

ADAPTIVE CLOTHING DESIGN FOR INJURED PEOPLE

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ABSTRACT

Researchers have been paying increased attention to adaptive clothing as society's awareness of inclusivity and accessibility grows. This focus on adaptive clothing is particularly important for Ukraine, where there is a consistent need for products that cater to the needs of injured individuals. The research took a comprehensive approach to studying the issue. It involved engaging with hospital staff and patients with limb injuries to understand their exact requirements during treatment or rehabilitation after injuries. As a result of this collaboration, the gathered information became the foundation for creating men's clothing sets, which have been highly praised for their convenience and quality. This information can be used in future research on designing virtual adaptive clothing for individuals with limb amputations. The survey results can also assist clothing designers in effectively addressing the specific needs of consumers with limb injuries.

KEYWORDS

Adaptive design; Adaptive clothing; Injury; Disability; Virtual clothing; CLO 3D.

INTRODUCTION

According to the World Health Organization, 1.3 billion people live with significant disabilities, which represents 16% of the world's population or 1 in 6 individuals [1]. A portion of disabilities can be attributed to different types of injuries, whether intentional (caused by violence towards oneself or others) or unintentional (from road traffic accidents, sports, work-related risks, burns, falls, poisoning, etc.). Injuries result in about 5.8 million deaths worldwide every year – more than malaria, tuberculosis, and HIV/AIDS combined. However, hundreds of thousands of people suffer non-fatal injuries that can lead to various forms of disabilities [2].

According to a situation in Ukraine, the Office of the United Nations High Commissioner for Human Rights has confirmed that since February 22, 2022, a total of 19875 civil adults (an average of 542 people per month) and 1298 children have been injured. Men make up 60 percent of the adult casualties. 94% of adults were injured by explosive weapons with wide-area effects. It is important to note that the actual figures may be higher than reported [3].

Disabling injuries can result in either temporary or permanent disabilities. A temporary disability can be overcome with time or treatment. For example, a

bone fracture can significantly impair the use of a limb but will heal over time with proper treatment. On the other hand, permanent disabilities cannot be overcome. These include limited mobility [4], hearing loss, and limb amputation [5].

Considering the high prevalence of disabilities in our society, it is crucial to find ways to integrate individuals with injuries into their daily activities. Most people with disabilities have special clothing needs. Although the market for adaptive clothing is insignificant in the apparel marketplace, it has the potential for further growth [6]. Therefore, adaptive apparel developers require specialized skills and knowledge to create high-quality products for individuals with disabilities.

Conceptually, adaptive apparel relates to modified or customized apparel that accommodates the needs of people with disabilities and/or impairments [7]. Several researchers have explored a wide range of specific issues related to individuals with disabilities, including those with various physical disabilities and their caregivers. This encompasses wheelchair users [8-10], people with rheumatoid arthritis [11] or muscular dystrophy [12], those with scoliosis [13], people with Down syndrome [14], and their respective caregivers [7] [11] [14].

Losing functionality in a limb can be incredibly stressful and can lead to negative consequences.

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Many amputees experience depression. Approximately 40% of amputees also experience anxiety, and roughly 20% experience depression. Some common challenges for amputees include loss of desire to live, apathy, difficulty accepting their new reality, social withdrawal, insomnia, and phantom pains [15]. Successful rehabilitation involves collaborating with doctors, therapists, and psychologists to adapt physically and psychologically to the new situation. Clothing also plays a significant role in this process.

Adaptive clothing can facilitate dressing and minimize awkwardness when accessing clothing and footwear. It can include features that aid rehabilitation, such as targeted compression or support for specific body areas. Adaptive clothing improves the quality of life for individuals with limb injuries undergoing treatment and long-term rehabilitation, positively impacting their physical and psychological well-being.

Modern adaptive clothing designs prioritize style [7] [16] and individuality, offering fashionable options that do not resemble medical attire. This contributes to positive self-perception and seamless social integration.

Perspective research on adaptive clothing should address the clothing needs of different age groups. This includes understanding the specific functional and aesthetic requirements at each stage of life and how these needs might change over time. There is also a need to examine the demand for gender-neutral adaptive clothing, identifying the obstacles and opportunities for such designs in the market.

Another critical area of research is the connection between adaptive clothing and self-identity or self-expression. This involves exploring how clothing choices mirror personal style, enhancing psychological well-being, self-esteem, and confidence by addressing psychological barriers.

Adaptive design research can utilize various qualitative, quantitative, and mixed methods. The mixed methods are more effective and may entail a combination of in-depth interviews and surveys, focus groups and surveys, in-depth interviews and experiments, or solely surveys [7] [17]. Combining methods helps comprehensively understand consumer needs and preferences [7].

Consumer reviews and feedback should assess adaptive design solutions for specific groups of people with disabilities. Recommendations regarding the effectiveness of adaptive clothing and its impact on quality of life and social inclusion should be based on experimental designs and actual data. Advanced data analysis techniques can reveal complex relationships and trends, enhancing the depth of research insights. To create more effective solutions, it's essential to involve people with disabilities and other stakeholders in the research process [7] [18].

