mobility based on the principle of morphological transformation. In addition to existing methods of designing hospital clothing, a new principle of "dismemberment-recovery" has been proposed, in which an item of clothing is dismembered into a separate zone and restored to its original shape using a temporary Velcro fastener after medical procedures.

1 Introduction

The main task in designing functional hospital clothing is to ensure that the patient is comfortable in clothing, as well as the convenience of working with the patient for the staff, i.e. making the design of clothing ergonomic for a given group of people. This is especially true for people with limited motor ability due, for example, to an injury to the upper or lower limb.

The range of clothing used in hospital settings can more likely be classified as home clothing rather than special clothing, which is necessary for medical institutions. The most complete and fundamental research on improving methods of ergonomic design and rationalization of workwear designs was carried out by E.Ya. Surzhenko [1].

Key results on the ergonomic design of functional clothing for patients (using the example of wheelchair users) were obtained by Chinese researchers from the Fashion Institute of Donghua University (Shanghai, China). When expertly wearing the developed sets of clothing, an assessment system was used, borrowed from rehabilitation medicine and sports tournaments. The results showed that with the new clothing, wheelchair users' ability to use the toilet increased by 52.9%. The time required to go to the toilet was reduced by 45.7%. Their ability to dress and undress improved by 24.6%. A study showed that new clothing designs can facilitate the clothing-related daily activities of wheelchair users [2].

Developers from the American company Joe & Bella (Chicago, USA) have proposed innovative clothing sets for patients. The design features of the clothing models include two side zippers and one zipper along the inner seam, which can provide full access from the

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front and back from the waist to the knees. Patented inseam zipper provides easy access to incontinence products and medical devices. The waist closure is strategically placed to avoid high-contact pressure points of clothing on the patient's body [3].

The most pressing area of research and development in the field of clothing for patients lies at the intersection of nanotechnology in electronics and biochemistry. Thus, Portuguese scientists from the University of Beira (Covilhã, Portugal), as well as Russian scientists from Kosygin University (Moscow, Russia), have developed scientific and methodological support for the process of designing clothing or accessories using biosensors for observing and measuring body movements, confirming that even without taking into account the use of muscle force, the simple movement of body segments (arms and legs) causes changes in size, which lead to various numerical measures taking into account physical criteria: ease of use, ease of wearing and comfort under various criteria of body movements [4-10].

The "person-clothing-working environment" system, which is part of the general ergonomic system, manifests itself in dynamic processes. Therefore, the main design task is to purposefully ensure the dynamic compliance of workwear with the characteristics and extreme movements of a worker in his production activities. However, when designing hospital clothing for people with limited mobility, this concept must take into account the sharp limitation on dynamic compliance, since as a result of limb injuries or surgical interventions, patients temporarily lose their previous mobility.

Analysis of the bio kinematic interaction of the elements of the "person-hospital clothing-therapeutic environment" system, in which the human body is considered a complex biomechanical system, allows us to give a quantitative description of movement restrictions. This allows us to form the basis of a systematic approach to the design of hospital clothing in general and, in particular, when designing adaptive-transformable clothing for patients with temporarily limited motor ability, which has a functional purpose and acquires signs of ergonomic design. Thus, it seems advisable to model hospital clothing according to the principle of morphological transformation - a method of shaping, in which the product is given functional ambiguity [11-13]. The concept of "morphology transformation" is interpreted by designers as a special thinking procedure, a design act that recreates the holistic process of object transformation within the framework of a design concept. Its possibility is due to the relationship between the morphology (structure) of material objects and their function. This means that by changing the structure, you can program functional properties. That is why it is so important to impart transformative properties to the morphology, especially when creating multi-element complexes.

It should be especially noted that "morphological transformation" is a method of shaping, and "transformation" is a means. The most typical property of morphology is structure. Each detail of a form turns out to be structurally connected with its other details, and the interaction of objective forms creates a set of morphologies that have a regular structure.

Methodologically, it seems important to highlight two aspects of the morphological structure: spatial and functional-technical [14]. The principles of organizing the spatial structure of clothing (transformation), which are known not only in design practice but also in clothing design, are shown in Fig. 1. The seven principles developed by designers are the most universal and acceptable for use in the practice of designing clothing, including hospital clothing, using the transformation method.

The use of functional design elements in hospital clothing can significantly facilitate the work of medical staff and ensure the comfortable condition of the patient, especially those with limited motor ability, during the period of treatment and rehabilitation. The use of transformation elements helps to increase the functionality and ergonomics of hospital clothing.

