

# Assistive Devices and Clothing: Exploring Adaptive Clothing Needs for Women with Lower Limb Prostheses Using the FEA Model

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**How to cite this paper:** Al Asmari, M. and Zedan, M. (2024) Assistive Devices and Clothing: Exploring Adaptive Clothing Needs for Women with Lower Limb Prostheses Using the FEA Model. *Open Journal of Applied Sciences*, 14, 2901-2922.

<https://doi.org/10.4236/ojapps.2024.1410190>

**Received:** September 20, 2024

**Accepted:** October 25, 2024

**Published:** October 28, 2024

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## Abstract

This study aimed to comprehensively investigate the essential considerations in designing adaptive clothing for women with lower limb prostheses in Saudi Arabia. Employing a qualitative methodology, the research entailed semi-structured, in-depth interviews with women utilizing lower limb prostheses and prosthetic specialists. This approach was selected to unearth pivotal design prerequisites and comprehend the specific challenges these women encounter within the realm of clothing. The utilization of selective sampling facilitated the collection of intricate and valuable insights. A Functional, Expressive, and Aesthetic (FEA) User Needs model was utilized to scrutinize participant feedback. Functional requisites encompass ease of dressing and undressing, accessibility to the prosthetic limb, comfort, mobility with the prosthesis, and appropriate fit. Additionally, participants highlighted various expressive needs, including privacy preservation, modesty, camouflaging disability appearances, maintaining alignment with non-disabled women's fashion, and considerations about the aesthetic aspects of garments.

## Keywords

Assistive Devices, Adaptive Clothing, Lower Limb Prosthetics, Functional, Expressive, and Aesthetic (FEA) Model

## 1. Introduction

One in seven people worldwide has a disability, making it a significant global health concern. The World Health Organization estimates that 1.3 billion people around the world live with a significant disability [1]. Among these disabilities is physical impairment due to limb amputation, and the number of people experiencing limb loss is expected to more than double by 2050 [2]. This increase is

attributed to various factors, including accidents, diabetes, surgeries necessitating amputation, and peripheral artery diseases [3]. The loss of lower limbs adversely affects physical function, as well as mental and social health [4]. Consequently, prosthetic limbs are vital for the rehabilitation and restoration of amputees' abilities to perform daily activities, thereby enhancing their quality of life [5].

In a study on lower-limb prosthetic users, women reported difficulty accepting the prosthesis, feeling it did not align with a feminine appearance and restricted their choice of feminine clothing [6]. The physical challenges faced by people with disabilities often lead to significant difficulties in finding clothing that meets their needs [7] [8]. The absence of suitable clothing creates barriers that affect their overall quality of life. Therefore, researchers have started to explore the needs and preferences of people with disabilities to design and develop adaptive wearable products that address these requirements. Research into disabilities and the clothing challenges faced by people with disabilities can lead to improvements in their daily lives [9].

Carroll and Kincade [10] noted that integrating individuals with multiple physical disabilities into market research is both challenging and complex due to their diverse needs and physical limitations. While most studies have focused on the needs of various categories of people with disabilities, there is a lack of research specifically addressing the needs of women using prosthetic limbs. One notable study by Ipaye and Eckerson [11] aimed to design sportswear for female amputees using prosthetics. This study concluded that creating clothing for prosthetic limb users is a complex issue requiring a comprehensive understanding of their needs from all perspectives before starting the design process. While Wang [12] developed adaptive trousers for individuals with leg length discrepancies (LLD) who use prosthetic legs. Although these studies addressed clothing for prosthetic users, Ipaye and Eckerson [11] did not cover the expressive needs of users, which is one of the main aspects that the current research focuses on. Meanwhile, Wang [12] emphasized that the final product only met the needs of participants with LLD who wore elevated shoes and did not address the needs or preferences of participants who used prosthetic legs, highlighting the need for further research with a broader participant base. Additionally, no studies have explored the clothing needs of this group of users in the same cultural context as the current research, where cultural considerations are a significant aspect emphasized by the FEA model.

In this context, the aim of the current research is to explore the needs that should be considered when designing adaptive clothing for women using lower-limb prosthetics in Saudi Arabia. This was achieved through semi-structured interviews with 11 users, using the Functional, Expressive, and Aesthetic (FEA) model of user needs to understand and identify their specific requirements.

## **2. Literature Review**

### **2.1. Adaptive Clothing**

Individuals who deviate from the “standard” user model often face obstacles when

using ready-made consumer goods, particularly fashion and clothing products. These items need to be specially designed to ensure comfort, safety, and overall well-being [13]. Ready-made clothing is frequently unsuitable and non-functional for individuals with disabilities. As the global prevalence of disabilities increases, there is a growing need for clothing design that caters to the unique requirements of people with physical disabilities [14]. Adaptive clothing can address these needs effectively.

“Adaptive clothing” refers to garments specifically designed to accommodate the physical limitations of individuals who struggle with dressing and undressing due to movement difficulties or issues managing closures [15].