When talking about adaptive design, it is crucial to say that it is primarily user-centered design, based on concentrating the design process on consumers' needs and limitations. Designer analysis and prototyping are central to the user-centered design framework, allowing users to engage with physical products in a real-world environment [7].

Another perspective method used in adaptive design is digital 3D Computer-Aided Design (CAD). A crucial feature of digital 3D CAD systems is their precision and digital prototyping, which allow designs to be created with minimal waste and directly start production from a digital model. This opens new opportunities for applying zero-waste design practices and allows for managing textile resources while allowing design experimentation [17] [19] [20]. One popular 3D software is CLO, which has 86 international companies listed as its users [21].

3D CAD systems were also used to prototype adaptive clothing digitally [22]. Researchers have used scanning technology, modelling, and reconstruction techniques to create a 3D body model sitting for virtual prototyping. This research showed how effective 3D CAD systems can be for virtually prototyping individual garments for paraplegics and how 3D tools can be used in adaptive design.

Ergonomic design [23] and new materials [24] [25] can improve comfort and functionality in adaptive clothing, meeting the needs of people with disabilities. Soft, stretchy textiles have been used in adaptive clothing production, offering enhanced comfort, pain reduction, body conformity, pressure alleviation, and minimized skin irritation. However, innovative features such as magnetic closures, adjustable fittings, shape memory alloys [26], and nano- [27] or e-textiles [28] can provide additional possibilities for adaptive clothing.

The researchers [8-14] have studied various challenges, focusing on specific types of disabilities and identifying specific apparel attributes that meet the functional and aesthetic needs of consumers with disabilities. Functional features encompass a diverse range of elements that enhance the performance and usability of garments, often leveraging cutting-edge technology and innovative materials to improve comfort, durability, and overall functionality [7] [29]. Using Velcro, magnetic fasteners, zippers, buttons, laces, adjustable parts (pants, sleeves, belts, cuffs), and elastic components simplifies the dressing process, especially for people with limited mobility or those needing assistance [14] [30] [31]. Additionally, adaptive clothing can have adjustable elements that can be customized to accommodate changes in body size and shape, allowing for variations due to swelling or weight fluctuations. The unique designs facilitate hygiene procedures without removing clothing, which is crucial for individuals in long-term body recovery. This comfort and independence in clothing enhance

a customer's dignity, self-control, and confidence [31].

Meanwhile, aesthetic attributes pertain to the visual and design-related components (style, fit, and adaptability to specific needs and body types [29] [32]) that contribute to the overall visual appeal and suitability of clothing for individuals with disabilities. In the study [32], during the analysis of responses regarding satisfaction with clothing for girls with disabilities, it became clear that the girls' ability to express themselves and the aesthetic aspects of their clothing were crucial, showing the importance of allowing them to express their individuality and feel good about their appearance. Functional aspects of putting on and taking off garments, especially fasteners, were also identified as significant issues. Thus, researching the aesthetics and functionality of adaptive clothing is essential to ensure consumers' overall satisfaction and comfort.

The research aims are to create specialized clothing that addresses the individual needs of people with injuries. The future of research lies in the thorough development and effective implementation of adaptive design methods that cater to a wide range of disability types, including permanent or temporary physical impairments resulting from injuries. Additionally, it is essential to solve this issue with a comprehensive, user-centered design framework to dialog with apparel designers and consumers with disabilities. It will enable the creation of adaptive apparel that meets their specific needs and preferences concerning apparel design [7].

Our scientific research involves analyzing existing clothing, understanding common injuries, and developing functional solutions for adaptive clothing. The study's tasks include conducting surveys with patients, doctors, and rehabilitation specialists, creating virtual models and patterns for adaptive clothing, and evaluating the clothing sets with input from patients and experts.

METHODOLOGY

The research on adaptive apparel has mainly focused on the design processes and methodologies involved [7]. The research plan comprised four stages of the standard user-centered design process: planning, analysis, creation, and verification [33]. In the planning stage, our multidisciplinary team of experts has planned a survey and interviewed stakeholders.

During the survey planning stage, a team of experts, including researchers, a sewing business owner, a psychologist, and a rehabilitation specialist, collaborated to ensure that the survey questions were formulated accurately and clearly. The questionnaire underwent testing with two amputee patients who had completed treatment and were in the rehabilitation stage. Their feedback and suggestions were instrumental in enhancing the questionnaire.

For the adaptive design, we used a mixed-method study [18], which included surveys and experiments to comprehensively understand adaptive clothing for consumers. We employed analysis, synthesis, comparison, data generalization, explanation, a systematic approach, and description during the research. Stakeholders were divided into two categories: (S1, $N_{S1}=30$) the hospital staff and (S2, $N_{S2}=20$) the injured patients. These groups were determined based on their involvement in the treatment and rehabilitation process and the possibility of their use of adaptive clothing during this period. Group S1 consisted of doctors and rehabilitation specialists with varying experience working with injured patients. We created two surveys tailored to their roles, each containing two question blocks (Table 1).