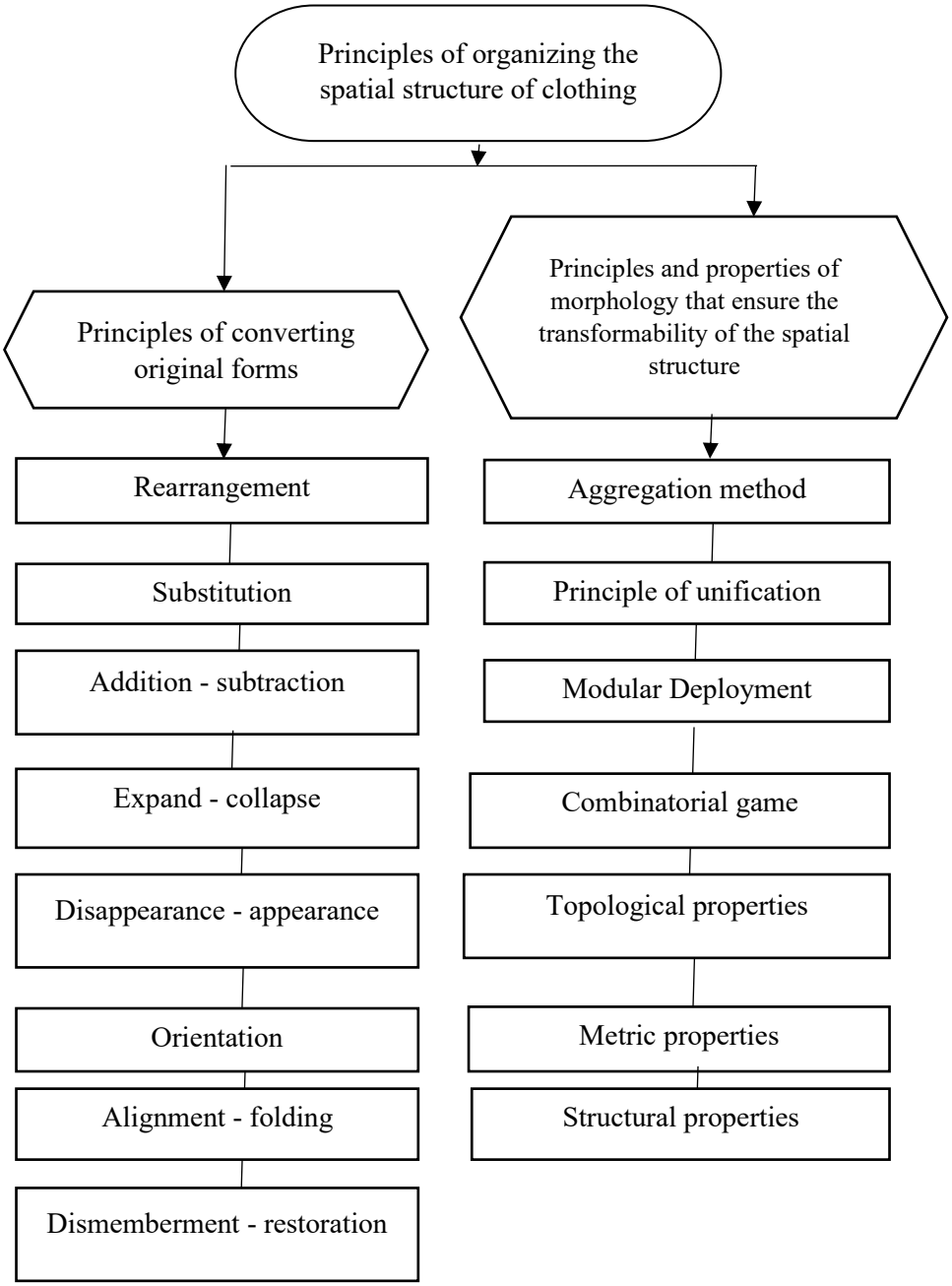

Fig.1. The principles of organizing the spatial structure of clothing systematize various design details in the form of initial transforms.

The range of clothing for patients [15] can be divided into several types:

1) clothing that has a therapeutic and prophylactic effect and the use of which contributes to a speedy recovery of the patient;

2) clothing used during medical procedures during the treatment and rehabilitation of the patient, which has functional, constructive, and transformable elements;

3) clothing intended for use during a severe period of illness, for people who are unable to care for themselves;

4) clothing for wearing medical devices and devices with special design elements intended for this.

Thus, the relevance of the presence of transformable elements in hospital clothing is obvious, which facilitates procedures for medical staff due to the provision of free access and improves the quality of life of patients. This is especially sensitive for patients with temporarily limited motor ability (patients in trauma and surgical departments).