## 2.2. The Importance of Adaptive Clothing for Individuals with Physical Disabilities

Adaptive clothing helps address the various functional challenges faced by individuals with disabilities. It supports their independence in putting on and taking off clothes and contributes to enhancing their self-confidence and self-esteem [14]. Moreover, adaptive clothing improves functional performance, provides exceptional comfort, and reduces physical effort and burden on caregivers [16] [17]. Wang *et al.* [8] and Kratz *et al.* [18] have demonstrated that adaptive clothing positively impacts daily, and sports activities compared to non-adaptive clothing. It also benefits the emotional, social, and physical health of individuals with disabilities [19]. [7] [12] [20] [21] indicate that individuals with disabilities who use medical and assistive devices, such as prosthetics or feeding tubes, often prefer clothing that conceals these devices. They seek adaptive clothing designed to accommodate these devices, as hiding their disabilities helps them present themselves more favorably in social situations and appear more like non-disabled individuals. Adaptive clothing also enhances social participation and integration into society, as individuals gain confidence when wearing clothing suited to specific activities or events. Conversely, the lack of suitable clothing can act as a barrier to social participation and exacerbate the challenges faced by individuals with disabilities [15] [22]. Similar findings were reported by McBee-Black and Ha-Brookshire [23], which highlighted that clothing plays a crucial role in the workplace participation of individuals with disabilities. Inappropriate clothing can hinder workplace participation, increase social stigma, and diminish self-efficacy.

The preceding discussion underscores the importance of adaptive clothing in addressing the challenges faced by individuals with disabilities and its multifaceted positive impact on their lives, emphasizing the relevance of the current research. To overcome these challenges and achieve the benefits outlined in the studies, it is essential to thoroughly investigate the needs of the target group, considering all aspects addressed by these studies. Neglecting any of these aspects can affect users' acceptance of adaptive products. Chae [24], Miller [25], Chae [26], Elena *et al.* [27], and Suri [28] have shown that individuals with disabilities are often dissatisfied with current adaptive clothing options, which are limited and

fail to meet their diverse needs and preferences. Furthermore, existing options do not adequately consider factors such as age or body type. Consequently, the FEA model was employed as a framework in the current research.

### 2.3. FEA Consumer Needs Model

The Functional-Expressive-Aesthetic (FEA) consumer needs model is an integrated, user-centered design framework used to identify end-user needs and establish design criteria [29]. Originally developed as an educational tool to help design students visualize the design process, the FEA model (Figure 1) has been applied in numerous studies related to functional clothing for people with disabilities [12] [24] [26] [28] [30].

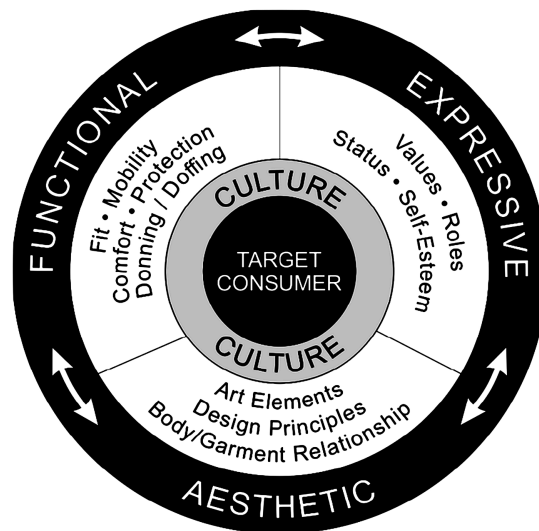


Figure 1. FEA consumer needs model [29].

In this research, the FEA model was employed to address the question: What clothing needs should be considered when designing adaptive clothing for women who use lower-limb prosthetics? The Functional needs focus on the practical aspects of clothing, including comfort, fit, safety, mobility, ease of dressing and undressing, and access to closures. Expressive needs pertain to the symbolic and communicative functions of clothing, such as reflecting personal values, social roles, social status, and enhancing self-esteem and confidence. Clothing serves as a non-verbal communication tool that allows individuals to express their identity and engage socially, emphasizing its role in conveying various messages. Aesthetic needs, on the other hand, relate to the physical attributes of clothing—such as color, design lines, texture, fabric, and pattern—that contribute to creating a design that incorporates artistic elements, design principles, and the interaction between the body and clothing. Balancing aesthetic features in clothing provides the wearer with a sense of psychological satisfaction [29], while the color and shape of clothing significantly influence first impressions [31].

Based on the aforementioned studies, researchers have highlighted the importance

of examining the needs of users with disabilities through the lens of the Functional-Expressive-Aesthetic consumer needs model. This approach reflects a growing interest in designing clothing that addresses all aspects of user needs, rather than focusing exclusively on functional requirements. Thus, the FEA model is crucial for identifying the adaptive clothing needs of women who use lower-limb prosthetics.

#### 2.4. Cultural Context of Saudi Arabia and Prostheses

Cultural norms and values in Saudi Arabia that are deeply rooted in Islamic traditions influence the clothing choices of women. Modesty is a central cultural value that shapes the dress code for women, emphasizing the need for loose-fitting garments that cover the body [32]. This norm is particularly important for women with prosthetic limbs, as they may prefer clothing that not only adheres to modesty standards but also provides additional privacy for their prostheses. However, the challenge lies in balancing modesty with functionality and aesthetic preferences. Many women prefer adaptive clothing that allows ease of movement and comfort while still appearing fashionable and respectful of cultural standards.