In our survey, the main aspects affecting adaptive design for injured individuals were:

- the types of injuries in the current treatment and rehabilitation process;
- the percentage of limb loss after injuries;
- the garment elements for enhancing clothing functionality.

The questions QN5, QN12-QN13, and QN16-QN28 had visualizations (Fig. 1) to help the respondents precisely imagine the garment elements.

The next step involved conducting a detailed analysis of the survey results and forming essential conclusions. During the creation stage, the team developed multiple design solutions by leveraging 3D technologies and creating physical prototypes for testing. The final part of the design process involved evaluating the design and technology through user testing after two weeks of adaptive clothing utilization.

RESULTS AND DISCUSSION

General information about respondents (QB1)

We gathered data from 30 hospital staff members and 20 injured patients (men) and analyzed the survey results using Microsoft Power BI, a data visualization software.

The survey findings revealed that a significant majority (90%) of the hospital staff (S1) were under the age of 30 (Fig. 2). Our research suggests that this demographic has limited professional experience, typically less than two years. This can explain the rise in the number of injured individuals after 2022, leading to an increase in inexperienced rehabilitation specialists.

The hospital staff's opinion on common injuries (Fig. 3, a) shows they are combined arm and leg wounds. Specifically, 70% of injured patients used adaptive clothing during their treatment. Furthermore, 90% of the patients wore non-adaptive clothing, such as sports pants and T-shirts, during rehabilitation (Fig. 3(b)).

Table 1. Sample interview questions.

Question block	Stakeholders	Question Number (QN)	Sample Questions
General information about the respondents (QB1)	The hospital staff (S1)	QN1	Enter your age
		QN2	How many years of experience do you have working with injured patients?
		QN3	What are the most common injuries that your patients have?
		QN4	Did your patients use adaptive clothing?
		QN5	What are the most commonly used types of clothing by your injured patients in the rehabilitation process?
	The injured patients (S2)	QN6	Enter your age
		QN7	What injury do you have?
		QN8	Do you have a limb amputation?
		QN9	Which limb did you lose?
		QN10	Do you have casts on your limbs?
		QN11	Do you have bandages on your limbs?
		QN12	Do you require clothing with features that make dressing and undressing easier?
		QN13	Have you worn clothes with features that make dressing and undressing easier?
		QN14	Is adaptive clothing needed for injured people?
The requirements for adaptive clothing for the injured people (QB2)	The hospital staff (S1), the injured patients (S2)	QN15	If you have previously used adaptive clothes, please rate their convenience on a 5-point scale: "5" - very convenient, "4" - convenient, "3" - neutral, "2" - inconvenient, "1" - very inconvenient.
		QN16	What sleeve length would be convenient?
		QN17	Would it be comfortable to wear a shirt that can be transformed into a T-shirt by unbuttoning the lower part of the sleeve?
		QN18	Is it comfortable to wear clothes with a fastener along the sleeve?
		QN19	Would clothing with a fastener at the bottom of the sleeve and in the side seam be more convenient?
		QN20	Would using fasteners on the shoulders and sides for injuries be more convenient?
		QN21	Which fastener (-s) in adaptive T-shirts is (are) more convenient?
		QN22	Would using a garment with a zipper insert to expand the sleeve make the dressing process more accessible and convenient?
		QN23	Would wearing pants with a side seam zipper be convenient?
		QN24	What is the most comfortable position when fastening adaptive pants?
		QN25	Would pants that transform into shorts be comfortable for an injured person?
		QN26	Would wearing pants with a back zipper be convenient?
		QN27	Which fastener (-s) in adaptive pants is (are) more convenient?
		QN28	Would using pants with a zipper insert to expand the leg make the dressing process more accessible and convenient?

27. Which fastener (-s) in adaptive pants is (are) more convenient? (choose one or several options)



Figure 1. The example for question QN27 with pictures.

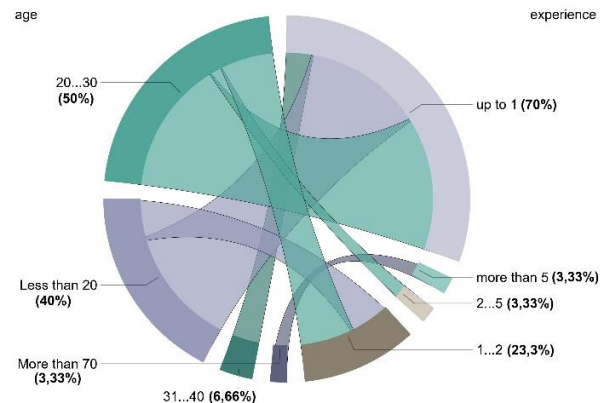


Figure 2. The hospital staff presentation by age and experience working with injured patients.