Transformable elements differ in structure, functions, and form-building properties - these are fittings, folds, perforations, etc. Depending on the size of the element to the design of transformable clothing of an elementary cut [16], they are divided into four groups: point, linear, planar, and volumetric. In this work, transforming elements are classified according to the types of spatiotemporal connections of elements and development, as well as the structural organization of the structure:

1. Static – rigidly fixed elements, the use of which changes the characteristics of the web once (folds, perforation, appliqué, puffs).
2. Dynamic - rigidly fixed elements that can change the shape of the product depending on its purpose and have the ability to return it to its original state (decorative elements, drawstrings, etc.).
3. Pulsating - rigidly fixed elements that change the shape of the product depending on its purpose and can return it to its original state (laces, loops, buttons, hooks, and loops).
4. Procedural - interchangeable or additional elements with temporary connections (belts, straps, brooches, pins).
5. Intermittent - interchangeable or additional elements that have temporary connections and change the shape of the product once.

2 Materials and methods

When designing clothing for patients with temporary limited mobility, it is necessary to first assess the amplitude of movements of the upper and lower extremities of the human body (elbow, shoulder, knee, hip, wrist joint), which, as a result of traumatic action, lose their previous mobility. Thus, according to [17], the limitation of movement in case of injury to the joints of the elbow, hip, knee, and ankle is 00 (degrees) during extension, flexion, abduction (hip), pronation, and supination (elbow) relative to differentiated values of the normal range of motion for different joints of the limbs.

From a biomechanical perspective, a sharp restriction of movement due to injury to the lower and upper extremities of the human body is associated with the loss of mobility of biokinematic chains, which act as analogs of joints in joints with simple hinges (cylindrical, ball) having certain degrees of freedom. For example, the analog of a ball joint in the human body is the shoulder and hip joints. As is known from the course on the theory of mechanisms and machines [10], a ball joint, unlike a cylindrical joint, allows more different movements, and the free link is capable of swinging around its longitudinal axis while remaining in place. To uniquely specify the position of the link, three angular coordinates are required and, accordingly, we have three degrees of freedom H = 3. The described movements are also typical for the hip joint.

Let us determine the number of degrees of freedom W of flat biokinematic chains that make up the sober mechanism and are presented in the form, for example, of a knee joint consisting of a torso (fixed link), thigh, and lower leg. We find the degree of mobility of flat mechanisms using the Chebyshev formula

$$W = 3n - 2p_5 - p_4 = 3 \cdot 2 - 2 \cdot 2 = 2$$

here n is the number of moving links, n=2 (thigh and lower leg);

p_5 – kinematic pair of the 5th class (rotational pair), $P_5=2$ (tibia-thigh; thigh-torso); p_4 – kinematic pair of class 4, $P_4=0$.

Thus, $W = 3 \cdot 2 - 2 \cdot 2 = 2$.

If, as a result of an injury, after applying a plaster cast, the thigh becomes immobile, then only one link remains mobile - the lower leg and $n=1$. Since now there is only one biokinematic pair of class 5 ($p_5=1$), the degree of mobility will be

$$W = 3 \cdot 1 - 2 \cdot 1 = 1$$

It becomes obvious that the degree of mobility of this biokinematic chain will be equal to W=0 if the lower leg is also motionless and n=0. Consequently, in the case of injury to the thigh and lower leg in clothing for patients with limited motor ability, morphological transformation is realized through changes in the geometric parameters and shape of structural elements. In this case, it is necessary to use elements that regulate the width of the trousers (Fig. 2), which is important for patients in the trauma department with a broken leg after applying a plaster cast. To do this, Velcro strips can be placed in two rows on the front and back side halves of the trousers, thereby adjusting the width of the trousers.

The front and back halves of the trousers can only be connected along the middle sections with braids or fasteners. Following the principles of organizing the spatial structure of clothing (Fig. 1), the described transformation meets the “unfolding-collapse” requirement.

A similar transformation of clothing is provided for injuries to the elbow joint. This clothing for patients with limited mobility is presented as a set of special clothing (Fig. 2, a) for procedures in the trauma department.

In case of injury to the hip joint, leading to almost complete immobility of the lower extremities, treatment procedures for the patient become more complicated and require the assistance of medical staff. Therefore, the intended purpose of designed clothing for patients with limited mobility is maximum adaptability to the patient’s condition and the ability to effectively carry out the prescribed treatment procedures. Sets of such clothing are ergonomic, as they create convenience for the work of medical staff and a comfortable condition for the patient.