Cultural influences also affect the fabric choices and color schemes. In Saudi Arabia's hot climate, lightweight, breathable materials that facilitate comfort are preferred, especially in adaptive clothing. Moreover, the evolving fashion industry in the region has led to a rising demand for adaptive garments that reflect modern styles, allowing women with prosthetics to dress in ways that resemble able-bodied peers without sacrificing modesty or cultural appropriateness.

In sum, the cultural context of Saudi Arabia creates a unique intersection between modesty, functionality, and aesthetic needs for women with prostheses, requiring adaptive clothing designs that respect tradition while offering personal empowerment.

### 3. Methodology

Since this study is exploratory in nature, qualitative methods were employed to gain a deeper understanding of the phenomenon from the perspectives of the individuals directly involved, especially given the limited existing knowledge [33] [34]. Semi-structured and in-depth interviews were conducted with women who use lower-limb prosthetics and prosthetics specialists to identify key needs for designing adaptive clothing and to understand the clothing constraints faced by users. Purposive sampling was used to gather rich and valuable information, as qualitative research emphasizes the quality and depth of data rather than the quantity of participants [35]. Accordingly, a small sample size was utilized in this research, consistent with several studies on adaptive clothing for people with special needs [24] [36]-[38]. These studies support the use of a small sample size in the current research.

Qualitative interviews were chosen as the initial methodology because they allowed for an in-depth exploration of the personal experiences, preferences, and

challenges faced by women using lower-limb prosthetics in Saudi Arabia. However, the second part of the study will incorporate both qualitative and quantitative approaches through a mixed-methods design. A survey will be conducted to quantitatively evaluate the adaptive clothing designs, gathering feedback from a larger sample to measure satisfaction levels, functionality, and aesthetic appeal. This combination of methods will offer a more comprehensive analysis, as the survey results will complement the detailed findings from the qualitative interviews, providing broader insights into the preferences and effectiveness of the proposed clothing designs.

#### 4. Participants

The recruitment process for this study, assisted by the Amputee Care Association (Butor), ensured a diverse sample of participants by including women with varying experiences in terms of amputation levels, prosthetic types, and assistive device usage. The sample consisted of 11 women with lower-limb prostheses, with different amputation levels—either above the knee or through the tibia—providing insight into how amputation type affects adaptive clothing needs. Most participants used endoskeletal prostheses, which were the most common, while three participants used exoskeletal prostheses. This variation in prosthetic types allowed the study to capture a range of experiences regarding functionality and comfort.

The study included participants who used other assistive devices, such as wheelchairs or crutches, when not wearing their prosthetic limbs, to further diversify the sample. The extent of adaptation to prosthetic limbs also varied among the participants. Nine women only used assistive devices when removing their prosthetic limbs, while three others wore their prosthetic limbs for shorter periods, supplementing their mobility with other devices throughout the day. This range of experiences provided a comprehensive understanding of how the need for adaptive clothing may differ based on the duration of prosthetic use and reliance on other assistive devices.

The participants' ages ranged from 21 to 58, and this was intentional to ensure a wide age representation to reflect differences in lifestyle, aesthetics, and functional requirements across various life stages. Furthermore, the focus on women in the sample was intentional, as research indicates that women face unique challenges in adapting to prosthetic limbs compared to men [6] [39]. Gender was a critical consideration, as studies have shown that women with prosthetic limbs often aim to maintain an elegant and feminine appearance while minimizing the visibility of their disability [40]. Additionally, the study focused on lower-limb prosthetic users, as lower-limb amputations account for approximately 85% of all amputations, making it a more prevalent condition to study [41].

Interviews were also conducted with two prosthetics and orthotics specialists from King Abdulaziz University to enhance the study's perspective. Their insights added a medical dimension to the understanding of how prosthetic limbs interact with clothing, further enriching the study's findings (see Appendix).

## 5. Research Ethics

Ethical considerations are a fundamental aspect of qualitative research, encompassing data collection, usage, interpretation, and analysis. Conducting research ethically means ensuring that the study avoids exploiting, harming, or coercing participants [42]. This research received approval from the Medical and Biomedical Ethics Unit of the Faculty of Medicine and University Hospital at King Abdulaziz University (Reference No 603-23). Participants were required to sign an informed consent form. At the beginning of each interview, participants were asked for their consent to audio recording and reminded that participation was voluntary. They were informed that they could withdraw from the study at any time and that their data would be kept strictly confidential. Personal identifiers would be removed, and data would be securely stored and destroyed upon completion of the research. Access to the data was restricted to the researcher and supervisor only.

Each participant took part in an in-depth interview lasting between 60 and 90 minutes, conducted via phone call, Google Meet, or in-person. The interview questions for women using prosthetic limbs were divided into three sections (see **Table 1**), as were the questions for prosthetics specialists.