Half of the respondents in group S2 were between 20 and 40 (Fig. 4). Notably, 50% of the injured individuals utilized adaptive clothing in the treatment and rehabilitation. Furthermore, an overwhelming 95% of the respondents did not have casts on their limbs, and only 20% had bandages.

The information regarding the types of injuries and the proportion of limb loss resulting from those injuries is crucial for understanding the varying levels

of restricted body mobility within the population and the associated challenges in creating adaptive clothing for this consumer group.

The survey analysis indicates that 20% of individuals experienced no limb injuries and maintained their body mobility despite other injuries. Additionally, some respondents (S2) reported limited mobility (25%) due to injuries to one arm or leg.

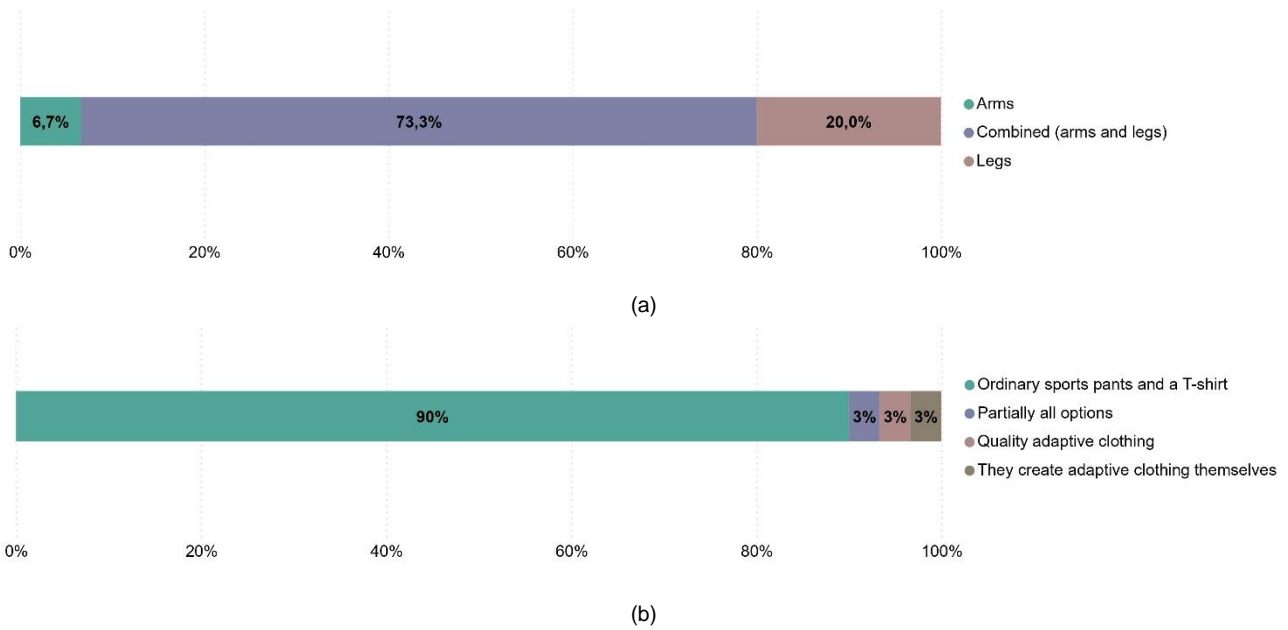


Figure 3. The hospital staff's opinion on common injuries (a) and the most used clothing of the wounded during rehabilitation (b).

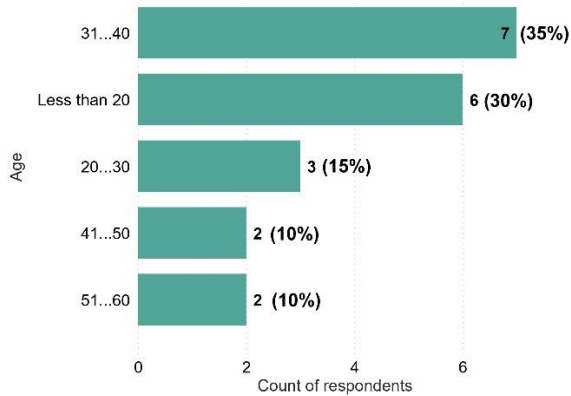


Figure 4. The injured patient's presentation by age.

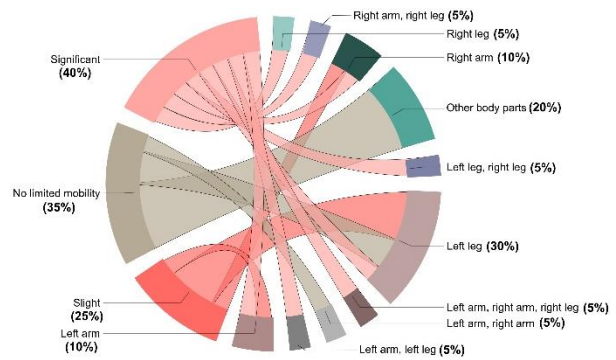


Figure 5. The relationship between limited body mobility and injury types.

