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Designing of casual wear for wheelchair users

Nataliya Sadretdinova[1,*], Sergii Bereznenko[1], Larysa Bilotska[1], Halina Szafrańska[2], Maria Pawlowa[2]

[1] *Kyiv National University of Technologies and Design, Kyiv, Ukraine*
[2] *Kazimierz Pulaski University of Technology and Humanities in Radom, Radom, Poland*
*Corresponding author *E-mail address:* sadretdinova.nv@knutd.com.ua

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ABSTRACT

Functionality and comfort are important requirements for adaptive clothing. To ensure the compliance of clothing with these requirements, it is necessary to take into account, on the one hand, consumer conditions, on the other hand specific needs driven from social and psychophysiological adaptation to the living conditions. Thus, for people who are restricted to the sitting position for their entire life due to their disabilities, it is important to avoid skin diseases that occur in conditions of constant contact of the skin with hard surfaces under pressure. Therefore, the aim of our work was to improve functional clothing for disabled people based on the analysis of ergonomics and consumer requirements through the application of new technologies.

Keywords
disabled people,
adaptive clothes,
antimicrobial inserts

1 Introduction

Taking into account the needs of people with disabilities around the world is considered an indicator of the degree of development of society. The promulgation of the UN Convention on the Rights of Persons with Disabilities in 2006 changed the approach and attitude towards people with disabilities in many countries, including developing ones. Programs aimed at eliminating or compensating for life restrictions and social adaptation are being created and successfully implemented. One of the examples of successful projects is the Paralympic Games, which not only drew public attention to people with disabilities, but also became a powerful impetus for their self-development.

Analysis of the current market has shown that despite growing efforts to develop clothing for people with disabilities, this billion-dollar market remains largely underestimated [1]. The range of clothing for the disabled is limited and often does not take into account the ergonomics of consumption of these

products. To create functional and comfortable clothing for people with disabilities, it is necessary to study the features of physiological changes in their physique, take into account specific psychophysical aspects, operating conditions, wishes of consumers and their employees, and determine how this may affect the choice of clothing and materials for manufacturing [2]. Therefore, as a rule, each individual case of making adaptive clothing requires an individual approach. Given this fact, the creation of comfortable adaptive clothing for various purposes is an urgent science-intensive task for professionals working in the field of light industry.

The most often used classification of disabilities is presented in The international classification of functioning, disability and health, endorsed in 2001 by the World Health Organisation [3]. This classification includes the following factors: body functions, body structures, impairments, activity limitations, participation restrictions and environmental factors. This means that functional, social and biological components must be taken into account in research and development for people with disabilities. Apparel-related concerns intersect all components of the ICF framework. For example, clothing might need to be modified to allow access to ports or catheters necessitated by impairments in body function, or might interfere with the ability to use assistive devices and thus a person's ability to execute different activities. Social participation has been linked to a higher quality of life for people with disabilities throughout the life course, and physical as well as social environments are known to influence participation [4].

In the process of designing adaptive clothing, various scientific approaches are used that consider one or another side of this multifaceted task. Thus, studies [5-8] are aimed at improving the functionality of everyday clothing, taking into account the types of disabilities by constructive and technological modification of prototypes. Samples of clothes for the disabled with certain structural elements or devices that increase ease of use are offered.

Functional clothing, as opposed to casual, is designed to meet the requirements of the user under certain operating conditions. Therefore, the process of creating functional clothing should begin with the formation of clear requirements. Summarizing the results of scientific developments in this direction [9,10], we note that clothing for the disabled must meet the same requirements as ordinary clothing: aesthetics, functionality, comfort, but slightly shifting accents, changing the weight of a group of requirements. Given the fact that the quality of life of such people is largely determined by their well-being, it is comfort that comes first.

Another important area in the study of clothing for people with disabilities is the provision of anthropometric compliance with digital technology. In the works of the authors [11,12] with the use of CAD systems, prototypes of products for people with motor disfunction were obtained, their compliance with the parameters of the figure was studied. For this purpose, 3D-scanning of people in a sitting position was performed, methods of processing the modeling of the human body grid and methods of surface reconstruction to obtain a three-dimensional model of the body were used.

The next direction in the creation of clothing for the disabled is systematic research aimed at improving the comfort of products in operation. Despite the large number of studies conducted in this area, the approach to determining comfort in each of them varies depending on the purpose. Most research has been conducted on thermophysiological comfort while wearing, while other types, such as sensory, ergonomic and psychological comfort, have been less studied. The main reason is the need to use a subjective approach to the assessment of these types of comfort, which is associated with the development of new equipment and techniques [13].