**Table 1.** Interview questions.

<b>Interview Questions for Women Using Lower-Limb Prosthetics</b>
<b>1. General Information and Health Status</b>
<ul style="list-style-type: none"> <li>○ Provide general information about yourself and your current health status.</li> </ul>
<b>2. Challenges with Ready-Made Clothing</b>
<ul style="list-style-type: none"> <li>○ Discuss the main challenges you have faced with ready-made clothing while using a prosthetic limb.</li> <li>● In your experience, which part of the prosthetic limb has the greatest impact on clothing?</li> </ul>
<b>3. Functional, Expressive, and Aesthetic (FEA) Needs and Preferences</b>
<ul style="list-style-type: none"> <li>○ Functional Needs: Describe the functional requirements that should be considered when designing adaptive clothing for women using lower-limb prosthetics. (e.g., needs/preferences related to closures, fabrics, cuts and patterns, length).</li> <li>○ Do you have any additional suggestions regarding functional needs?</li> <li>○ Expressive Needs: Describe the expressive needs that should be addressed when designing adaptive clothing for women using lower-limb prosthetics. (e.g., needs/preferences related to how clothing reflects personal values, social roles, and enhances self-esteem).</li> <li>○ Aesthetic Needs: Describe the aesthetic needs that should be considered when designing adaptive clothing for women using lower-limb prosthetics. (e.g., needs/preferences related to colors, fabrics, cuts, patterns, and overall design).</li> <li>○ Do you have any other suggestions regarding needs that should be considered?</li> </ul>

**Continued**

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**Interview Questions for Lower-Limb Prosthetics and Orthotics Specialists**

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**1. General Information about the Specialist**

- Please provide general information about your professional background and expertise in prosthetics and orthotics.

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**2. Prosthetic Information**

- Discuss the types and materials of prosthetic limbs commonly used.
- Describe the proper methods for wearing, removing, and caring for prosthetic limbs.

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**3. Clothing Considerations for Prosthetic Users**

- Are there specific safety considerations related to prosthetic limbs that lower-limb prosthetic users should keep in mind when selecting clothing? For example, considerations related to length, fit, and type of material.
  - Based on your experience, what factors should be considered when designing adaptive clothing for women using lower-limb prosthetics?
- 

**6. Data Analysis**

The interviews were recorded using two separate devices to minimize the risk of mechanical failure or sound quality issues. After each interview, the researcher ensured that the recordings were transcribed within 24 hours, and the transcripts were compiled in a Google Drive document. During transcription, any phrases or words that could identify the speaker were coded to maintain data confidentiality. The data were analyzed using the Directed Qualitative Content Analysis method, with the Consumer Needs Model FEA [29] serving as the framework for the study. This approach is appropriate when a pre-existing model or theory guides the research, allowing the researcher to identify main themes based on the theory or model before data collection [43] [44]. The interview data were manually coded using color-coding to differentiate each theme. For example, all responses related to functional needs were marked in green.

**7. Results**

The analysis of interview data from participants and prosthetic specialists revealed that women using lower-limb prosthetics have specific clothing needs that must be addressed in terms of design, material, and closure mechanisms. These needs stem from the challenges they encounter when using prosthetic limbs. According to the FEA model, the researcher categorized these needs into three main areas: functional, expressive, and aesthetic, each with several sub-themes. These will be discussed in detail, accompanied by quotes from the participants.

**7.1. Functional Needs**

The analysis of responses regarding the functional needs for designing adaptive clothing for women using lower-limb prosthetics identified several key requirements.

These include ease of donning and doffing, accessibility to the prosthetic limb, comfort, mobility, the ability to sit comfortably while using the prosthetic limb, and appropriate waist sizing and length. Detailed findings are provided below.

### **7.1.1. Ease of Donning, Doffing, and Accessing the Prosthesis**

The analysis of responses from both participants and prosthetic specialists highlighted that adaptive clothing for prosthetic users must facilitate easy donning and doffing while wearing the prosthetic limb. Additionally, the design should provide convenient access to the prosthesis for removal or reattachment as needed. To address these needs, participants recommended incorporating specific adaptive features into various types of clothing, such as sportswear, wide-leg pants, and medium-width pants. Suggested features include long side or front openings secured with closures like hidden zippers, magnetic buttons, and concealed buttons. As one participant noted, “I prefer pants with side openings that can be closed and opened with buttons and zippers; they make it easier to put on and take off the prosthesis” (Participant 7).

Participants emphasized that clothing designed for ease of donning and doffing would simplify managing their clothing and prosthesis in various situations, including during rest, sports, and physical therapy, while traveling, at the clinic, and in public or workplace settings. In addition to minimizing the time and effort required for these tasks, enhance their sense of independence, and improves their overall quality of life. As one participant highlighted, “It’s very important that clothing allows for easy putting on and taking off of the prosthesis; for example, for health reasons, the prosthesis needs to be removed every four hours. We also need clothing that makes it easy to put on or take off the prosthesis in the airport, at work, and in public places” (Participant 9). Moreover, clothing designs that provide easy access to the prosthesis facilitate the work of Specialists in clinics, whether during examinations or measurements. Prosthetist Specialist 1 suggested incorporating closures like zippers into clothing designed for clinic visits, stating, “I recommend designing clothes suitable for patient appointments, with zippers added to help them easily remove the prosthesis” (Specialist 1).