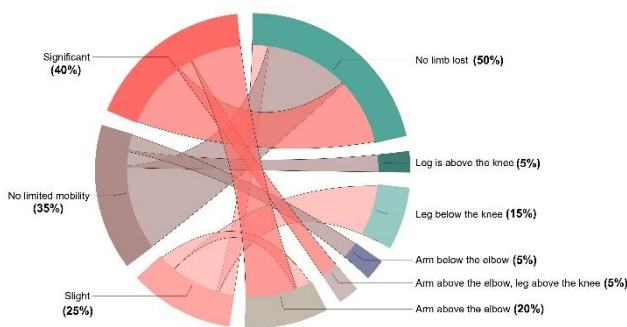


Figure 6. The relationship between limited body mobility and lost limbs.

Furthermore, the study revealed that 40% of people experienced significantly restricted mobility, with 20% of them having sustained combined limb injuries.

The relationship between limited body mobility and injury types is presented in Fig. 5. The research results show that 50% of respondents (S2) lost one or

two limbs. 80% of patients with lost limbs had varying degrees of limited body mobility. However, some patients had significantly limited mobility without limb amputations (Fig. 6). The general data gathered about the participants in both groups (S1 and S2) has insights into the precise nature of the injuries sustained, the significant challenges in mobility faced by the injured individuals, and the urgent requirement for customized adaptive clothing to cater to their specific needs. This comprehension provides solutions to the hurdles associated with creating adaptive designs tailored to meet the needs of this particular consumer group.

The requirements for adaptive clothing for the injured people (QB2)

The second question block provides information regarding whether injured individuals require adaptive clothing. In a survey, 70% of hospital staff believed that adaptive clothing is essential for injured patients, citing the need for comfortable and

convenient attire that accommodates medical equipment and assists patient care. Conversely, 30% thought that adaptive clothing is required only in specific situations, emphasizing the importance of flexibility and adaptability in providing tailored care to patients with diverse needs.

Question QN15 involves rating the convenience of the garments on a 5-point scale to evaluate the current adaptive clothing. According to the scale, "5" indicates that the garment was very convenient, "4" for convenient, "3" for neutral, "2" for inconvenient, and "1" indicates it was very inconvenient.

Fig. 7 and Fig. 8 depict the results of respondents S1 and S2 evaluating current adaptive clothing.

Hospital staff opinions regarding existing adaptive clothing indicate that 36.6% find it very convenient, while 3% consider it neutral. Amongst patients, only 15% perceive adaptive clothing as highly convenient. However, some respondents (S1 – 26.6%, S2 – 45%) did not provide an answer to this question. This could be because some staff members may not have observed the use of adaptive clothing, or some patients may not have had experience with these items before the survey.

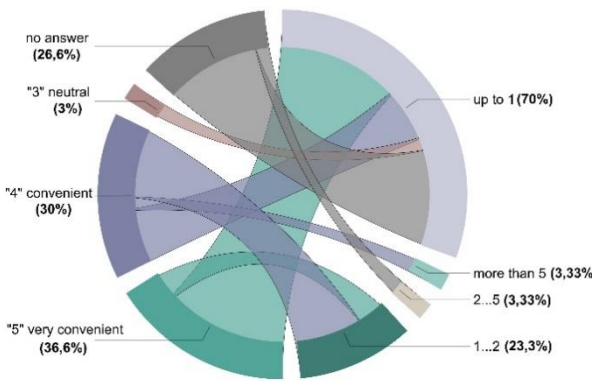


Figure 7. The relationship between evaluating existing adaptive clothing and hospital staff's experience.