Despite the considerable attention paid by scientists around the world to the chosen field of research, the issue of developing comfortable casual wear for people with disabilities remains relevant. According to the results of the study [14], people with disabilities of different ages express a great desire to have comfortable and fashionable clothes of different assortments to look modern, be able to perform certain functions and be no different from healthy people.

The development of adaptive clothing for people with disabilities will reduce the negative effects of disability, increase domestic independence, improve quality of life, accelerate their social adaptation. Such clothing should take into account all the functional needs of people with body structure and at the same time not look like “overalls” or hospital clothes. It must meet all the requirements for modern functional clothing, provide all kinds of comfort during operation, mask possible body defects and allow you to seamlessly place special care items (catheters, diapers, prostheses, etc.).

2 Experimental

2.1 Requirements for adaptive clothing

According to [15], about 1% of the total number of people with disabilities are people with musculoskeletal impairment. Most of the activities are performed while in a sitting position. According to observations and survey data, the average time a person is in a wheelchair is about 15 hours. The rest of the day falls on the supine position. The disabled person who remained for a day is in a supine position. Lack of mobility causes fatigue, reduced functional and energy potential of the body. In the case of the use of uncomfortable clothing that restricts movement or causes excessive pressure on the body, the negative consequences are compounded by circulatory disorders and injuries to the skin. As comfort and ergonomics of everyday clothes are of special importance for this group of disabled people, our further research is focused in this direction.

Among other factors, monitoring the operation of the system “disabled people (DP)-clothing-environment” allows to identify a group of factors that determines the consumer attractiveness of adaptive clothing: functionality, aesthetic compliance, ease of use, quality of materials used and product life. In order to clarify their importance, sociological surveys were conducted, which involved the main categories of persons directly involved in the operation of adaptive clothing: DP; assistant caregivers; medical staff providing medical treatment and rehabilitation. Graphic processing of the survey results (clothing requirements for DP from the point of view of selected groups of respondents) is presented in the form of diagrams (Fig. 1-3).

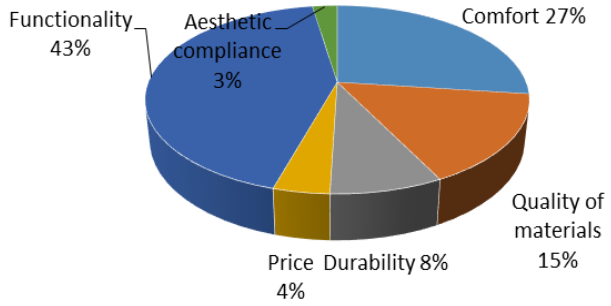

Fig. 1 Requirements for clothing, according to the evaluation of disabeld people (DP).

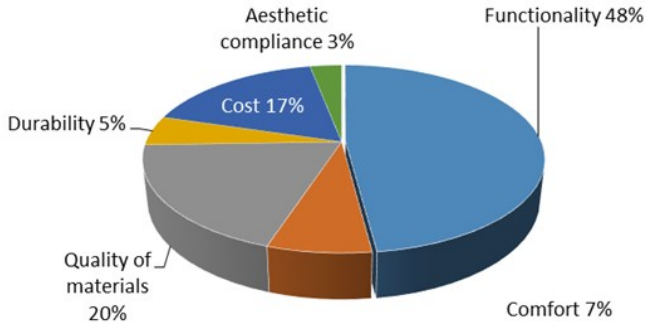

Fig. 2 Requirements for clothing, according to the evaluation of assistants.

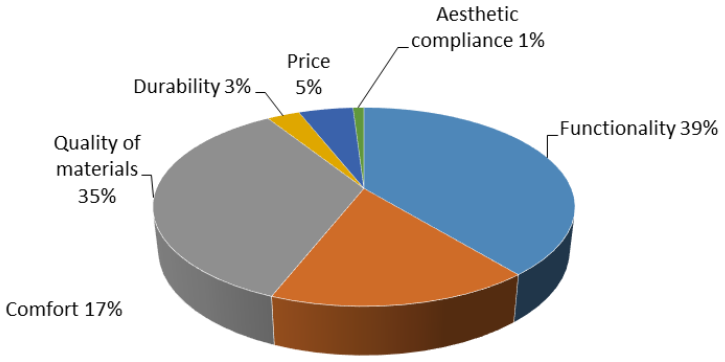

Fig. 3 Requirements for clothing, according to the evaluation of doctors and medical staff.