Regarding closure mechanisms, all participants expressed a preference for hidden types, such as concealed zippers and hidden buttons. They also highlighted considerations related to the materials used for clothing closures. Six participants mentioned that metal buttons might produce noise when in proximity to the prosthesis, as one participant noted: “Metal can make noises with the prosthesis” (Participant 6). Eight participants suggested using magnetic buttons, though they had not used them before. Some participants raised concerns about magnets sticking to the prosthetic leg, with Participant 8 stating, “Magnets might stick to the metal in the prosthetic leg”. However, Prosthetist Specialist 1 clarified that most materials used in prosthetic leg construction are not attracted to magnets, except for steel, which is now rarely used due to its heavy weight and the availability of lighter and cheaper alternatives, such as stainless steel. Additionally, nine participants expressed a preference against using Velcro strips for several

reasons. They cited concerns about durability, noting that Velcro can wear out with use and washing: “Velcro strips can wear out with washing” (Participant 10), a sentiment echoed by Participant 2. They also pointed out that Velcro can become dirty quickly.

### **7.1.2. Comfort, Mobility, and Sitting**

Comfort during movement and sitting while using a prosthetic limb is a crucial functional need when designing adaptive clothing for women with lower-limb prosthetics, as it significantly impacts their ability to move effectively with the prosthesis. All participants agreed on this point. One participant noted, “It is very important that the clothing is comfortable during movement and sitting, as it affects our ability to move with the prosthesis” (Participant 5). Participants highlighted several factors contributing to their comfort, including the length, width, and type of fabric used in the clothing. Regarding clothing length, all participants emphasized that adaptive clothing should not extend beyond the ankle to prevent tripping while walking. Participants also expressed a need for pants with a medium width to facilitate movement, sports activities, and physical therapy. Medium-width pants were considered comfortable for movement with the prosthesis and well-suited for exercises and physical therapy. One participant remarked, “Medium width is the best for walking and is comfortable with the prosthesis” (Participant 3). Another added, “I prefer them to be of medium width for my comfort and the comfort of the prosthesis” (Participant 1).

Most participants recommended avoiding tight designs, as they restrict movement and hinder exercise and physical therapy with the prosthesis. Conversely, four participants (8, 2, 3, 5) noted the importance of avoiding overly loose designs, as they can twist and wrap around the prosthesis during walking, impeding movement and increasing the risk of tripping and falling. The analysis also highlighted the importance of selecting the right type of fabric to ensure comfort and ease of movement while using the prosthesis. Four participants suggested that medium-thickness fabrics, such as blended linen and treated polyester, are ideal for achieving comfort and freedom of movement. One participant explained, “I prefer medium-thickness fabrics because they avoid the issues associated with heavy and light materials. Heavy fabrics are unsuitable for summer and movement with the prosthesis, while light fabrics may tear with prosthesis use” (Participant 8). Participants also preferred to avoid inner linings or reinforcements in their clothing to reduce the risk of overheating inside the prosthesis, which could negatively impact their movement and comfort. As one participant noted, “It’s important to avoid adding layers of fabric or linings, as they make the prosthesis heavier and increase heat while walking” (Participant 10).

Similarly, five participants recommended avoiding lightweight fabrics like chiffon, silk, and satin, due to their tendency to tear when rubbing against the prosthetic socket during movement and sitting: “Light fabrics tear at the socket” (Participant 3). Additionally, six participants favored pants designed with medium-width cuts made from stretchable knit fabrics, such as blended polyester, blended

cotton, and lycra. Reflecting on her long experience with using a prosthesis, one participant stated, “From my experience of nearly ten years using the prosthesis, I find that elastic fabrics work best, provided the design isn’t tight” (Participant 9).

### 7.1.3. Waist and Length Fit

The fit of clothing is a critical functional need that all participants agreed must be considered when designing adaptive clothing. They emphasized the importance of accommodating the size of the prosthetic limb, the characteristics of its movement, and any additional mobility aids they might use alongside the prosthesis. To address these needs, they suggested incorporating adaptive features that allow for adjustments in waist size and clothing length. Seven participants proposed that the waist design should be flexible, elastic, and adjustable without requiring external modifications. One participant stated, “I prefer a design that allows the waist to be easily adjustable, such as adding an elastic waistband that can be tightened to fit different waist sizes” (Participant 10).

Regarding length, four participants suggested incorporating adaptive features into the pant legs to enable easy Bend it up when removing the prosthesis. Additionally, three participants recommended designing pant legs with adjustable hems to accommodate movement when using other mobility aids, such as a wheelchair or crutches, after removing the prosthesis. This would help prevent hindrance during movement and reduce the risk of tripping. As one participant noted, “I prefer a design solution that allows us to secure the pant leg above the knee when the prosthesis is removed, so it doesn’t stay down and cause tripping while using crutches or a wheelchair” (Participant 5).

## 7.2. Expressive Needs

Based on the analysis of participants’ responses regarding their clothing needs, it is evident that their requirements extend beyond functional aspects to include expressive ones. Participants prefer clothing that aligns with their social and cultural norms, as this significantly impacts their body image satisfaction, boosts self-confidence, and facilitates social integration. The expressive needs identified include maintaining privacy and modesty, concealing the appearance of the disability, and ensuring that the clothing is consistent with what is worn by able-bodied peers.