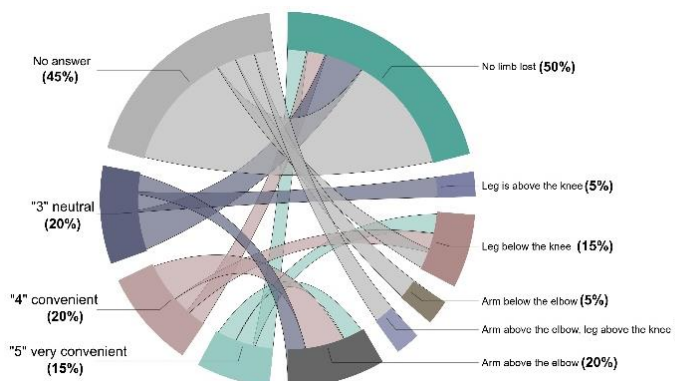
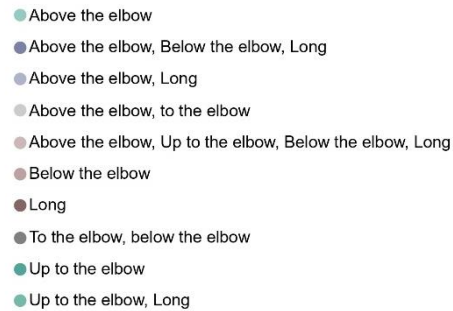
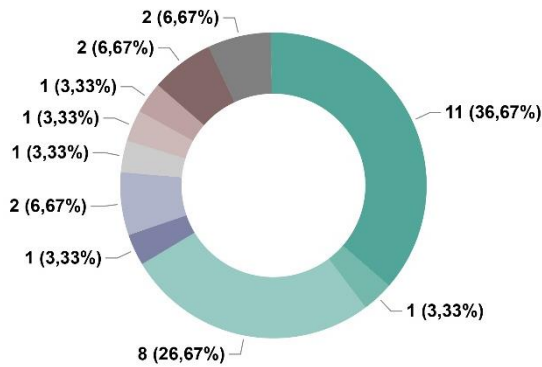
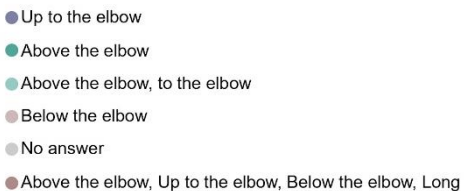
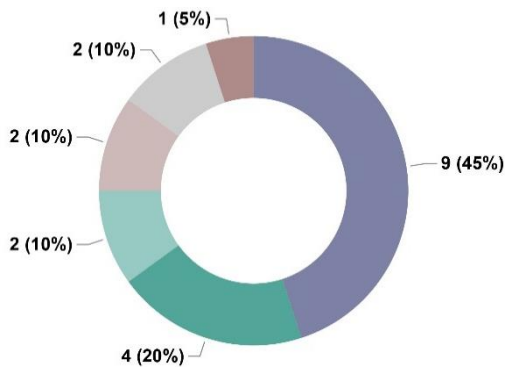


Figure 8. The relationship between evaluating existing adaptive clothing and availability of limbs.



(a)



(b)

Figure 9. The preferred sleeve length of adaptive clothing by the insights from surveys S1 (a) and S2 (b).

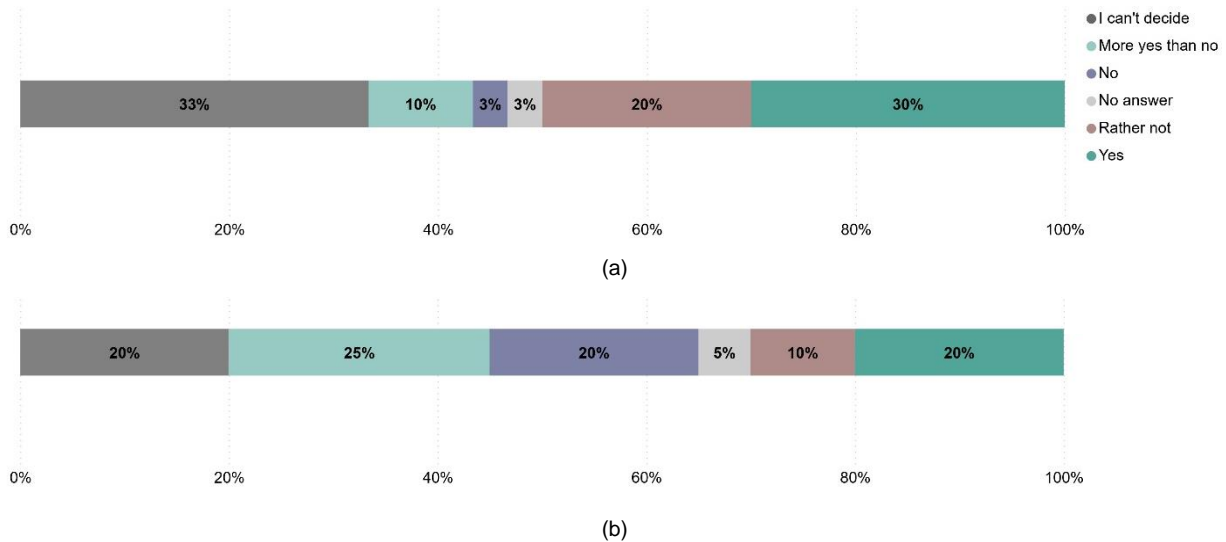


Figure 10. The respondents' opinions about widening pants legs by zipper fasteners.

Questions QN16-QN28 focused on features that improve clothing functionality through the garment elements. Fig. 9 illustrates survey results for optimal sleeve length.

According to the survey, 10% of hospital staff and 25% of injured patients expressed that they found the idea of wearing a shirt that could be converted into a T-shirt by unbuttoning the lower part of the sleeve comfortable and convenient. Meanwhile, 3.33% (S1) of the respondents from one group and 20% (S2) from another group mentioned that they did not find this clothing design convenient. 16.67% of respondents in both groups haven't determined the answer.