The obtained data allow us to identify the most important group of factors; these are functionality (convenience at dressing and removal, a rational arrangement and convenience of use of constructive and decorative elements (pockets, fasteners, etc.)), comfort, quality of the applied materials, and service life of a product.

Taking into account the proposed set of special requirements for the design of adaptive clothing will create clothes that have high technical and economic performance and meet the needs of this range of consumers.

2.2 Research and selection of materials

One of the main factors that ensure compliance of the product with the established list of requirements is a properly selected package of materials. Knitted fabrics with cotton content are mainly used for the production of casual clothes for DP, because along with high hygienic properties, they have sufficient plasticity, which provides additional freedom of movement of the upper torso when moving in a wheelchair. Another advantage is the relatively low price and availability of these materials.

For comparative analysis of ergonomic properties, three types of modern knitted fabrics are selected, the characteristics of which are given in Table 1. Taking into account the results of the survey presented in the previous section and the analysis of the literature, the main groups of indicators that determine the comfort of adaptive clothing are identified. These include humidity, breathability, abrasion resistance in the plane, elongation and dimensional stability.

The research was carried out using standard methods: air permeability was determined according to GOST 8847-85, water vapour absorption according to DSTU GOST 3816: 2009, deformation and its components using a Relaxometer type Stable at a load of 3 daN according to GOST 8847-85.

The results of studies of these indicators for selected samples of knitted fabrics are shown in Table 1.

Table 1. Knitted fabrics characteristics.

Sample number	Raw material (%)	Binding	Mass per unit area (g/ m^2)	Coefficient of air permeability (dm^3/m^2·s)	Water vapour absorption (%)	Total deformation (%)		Irreversible deformation (%)	
						warps	courses	warps	courses
TM1	100 cotton	footer	250	159	14.2	39	45	2	3
TM2	97 cotton, 3 PU	footer-stretch	225	302	15.3	35	42	4	5
TM3	80 cotton, 16 PE, 4 PU	footer-stretch	205	237.5	9.6	61	38	6	6

According to the data obtained (Table 1), the greatest ability to stretch both in the longitudinal and transverse direction has a knitted fabric footer-stretch (sample TM3). An important factor that determines the required shape stability of the product is the ratio of the components of total deformation – the smaller the part of the irreversible deformation, the faster the product takes its original shape after stretching. For the TP3 knitwear sample, 90% of the tensile deformation falls on the reverse part (fast and slow reversible), only 10% of the relaxation is irreversible.

As for the indicators of hygiene, all the studied fabrics have a high enough ability to ensure a normal climate of the underwear environment during the operation of the products [16].

The obtained data allow varying the materials in their design for the manufacture of adaptive clothing, giving preference to certain properties and ensuring compliance with the functional environment.

2.3 Antimicrobial attachments

Along with other changes in many body functions caused by prolonged stay of the DP in a wheelchair in a sitting position, an important negative consequence is irritation or damage to the skin in places of constant contact with hard support surfaces [17].

Prevention of such diseases is the timely removal of excess moisture and protection against the penetration of bacterial flora. To reduce the negative impact of this factor, we propose to use antimicrobial inserts in places of prolonged contact of the body with the hard surface of the wheelchair. They can be fixed on the inside of the clothes by placing them in a special open “pocket”. To ensure bactericidal properties, we used an ecologically clean method of nanoprocessing of knitted fabric with colloidal solution of silver nanoparticles developed with the participation of scientists of Kyiv National University of Technology and Design, using fungal mycelium as stabilizer [18]. The nature of the impact of the proposed nanoprocessing on the bacterial microflora was established in previous studies [19]. A mesh knitted fabric was used as the top layer of the pocket, which is in direct contact with the skin.

2.4 Comfort assessment

Modern assessment of the degree of clothing comfort is often based not on the human feelings, but on the measurement of specific indicators of the characteristics of the clothing and the properties of the materials from which clothes are made. Quantitative assessment of comfort indicators makes it possible to objectively characterize the degree of comfort and on this basis to rationally choose the material and design of clothing. Proper combination of modern materials with their physical, mechanical and chemical properties makes it possible to provide the required temperature, humidity, air permeability and other indicators of the sub-clothing area. Deviation of indicators from physiological norms also causes feeling of discomfort.