### 7.2.1. Maintaining Privacy and Modesty

Participants emphasized the importance of designing clothing that allows access to the prosthetic limb without exposing unnecessary parts of the body. Privacy and modesty are critical needs, particularly during medical examinations, physical therapy sessions, sports activities, travel, and at the workplace. Clothing that supports these needs enhances self-confidence and reduces feelings of embarrassment. As one participant noted, “It’s very important to design clothes that accommodate the use of prosthetics while considering privacy and modesty, so we can attend the gym, physical therapy, and medical appointments without feeling

embarrassed” (Participant 6). Another participant (Participant 11) suggested creating modest clothing suitable for physical therapy, stating, “I would like clothing designs that are appropriate for physical therapy activities while maintaining modesty and privacy”. The prosthetist agreed with her (Specialist 2).

### **7.2.2. Concealing the Appearance of Disability**

Based on the participants’ responses, it is evident that concealing the appearance of the disability is a crucial expressive need to consider when designing adaptive clothing. Since the prosthetic limb is an assistive device that can be covered by clothing, participants prefer designs that help achieve a natural and unobtrusive appearance. They tend to avoid tight-fitting designs and lightweight fabrics, as these can highlight the prosthetic limb, making it more visible and noticeable to others. One participant noted, “It is very important to me that the clothing hides the prosthetic limb” (Participant 1). Another participant concurred, saying, “I prefer that when designing clothes for us, consideration is given to help conceal the details of the prosthetic limb” (Participant 10). Participant 4 added, “I prefer not to use lightweight fabrics like chiffon because they accentuate the shape of the prosthetic limb”.

### **7.2.3. Matching with Clothing Designed for Their Able-Bodied Peers**

Participants believe that one of the most important expressive needs in designing adaptive clothing is to ensure it aligns with the clothing designed for able-bodied individuals. They emphasized that their clothing should be inclusive and resemble what other women wear for various events, work, and daily activities. The goal is to have clothing that does not specifically indicate a disability but is modern, feminine, and indistinguishable from mainstream fashion. One participant remarked, “The design of the clothing should not specifically target prosthetic limb users; it should be similar to ready-made clothing available in the market” (Participant 5). Consequently, participants favor hidden closures, as these make adaptive clothing appear more like regular market options. One participant noted, “I prefer hidden buttons and zippers because they resemble regular clothing and are not designed for a specific group” (Participant 5). Additionally, participants felt that clothing designed to match what able-bodied women wear significantly impacts their social participation and integration, boosting self-confidence and satisfaction with their body image alongside the prosthetic limb. Participant 9 stated, “Clothing that fits well with the prosthesis and looks good encourages social participation and boosts my confidence”. They added, “Clothing that complements the prosthesis enhances my satisfaction with my body image”.

## **7.3. Aesthetic Needs**

The analysis of participants’ responses revealed that, beyond their functional and expressive needs, they also have aesthetic needs related to the appearance and attractiveness of their clothing. They desire adaptive clothing that addresses these aesthetic needs, which are often unmet by ready-made options suitable for

prosthetic use. These needs encompass various aspects, including clothing design details (such as style and cuts), fashion trends, colors, and fabrics.

### **7.3.1. Design Details (Style, Cuts)**

Participants expressed a preference for adaptive clothing that is modern, aligns with current fashion trends, and is appropriate when using prosthetic limbs. Seven participants emphasized the importance of this aspect. Participant 7 noted, “It is crucial for the clothing design to align with current fashion trends, as it represents a positive change from the style we are used to. “Regarding their preferences for clothing types and design details, eight participants favored medium-width cuts, such as straight-leg and wide-leg pants (Palazzo pants). These styles offer an elegant appearance and are practical for use with prosthetic limbs if they incorporate adaptive features. However, many available options on the market often lack the functional features needed for prosthetic use. Participant 6 noted that medium-width clothing is both functionally and aesthetically satisfying, unlike tight-fitting clothing: “Medium-width pants are aesthetically pleasing and suitable for use with prosthetics, unlike tight pants which are aesthetically pleasing but not practical”. Conversely, six participants found extremely loose clothing, such as Gaucho or Culottes pants, unsuitable for prosthetic use. They felt such designs did not meet their aesthetic needs and failed to provide a flattering appearance. Participant 10 remarked, “Loose clothing often does not give a sleek look and adds bulk to the body”.

### **7.3.2. Fabrics**

The type of fabric is a significant aesthetic need that all participants agreed upon. While most participants preferred solid fabrics, Participant 1 favored patterned ones. Participants 8 and 10 explained that Plain fabric fabrics for lower garments are easier to coordinate with various upper garments: “I prefer pants and lower garments to be made of solid fabrics so I can coordinate them with different upper garments” (Participant 10). Seven participants expressed a preference for non-thick jeans, noting their stylish and modern appeal. Participant 11 remarked, “I prefer non-heavy jeans because they are elegant and trendy”. Additionally, participants preferred fabrics that are both fashionable and modern.

### **7.3.3. Colors**

Color is a fundamental aesthetic requirement for all participants, significantly impacting their satisfaction with the visual aspects of clothing. Participants’ color preferences varied: most favored neutral colors such as beige, white, navy, gray, black, and brown for their practicality and ease of coordination with other garments. As one participant explained, “I prefer colors that are versatile and practical, making them easy to mix and match with other items”. Black was the most preferred color, as many participants felt it created a sleek and attractive appearance. Participants 4 and 2 noted that black helps make the body appear slimmer and hides imperfections. Participant 4 remarked, “I like dark colors, especially black, because they give a sleek shape, conceal imperfections, and make me look

slimmer”.