Based on the survey results, 40% of respondents (S1) and 50% (S2) preferred clothes with a fastener along the sleeve, indicating that they find this feature comfortable. Additionally, 6.66% of respondents (S1) answered "No" when asked about their comfort level with this type of clothing.

Clothing with a fastener at the bottom of the sleeve and in the side seam would be convenient for S1 (26.67%) and S2 (45%). Various fasteners secure the garment's shoulders and sides. This design decision was approved by 60% (S1) and 50% (S2).

Our research identified more user-friendly fasteners for adaptive T-shirts: Velcro (S1 – 32%, S2 – 28%), zipper (S1 – 13%, S2 – 30%), and press stud (S1 – 25%, S2 – 20%); for adaptive pants: Velcro (S1 – 43%, S2 – 22%), zipper (S1 – 24%, S2 – 45%), and press stud (S1 – 30%, S2 – 30%).

Adaptive clothing incorporates elements that allow certain garment parts to expand, such as using a zipper fastener to extend the sleeves or legs. Our research revealed that 27% (S1) and 30% (S2) of participants expressed positive views about using zipper fasteners to make sweatshirts and hoodies more accessible and convenient. Meanwhile, 30%

(S1) and 20% (S2) approved similar elements for pants (Fig. 10).

Our research found that the most comfortable ways to fasten adaptive pants are from the hip to the bottom (S1 – 41%, S2 – 30%) and from the top to the bottom (S1 – 35%, S2 – 30%). Fasteners from the knee to the bottom were preferred by 15% of S1 and 27% of S2. Additionally, 27% of S1 and 35% of S2 respondents preferred pants that can transform into shorts. On the other hand, 40% of S1 and 45% of S2 found pants with a back zipper to be inconvenient. However, 63% of S1 and 50% of S2 found pants with a zipper fastener in the side seams to be comfortable.

This information provides insights into the most common elements of garments that can be utilized in the adaptive design process.

Adaptive clothing design

The survey's results again affirm the pressing need for developing high-quality adaptive clothing that considers the specific requirements of patients, their caregivers, and medical professionals. The authors have put forward two sets of adaptive clothing designed to be worn together, catering to both summer and transitional seasons. These sets have been specifically designed to cater to the needs of men aged 18 and above, incorporating consumer preferences from our survey. Figure 11 presents a visual representation of the developed adaptive clothing sets.

A demi-season set consists of a hooded sweatshirt and pants (Fig. 11, a), a summer set of clothes consists of shorts and a T-shirt (Fig. 11, b), and a mixed set consists of a summer T-shirt and demi-season pants (Fig. 11, c).

The adaptive garments are loose-fit and designed to accommodate changes in injured patients' body sizes and shapes, allowing for variations due to swelling or weight fluctuations common during treatment and

rehabilitation. The garment features additional Velcro openings in strategic locations, such as the side seams of the pants, T-shirt, hoodie, shoulder seams, and sleeve top, specifically designed for easy access to medical devices and catheters without requiring complete undressing. These deliberate design elements not only ensure unhindered access to medical interventions but also facilitate hygienic procedures without necessitating the removal of the garment, thereby playing a vital role in ensuring optimal care for patients undergoing long-term recovery.

Using the CAD Julivi, we developed patterns of adaptive clothing (Table 2). For men, we used sizes L—XL. The resulting patterns were dressed in 3D male models using Clo 3D Fashion Design Software to evaluate the fit of products and all design solutions of adaptive clothing from Fig. 11.

Knitted double-thread fabric (250 GSM) with an extensibility of 10% was used to produce experimentally developed adaptive clothing, namely, a hoodie, pants, and shorts. A plain cotton jersey fabric was used to produce a T-shirt. Accessories for fasteners were Velcro and laces for additional fixation of pants and shorts at the waist. After interview meetings with doctors and hospital patients, feedback on the newly designed adaptive clothing was given. These interviews suggested further expanding the legs and sleeves and adding another Velcro fastener location. They also emphasized the importance of using Velcro with high-quality adhesive properties.

After the recommended design alterations were incorporated, a specialized adaptive clothing batch was manufactured and distributed to hospital patients. Subsequently, a survey was conducted, involving in-depth interviews with nine male patients aged 20 to 45 who had been utilizing adaptive clothing for two

weeks. Seven respondents reported having sustained leg injuries, while one patient had an arm injury, and another had a spinal injury, resulting in the inability to use both legs.

The survey asked participants to rate the convenience of developed adaptive clothing, the manufacturing quality, the textile quality, and the quality of the textile fastener on a five-point scale: "5" – very high quality/convenience; "4" – satisfactory; "3" – average; "2" – low; and "1" – poor quality/inconvenient. The survey results are shown in Figure 12.