Physiological norms of a comfortable condition of the person in clothes on temperature, humidity, air permeability, stiffness and roughness of materials can be considered certain [20]. However, experience shows that not all properties of materials are taken into account when assessing comfort. There are a number of parameters and characteristics of materials that are quite difficult to determine. This is especially true for the electromagnetic characteristics of materials that are insufficiently studied and not quantified. Their definition can add an additional component to the overall scheme of assessing the comfort of clothing.

Recent research in the field of biomedicine and boundary areas of physiology reports interesting methods for analyzing the biofield *surrounding* living biological objects. In the literature the authors speak about “energy exchange“, where the type of energy is not exactly specified. The human biofield is a challenging concept that is not fully compatible with the dominant medical paradigm. The mechanisms behind this phenomenon are still unclear or unknown. However, some experimental results and clinical applications support rather than deny its existence, thus justifying further studies about its nature and action mechanism [21]. According to several authors, this phenomenon could be partially related to electro-magnetics, acoustic- and thermal-related effects [22-24], and possibly subtle biofields, which, in some cases, seem to generate physical changes that are measurable with current technological methods, and related to health or disease patterns [25,26]. Thus, the use of methods based on these diagnostic systems and devices allows in practice to implement the popular idea of using express technologies to determine the impact of clothing on the functional state of the human body and thus assess the subjective component of clothing comfort.

Measurement of the impact of materials on the functional level of the main organs and systems of the body and the psycho-emotional state of a testing person was carried out using a system named APK ROFES [27]. Based on the diagnosis, it was important to find out whether the changes observed in the functional state of the body of the subjects, caused by energy and information effects of this material, are harmful to the body or, vice versa, useful. To do this, the level of energy-informational impact of

textile materials on organs and organ systems of the human body was quantified. The tests were performed at rest, without the use of textile materials, and taking into account the influence of textile samples. The condition of human organs and organ systems was assessed in points from 1 to 5, where 1 is the limit state of the organ / system, overstrain (stress), when the organ or system was in the strongest stress; 5 means excellent condition of the body / system, no voltage, when you do not need more effort to respond; 2, 3, 4 are intermediate states. Based on the data obtained, it was calculated how many organs under the influence of the samples received better or worse scores compared to the neutral state, and how many organs did not change the score. The results are presented on a scale where „excellent“ is the percentage of organs that received a value of 5, “good” is the percentage of organs with a value of 4, and “average” with a value of 3 (Fig. 4).

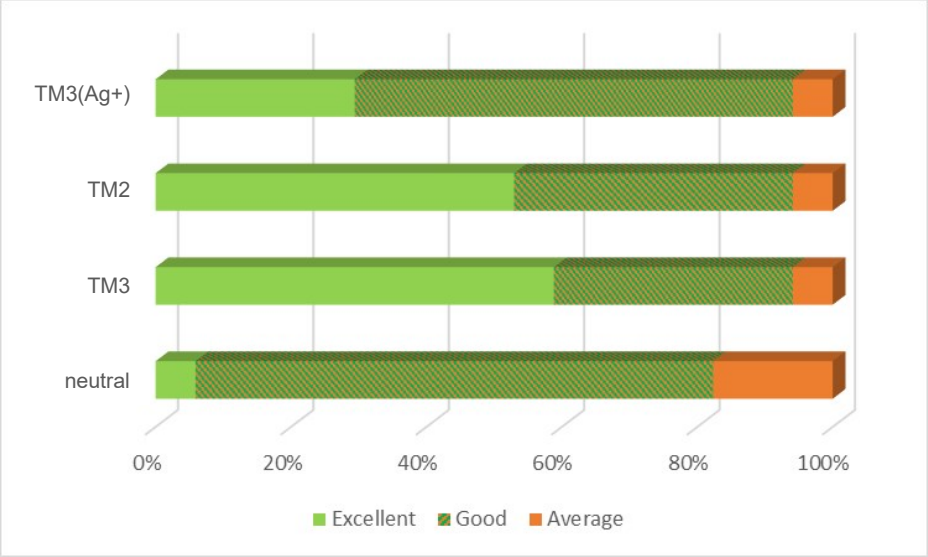

Fig. 4 Graphical representation of the general functional state at rest and depending on the raw material composition.