Conversely, Participants 1 and 2 preferred bright colors. Participant 1 expressed that bright colors enhance her sense of elegance and comfort: “I like light colors because they make me feel elegant and comfortable”. Participant 2 added that bright colors contribute to a sense of beauty and attractiveness: “I prefer bright colors like orange and yellow because they give me positive energy and make me feel beautiful and attractive”. Participants 8 and 4 also pointed out that light-colored fabrics might reveal the color of the prosthetic socket if it is dark. Participant 4 noted, “Light colors can show the color of the prosthetic socket if the fabric is light”. Participant 8 agreed, saying, “Light colors and fabrics can reveal the dark color of my prosthetic socket”.

## 8. Discussion of Results

The aim of this study was to explore the needs of women who use lower-limb prosthetics to inform the design of adaptive clothing. Responses from participants and prosthetic specialists were analyzed using the Consumer Needs Model (FEA), revealing three main themes: functional needs, expressive needs, and aesthetic needs.

### 8.1. Discussion of Functional Needs Results

The functional needs of women with lower-limb prosthetics focus on ease of donning and removal, as well as accessibility to the prosthetic limb. These findings align with previous research on clothing for individuals with mobility impairments using assistive devices, including [11] [12] [24] [28] [36] [37]. Participants in this study preferred clothing with side or front openings to facilitate the process of donning, removing, and accessing the prosthetic limb. This is also consistent with [45], who emphasizes that openings in adaptive clothing should be concealed by using hidden zips or buttons.

Regarding closure mechanisms, participants favored small, hidden zippers or buttons over Velcro strips. This result varies from findings by [10] [19] [30] where Velcro was preferred. The varies may be attributed to the nature of the participants’ disabilities; unlike those in the aforementioned studies, the current participants did not experience upper-limb movement restrictions. This suggests that functional improvements in clothing for individuals with disabilities are influenced by the specific characteristics and types of disabilities, a conclusion supported by [7]. Additionally, this study identified a potential issue with magnetic buttons attracting prosthetic limbs, a concern not previously documented in the literature.

In a related context, the functional needs of women using lower-limb prosthetics also include comfort and the ability to move and sit effectively while using the prosthetic limb. This finding aligns with [10] and [46], who emphasized the importance of integrating assistive devices into the design of adaptive clothing for individuals with disabilities. The current study reveals that three main aspects—

length, width, and fabric type—are crucial for ensuring optimal comfort during movement and sitting. Participants indicated that clothing length should extend only up to the ankle to prevent tripping, and medium-width clothing is preferable for movement with prosthetics, exercise, and physical therapy, as tight clothing can restrict movement. This aligns with [47], who found that overly loose or long clothing could impede the effective use of assistive devices and potentially cause harm if it becomes caught or tangled during movement.

In addition to the previously mentioned aspects, the current study revealed that the thickness, flexibility, and durability of fabrics directly impact comfort during movement with the prosthetic limb. Participants preferred fabrics of medium thickness, as they are most suitable for the movement characteristics associated with prosthetics. This finding aligns with [12]. Some participants also favored stretchable knitted fabrics, contrasting with [11], who found that participants preferred additional lining or reinforcement around the area where the prosthetic limb meets the residual limb. In this study, participants did not favor such additions, as they could increase heat and sweating inside the prosthetic limb, affecting comfort. This discrepancy may be attributed to differences in environmental climates, or the type of liners used in prosthetic limbs; all participants in the current study used silicone liners, which are known to increase sweating.

The study also highlights the importance of an elastic waistband for adaptive clothing, allowing for easy adjustment. This is particularly relevant as the size of the prosthetic socket may necessitate choosing clothing sizes larger than the user's actual body size. This finding is consistent with [21] [37] [48] who reported that individuals with disabilities prefer clothing with a flexible, elastic waistband. Additionally, participants expressed a need for adaptive features that allow them to adjust the length of pants and clothing when removing the prosthetic limb and using mobility aids such as crutches or wheelchairs, to avoid obstructing their movement.

## 8.2. Discussion of Expressive Needs Results

The results of the current study reveal that designing adaptive clothing for women who use lower limb prosthetics requires attention not only to their functional needs but also to their expressive needs, which encompass psychological aspects reflecting both personal and social dimensions [49] expressive needs for these women include privacy and modesty. All participants stressed the importance of incorporating features into clothing that allow them to maintain privacy and modesty in line with social, cultural and religious beliefs. This is because women in Saudi Arabia adhere to Islamic principles, which advocate for women to dress modestly [50] [51]. Wherein ensuring that clothing respects privacy is crucial for enhancing patient satisfaction and comfort, as noted by [52] [53].

In addition to the previously mentioned needs, one of the key expressive needs when designing clothing for women using lower limb prosthetics is the desire to conceal their disability, specifically by hiding the prosthetic limb to achieve a more

natural body appearance. This need is a recurring theme in previous research on clothing for individuals with disabilities, including [20] [26] [30] [37] [47]. This preference is rooted in the psychological differences between people with disabilities and those without. To maintain psychological stability and a social identity similar to that of non-disabled individuals, those with disabilities often prefer clothing that conceals their disability and assistive devices [7]. Consistent with this, the current study found that women using lower limb prosthetics want their clothing to resemble that of women without physical disabilities. This preference is driven by a desire to boost self-confidence, enhance body image satisfaction, and increase social participation. These findings align with previous studies by [21] [22] [26] [36], which highlight the importance of designing clothing that resembles that worn by non-disabled individuals.