3 Results and its discussion

By [18], a set of clothing was developed for a patient with limited mobility (Fig. 2). For carrying out medical procedures, a model of special clothing for trauma patients has been proposed, characterized in that the back of the halves of the trousers from the waist has a dismemberment, which is easily restored and maintains the given shape of the clothing. Consequently, it can be argued that in addition to the well-known principles of transformation of initial forms (Fig. 1), another principle has been formed, based on “dismemberment-restoration”. This principle involves dividing an item of clothing into a separate zone and restoring its original shape using a temporary connection, for example, in the form of Velcro.

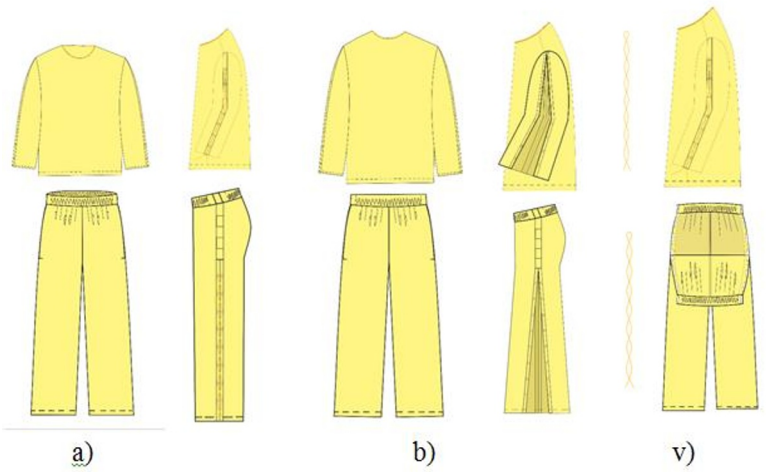

Fig.2. A series of models of special clothing (a) for trauma patients (patent No. SAP 0226): for trauma to the joints of the upper and lower extremities (b), made according to the new principle of transforming the original forms - "dismemberment-reconstruction" (v).

The proposed industrial design is designed in the front area to be unfastened and attached to the sides with Velcro fasteners. The design is distinguished by the sidewalls of the trousers being made with unfastening and fastening laces, the sidewalls with a slit, the edges of the slit in the form of an edging, and on the edging there are air loops intended for lace.

Data from experiments [17] in the form of experimental wearing of designed ergonomic hospital clothing, conducted in two groups of patients with limited motor ability, showed the following. During experimental wear for 10 days (Department of Traumatology and Orthopedics at the Yakkasaray Medical Association, a multidisciplinary central clinic with an inpatient part), patients of the first group (20 people, 12 men, 8 women) of different ages felt comfortable state, treatment procedures and techniques manipulations were carried out without difficulty, and no secondary nosocomial infections were observed. The clothing set includes sleeves with a slit in the center with a stretching and tightening cord, a medium-width belt gathered with an elastic band, a front groin area that is stretchable and attached with Velcro fasteners on the sides, and side legs of the trousers with an unfastening and fastening cord.

The second group of patients (20 people, 13 men, 7 women) wore the usual clothes provided for this medical institution. Such clothing, not suitable for patients with temporary limitation of movement, created difficulties during manipulations of the patient (it was necessary to turn the patient on his side) and difficulties in carrying out medical procedures (the need to remove all clothing). Since the patient is forced to lie on the injured part of the body, this increases pain and causes discomfort. When wearing clothes made of synthetic material, intense sweating is observed, which contributes to secondary infection in patients.

Thus, the design of ergonomic clothing for patients with limited mobility should be based not only on a rational design based on the principles of morphological transformation but also on taking into account the requirements for materials for hospital clothing.

4 Conclusion

Materials for hospital clothing must comply with toxicological and sanitary standards. They must provide a stable under-clothes microclimate due to appropriate hygienic properties: air

and vapor permeability, hygroscopicity, moisture conductivity, and thermal conductivity, and the materials must have sufficient rigidity for active air circulation in the under-clothes space. In the absence of air circulation, protection against the penetration of pathogenic microflora into the space under clothing is impaired, which leads to damage to the skin, since materials for hospital clothing come into direct contact with the surface of the human body.

According to medical workers, when hygienic assessment of material, the standard is cotton fabrics that have a good ability to absorb moisture from the surface of the human body and release it into the environment; materials should be light (surface density 130-190 g/m^2), non-toxic, and have a small thickness (0.2-0.5 mm) and a stable structure (it is not permissible for particles of material to get into damaged areas of the patient's skin), have high hygroscopicity and moisture capacity, air permeability (at least 135 $dm^3/(m^2s)$), resistance to aggressive environments, washing, and abrasion, high strength to prevent premature destruction of the product and have an attractive appearance.

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