According to the above data, the addition of chemical fibers to the fabric significantly reduces the spectral density of tissue radiation, and therefore adversely affects the comfort of materials. TM3 is the most favorable for the body’s reaction to the interaction with textile material. It was also found that nano-treated silver ion material is neutral in relation to the physiological state of organs and organ systems, as it does not cause either positive or negative changes.

While it is not known now on which scientific basis the changes in the field are happening and how they are detected, from this measurement it is visible that changes in the biofield are detectable and measurable. If they are based on changes in the conductivity regarding electromagnetic fields, or if the changes are based on the reaction of the air molecules and the textile materials or anything else, this remains unknown for the current engineering research. It remains an open task for scientists in the future to check critically, with which parameters of the structures the detected changes by the named APK ROFES are correlated, what the levels of reproducibility and sensibility of the device are, and how the detected values are correlated to the comfort feeling.

3 Design and manufacture of the sample

It has been mentioned above that wheelchair users are almost always in a sitting position, which causes a number of problems related to both aesthetic and ergonomic features. Therefore, to ensure a holistic approach, it is advisable to use design methods aimed at forming a set of ergonomic and aesthetic factors: modern design, taking into account the changed proportions in forming the composition of the suit, harmonization of individual elements and forms as a whole. In addition, the ergonomics of consumption make special demands on the cut of clothing: shifting the waist, lengthening and shortening

of certain areas, bending the surfaces of the knees and buttocks, regulators to reduce pressure in the areas of fixation, comfortable fasteners, etc. (Fig. 5).

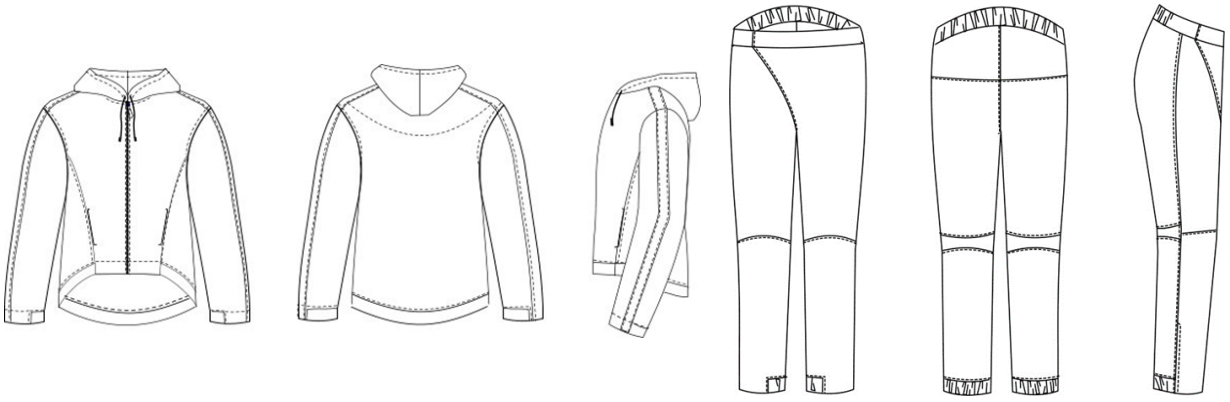

Fig. 5 Sketch of the adaptation suit for DP.

Adaptation of clothing designs for the needs of DP should be based on a detailed study of the operating conditions of the designed product. Thus, in clothing for people in wheelchairs, ergonomics can be achieved not only through the use of elastic materials, but also through increments in areas of products that meet the greatest range of motion. In clothing for people in wheelchairs, the main dynamic changes in size occur in the part of the body where the movement of the arms “back and forth”, when “bending and unbending” the arm at the elbow and tilting the torso forward. The outwear pattern design for the “sitting” position is carried out on the basis of adjusted dimensions and increments. The result is presented in Fig. 6 and 7 and consists in the following transformations of the structure: lengthening the back to fit the buttocks in the human position “sitting”; reduction of the length of the front, which avoids the formation of unwanted folds; deepening of the armhole and widening of the sleeve, which provides additional freedom of movement; transfer of articulations of the backrest, front and further shaping of parts to achieve greater comfort in accordance with the spatial position of the body in a wheelchair; in waist products, parallel conical dilution-narrowing is performed in order to change the ratio of the lengths of the middle section of the front and rear halves; design of structural divisions that allow easy modification of the model.