The evaluation results indicate that the patients expressed high levels of satisfaction with the quality and convenience of the proposed adaptive clothing. Specifically, 89% of the surveyed individuals deemed the clothing to possess a high or satisfactory level of convenience, textile quality, and textile fasteners. Furthermore, all respondents, accounting for 66.7%, recognized the high production quality of adaptive clothing.

In addition, the respondents highly evaluated the quality of the textiles (44.4%) and the quality of the Velcro (77.8%), confirming the choice of high-quality materials for the production of adaptive clothing.

Among the various recommendations for enhancing adaptive clothing quality, the surveyed individuals emphasized the importance of using thinner and lighter textiles for manufacturing shorts. This suggestion was mainly motivated by high ambient temperatures above 30°C during summer.

In conclusion, the alterations made to the design of adaptive clothing have notably improved its overall convenience. Additionally, the meticulous selection of textiles and accessories was identified as crucial to ensuring high-quality adaptive clothing.



Figure 11. Adaptive clothing 3D models designed in Clo 3D: demi-season set (a), summer set (b), mixed set (demi-season pants and summer T-shirt) (c).

Table 2. Structural features of the developed adaptive clothing.

Product	Pattern screens of products developed in CAD Julivi
Shorts, pants	
T-shirt	
Hoodie	

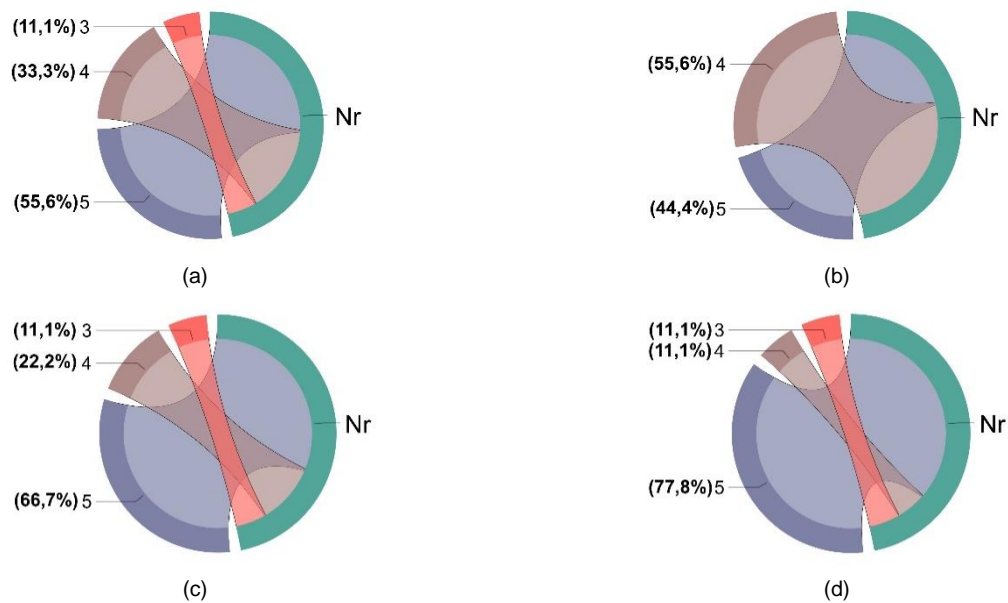


Figure 12. The evaluation of developed adaptive clothing by convenience (a), textile quality (b), production quality (c), and Velcro quality (d): Nr – total number of respondents (Nr=9); 3 – average, 4 – satisfactory, and 5 – high level.

CONCLUSIONS

Based on the literature analysis, it is evident that the field of adaptive clothing design is gaining attention from researchers due to the increasing societal focus on inclusiveness and accessibility. This heightened interest in adaptive clothing is especially important for Ukraine, where now there is a continuous demand for products that cater to the needs of injured individuals.

The research used a comprehensive approach, including engagement with hospital staff and patients with limb injuries to understand their exact requirements during treatment and rehabilitation. This collaboration provided insights into the nature of the patient's injuries, the deficiencies of their current clothing, and their preferences for functional solutions in adaptive clothing.

The information obtained was the foundation for creating sets of men's adaptive clothing, including sweatshirts, pants, T-shirts, and shorts. Considerations were made regarding the placement of cuts in the products, the type of fastenings, transformability, and the sizes and locations of individual parts. A post-wear survey conducted after two weeks confirmed the effectiveness of the developed adaptive clothing sets, with patients expressing high levels of satisfaction with their comfort and quality. The results of this study offer valuable guidance for adaptive clothing designers to address the specific needs of consumers with limb injuries effectively.

This research promotes accessibility and inclusivity by providing comfort and fostering opportunities for personal development among individuals with various limb injuries. The insights gained from this study will be utilized in future research on designing virtual adaptive clothing for individuals with limb

amputations. Moreover, we aim to focus on future studies incorporating principles of circular economy and multifunctionality into the design and production of adaptive clothing, further advancing the field in a sustainable and impactful manner.

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