### **8.3. Discussion of Aesthetic Needs Results**

The current study highlights the importance of addressing aesthetic needs in the design of adaptive clothing for women using lower limb prosthetics. It emphasizes that such clothing should be attractive, modern, and fashionable. Participants expressed a preference for various types of clothing suitable for different daily activities, integrating both functional and aesthetic elements. The study also underscored that fabric choice and color are crucial for satisfying the aesthetic needs of prosthetic users. Participants favored Plain fabrics and neutral colors that are easy to coordinate with other clothing. This result is consistent with [7], who noted that individuals with disabilities have specific aesthetic requirements. These needs reflect a desire for stylish and attractive clothing, which can significantly impact their self-esteem if not addressed.

In conclusion, the Consumer Needs Model (FEA) has proven instrumental in identifying and evaluating the design elements necessary for adaptive clothing for women using lower limb prosthetics, effectively addressing their functional, expressive, and aesthetic needs.

### **8.4. Design Recommendations**

Based on the findings, several design recommendations can be made for clothing manufacturers targeting women using lower-limb prosthetics. One key suggestion is to incorporate hidden closures for accessibility, such as side or front openings with small, discreet zippers or buttons. These facilitate donning and removing clothing while maintaining a stylish appearance. In addition, elastic waistbands should be included for adjustability, ensuring a comfortable fit despite variations in body size due to prosthetic sockets.

Medium-width cuts, like straight-leg or wide-leg styles, are recommended to enable ease of movement, especially for activities such as exercise or physical therapy. Adjustable clothing lengths, such as roll-up hems, would also allow users to modify their outfits when switching to mobility aids like crutches or wheelchairs. For comfort, manufacturers should prioritize breathable, flexible, and durable

fabrics. Medium-thickness and stretchable materials are preferred, as they provide optimal mobility and reduce heat or sweating inside the prosthetic limb. Closures such as magnetic buttons and Velcro should be avoided, as magnetic elements may interfere with prosthetic limbs, and participants preferred zippers and buttons for ease of use.

Finally, aesthetic preferences lean toward neutral colors and simple designs that are easy to coordinate with other garments. Manufacturers should aim for modern, fashionable pieces that allow women to blend in with non-disabled peers, boosting self-confidence and body image satisfaction. Incorporating these elements can significantly enhance user satisfaction with adaptive clothing for women using lower-limb prosthetics.

## 9. Conclusions and Future Research

Overall, the results highlight the need for further scientific investigation and design consideration regarding the clothing needs of women using lower limb prosthetics. This study supports employing the FEA model to identify and address clothing requirements in design research. Adaptive clothing should be functional, comfortable for movement, easy to put on and take off, and also stylish, modern, and available in a range of designs and colors. Additionally, it should maintain privacy and modesty in line with social norms, and conceal their disability to avoid distinguishing users from their non-disabled female peers. Addressing these needs in adaptive clothing design can significantly enhance the quality of life for women using lower limb prosthetics, increase their satisfaction with their clothing, and improve their adjustment to the prosthetic limb.

Based on these findings, several recommendations are proposed for future research. Future studies should focus on designing clothing that meets these needs and evaluate them from the users' perspectives. Expanding the sample size and exploring the needs of women using upper limb prosthetics are also recommended. Including male prosthetic users in future research and developing materials that minimize friction with prosthetic limbs could provide valuable insights and advancements.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Appendix: Demographic Characteristics of Participants

Participant symbol	Age	Amputation level	Prosthetic limb type	Duration of wearing the prosthetic limb per day
1	45	Above the knee	An above-the-knee prosthesis with an endoskeleton	Varies (due to hip fracture)
2	28	Through the knee	Endoskeleton prosthetic limb (electronic)	Throughout the day, it is only removed during rest and sleep.
3	52	Above the knee	Endoskeleton prosthetic limb	5 to 6 hours a day
4	36	Above the knee	A prosthetic limb with a supporting exoskeleton (cosmetic)	Throughout the day, it is only removed during rest and sleep.
5	23	Below the knee	Endoskeleton prosthetic limb	4 - 6 hours a day
6	29	Below the knee	Exoskeleton prosthesis (cosmetic)	Throughout the day, it is only removed during rest and sleep.
7	46	Through the knee (there is no knee because it is a congenital deformity from birth)	A prosthetic limb with a supportive exoskeleton	Throughout the day, it is only removed during rest and sleep.
8	21	Below the knee	Endoskeleton prosthetic limb	Throughout the day only time for rest and sleep is taken off.
9	21	Above the knee left	Supportive Endoskeleton prosthetic limb	Throughout the day, it is only removed during rest and sleep.
10	58	Below the knee	Supportive Endoskeleton prosthetic limb	The duration varies according to the type of activities.
11	40	Below the knee	Experimental limb	Throughout the day, it is only removed during rest and sleep.
Participant	Job title		Years of experience in prosthetics	
Prosthetics specialist 1	Specialist in prosthetics and prosthetics		One year	
Prosthetics specialist 2	Specialist in prosthetics and prosthetics		One year and six months	