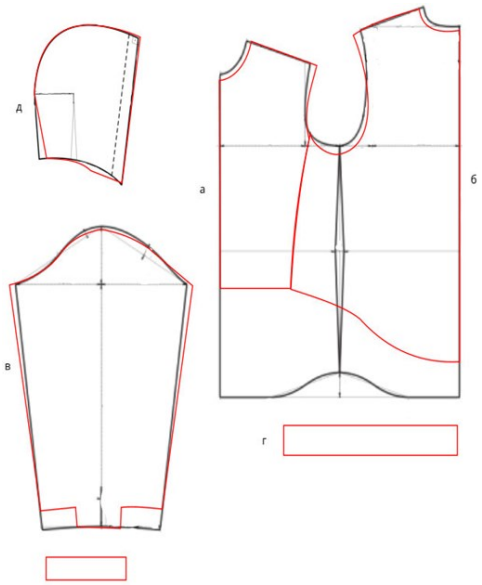

Fig. 6 Drawing of the model design of the jacket details: a) file; b) backrest; c) sleeve; d) the bottom of the product; e) hood.

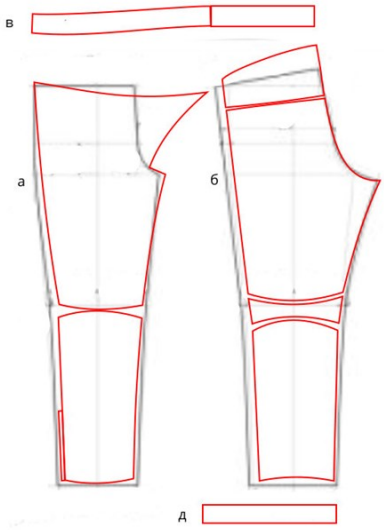

Fig. 7 Drawing of the model design of the pants: a) details of the front half of the pants; b) details of the back half of the pants; c) belt; e) the cuff of the bottom of the pants.

As it was found during the experimental wearing of jackets and pants adaptation kit, during operation there is a load on certain areas of the seams, so it is advisable to use connection methods that provide high strength seams under specified operating conditions.

In the manufacture of the adaptation kit, recommendations for the processing of standard components in accordance with [26] were used. Areas of step seams in trousers, seat seam are most prone to breaking stresses; in the jacket zone armholes. The strength of these seams largely depends on the strength of the threads, seam design, connection parameters, type and number of stitches.

A feature of the design of adaptive pants is the clasp with Velcro textile tape, which is designed to be easy to put on and take off both completely and to meet the physiological needs of DP. The Velcro tape allows you to adjust the volume of the abdomen and allows you to better fix the pants at the waist. The map of methods of processing of the basic knots of an adaptive set of clothes for DP is presented in Fig. 8.

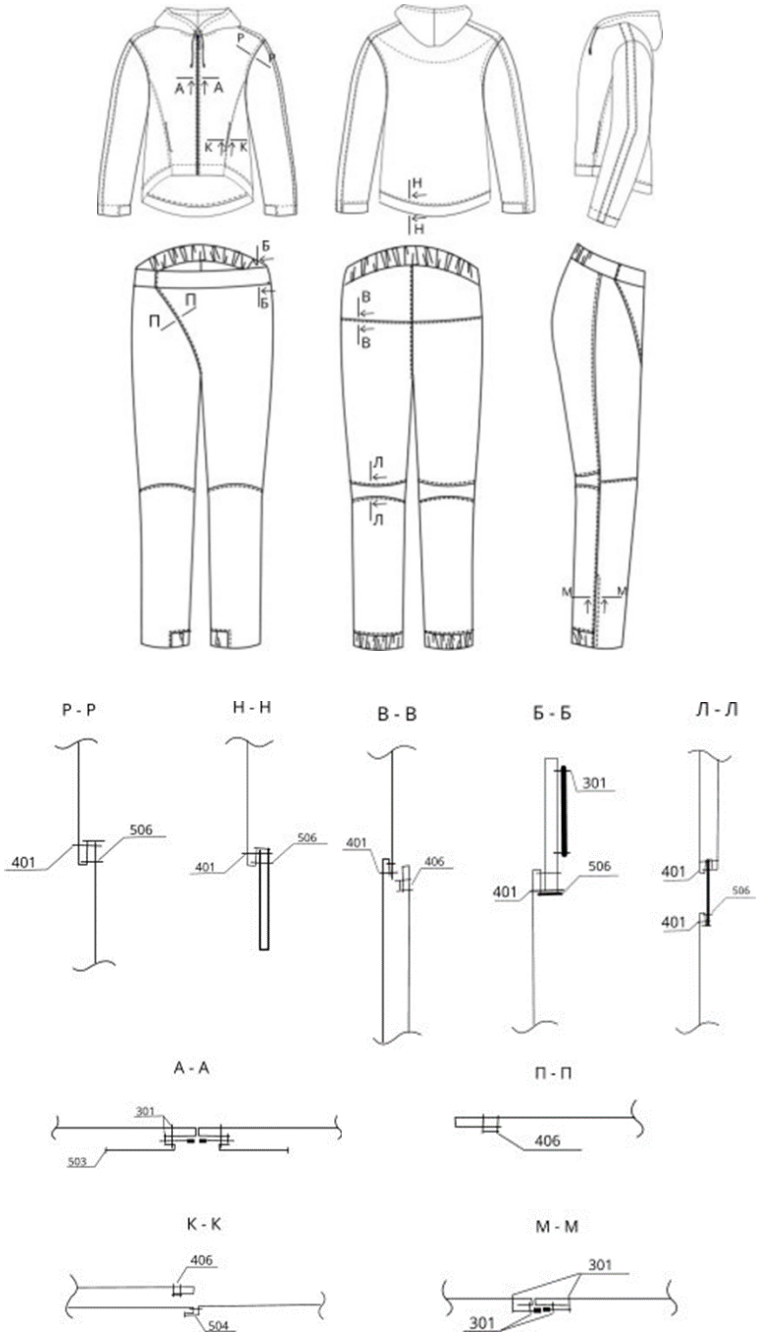

Fig. 8 Technical map of the main nodes of the adaptation kit for DP.

In order to get the most complete idea of the degree of influence of the adaptation kit on the physiological state of the spinal cord, the evaluation of the sample was carried out in stages. An experimental sample was made for the experimental using, which was corrected taking into account the wishes of the tester. At the first stage for testing the properties of the kit was tested in real operating conditions (Fig. 9). The degree of comfort in operation was determined by assessing the subjective feelings of the tester.

Fig. 9 Image of the adaptation suit on the DP.

The end result of the experimental investigation was the wish to change the design features, namely:

- zipper band on the bottom of the right pants for easy removal of the urinal;
- lengthening the back of the jacket;
- loops on the puller of the zipper (for easy grip with your fingers);
- straps at the bottom of the pants for a more comfortable fit.

Subjective assessment of DP sensations after wearing the adaptation kit was 97% positive.

4 Conclusions

The literature review indicates that despite the attention paid by scientists around the world to the chosen issue, the creation of comfortable adaptive clothing for various purposes remains an urgent science-intensive task that requires a comprehensive approach. The generalization of the data obtained as a result of the sociological survey suggests that the most important group of factors that determine the requirements for clothing for people with disabilities are functionality, comfort, quality of materials used and durability. Subsequent studies were aimed at meeting the requirements in the process of designing adaptive clothing. The results obtained during the research are highlighted in the following provisions:

- In accordance with the proposed factors, materials were selected for the manufacture of adaptive clothing from the range of modern knitted fabrics and a study of their defining properties. The obtained data allow varying the materials in their design for the manufacture of adaptive clothing, giving preference to certain properties and ensuring compliance with the functional environment;
- in order to prevent the development of complications caused by prolonged stay of the DP in a sitting position, the use of antimicrobial attachments is proposed;

- to assess the impact of the materials used on subjective perceptions of the comfort of using different types of materials in adaptive clothing, the latest approach using energy information technologies is proposed. The implementation of the chosen method allowed to establish the character of the influence of different raw materials on the biofield characteristics of the human body, although the scientific basis of this challenges remains as open task for scientists in the future;
- design and adaptation of an adaptive men's suit for everyday use was performed, taking into account the needs of aesthetics, ergonomics and socialization. Based on the study of operating conditions, an ergonomic design of jackets and pants for people using wheelchairs has been developed;
- variants of technological solutions will ensure the durability of the proposed model of the suit, as well as the use of inserts with antimicrobial treatment as an inner layer of clothing;
- experimental testing of the model allowed to confirm the success of the development and make some adjustments.

The study offers a conceptual basis for designing sportswear for wheelchair users. Further research will be aimed at unifying the research procedure and developing a methodology using digital technologies.

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