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REVIEW ARTICLE OPEN ACCESS

Woven Comfort: Navigating Hyperesthesia through Fabric Innovation

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Abstract:
Hyperesthesia is characterized by heightened sensitivity to stimuli that typically does not evoke pain, manifesting as allodynia (pain from non-painful stimuli) or hyperalgesia (exaggerated pain from painful stimuli). This condition is commonly linked to neuropathic pain, arising from nerve fiber damage or alterations, particularly affecting A-fibers. Hyperesthesia can result from systemic diseases, mechanical trauma, or hereditary factors, affecting approximately 10% of the population. Mechanical hyperesthesia, the more common type, results from heightened sensitization of the somatosensory system, leading to discomfort from light stimuli like pinpricks or clothing friction.

Managing hyperesthesia requires a multidisciplinary approach focusing on both underlying causes and improving quality of life. First-line treatments include antidepressants (TCAs and SNRIs), gabapentinoids, and topical agents like lidocaine and capsaicin. For refractory cases, interventional therapies, such as nerve blocks and neurostimulation, may be considered, though these are not first-line treatments due to limited evidence. Additionally, non-pharmacological approaches like choosing friction-reducing clothing fabrics play a critical role. Clothing materials with low friction coefficients, such as cotton or silk, can significantly improve comfort by reducing sensory triggers for those with hyperesthesia. Further research into fabric technologies, such as friction-reducing treatments and textronics, offers promising avenues for improving comfort and pain management.

Keywords: Hyperesthesia, Allodynia, Cutaneous sensitivity, Clothing dermatitis, Quality of life, Fabric friction, Coefficient of friction (CoF), Skin sensitivity management, Friction-reducing technology.

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1. INTRODUCTION - UNDERSTANDING HYPERESTHESIA AND ITS CHALLENGES

1.1. Pathophysiology and Causes of Hyperesthesia

Hyperesthesia is characterized by heightened cutaneous sensitivity to stimuli that typically would not evoke pain. It is classified into two types: allodynia and hyperalgesia. Allodynia involves perceiving non-painful stimuli, such as clothing texture, as painful, while hyperalgesia amplifies the pain response to typically painful stimuli, like a pinprick. Hyperesthesia is commonly associated with neuropathic pain, often arising from injury or alteration to afferent nerve fibers, particularly A-fibers [1]. Triggers for peripheral neuropathy, which shares similarities with hyperesthesia, include diseases like diabetes, infections, trauma, and hereditary factors. Hyperesthesia, a chronic pain disorder, affects approximately 10% of the population [2, 3]. Among the forms of hyperesthesia, mechanical hyperesthesia is the more common type [4, 5]. This type of hyperesthesia, which includes a painful sensation of a light pinprick and the friction of clothing, is due to the heightened sensitization of the somatosensory system and impaired natural pain regulation [6].

1.2. Treatment and Management Approaches

The current literature highlights a multidisciplinary approach to managing hyperesthesia, a condition that often requires a multistep process. Standard treatments focus on addressing both the underlying cause and impaired quality of life through pharmacological interventions and therapy [7]. First-line treatments include medications for neuropathic pain, such as antidepressants (TCAs, SNRIs) and anti-epileptics like gabapentinoids, along with topical agents like lidocaine and capsaicin cream. For severe cases, opioids may be considered [7]. Interventional therapies, such as nerve blocks and neurostimulation, are available for patients who do not respond to standard treatments, though these methods are still being studied and are not recommended as first-line options due to limited clinical data [7].

Each of these medications and therapies has potential side effects. Therefore, it is essential to explore alternative strategies for managing hyperesthesia, such as lifestyle changes that avoid or modify triggers. Although limited research exists, personal weblogs provide a platform for individuals to connect with others facing similar conditions. Recent studies suggest that some patients find relief by choosing certain types of clothing fabric. Even mild tactile stimuli, such as clothing textures, can cause discomfort or pain for those with hyperesthesia [8]. Selecting appropriate clothing materials and designs that reduce irritation and offer comfort may significantly improve their quality of life. Specialized garments that minimize friction and pressure on sensitive areas may also provide relief and enhance daily functioning. Overall, clothing plays a vital role in reducing sensory triggers and enhancing comfort for individuals managing hyperesthesia. Future research may focus on the coefficient of friction in fabrics and developing minimal friction fabrics [8].

2. RESEARCH METHODOLOGY

This short review involved a comprehensive search to explore how textile properties, particularly a fabric’s coefficient of friction (CoF), affect individuals with cutaneous sensory disorders, such as hyperesthesia. Searches were performed across PubMed, Scopus, and Google Scholar, using keywords including “hyperesthesia,” “allodynia,” “clothing dermatitis,” “fabric friction,” “coefficient of friction,” and “atopic dermatitis and clothing.” Inclusion criteria involved articles that addressed human textile-skin interaction with relevance to fabric type, weave, finish, or CoF, as well as articles that investigated sensory discomfort or dermatologic conditions, including hyperesthesia, fibromyalgia, and sensory processing disorders. Exclusion criteria excluded studies lacking sensory or clinical relevance. Furthermore, opinion-based articles without original research, such as commentaries and opinion pieces, and articles focused solely on chemical allergens or textile toxicology were also excluded. User-generated web content, such as Reddit and online forums, was reviewed for context and anecdotal trends but excluded from formal data analysis due to a lack of peer review and standardization. We also reviewed recent advancements in textile use for other dermatological conditions, such as atopic dermatitis, to identify overlapping features, including breathability, antimicrobial activity, and friction reduction.

3. RESULTS - COEFFICIENT OF FRICTION AND CLOTHING SELECTION

3.1. Definition and Significance of the Coefficient of Friction

The skin, as the body's primary barrier, is frequently subjected to friction and pressure, leading to conditions, such as chafing, pressure ulcers, blisters, and abrasions. Although clothing offers protection, excessive friction between fabric and skin can cause discomfort, particularly for those with sensitive skin [9]. The Coefficient of Friction (CoF), a widely accepted measurement, describes the frictional properties of fabric surfaces and is determined by the force at which a block begins to slide on a fabric-covered surface (Fig. **1**). CoF is influenced by fiber type, fabric weave, yarn type, and finishing agents [10]. Alongside CoF, fabrics also generate electrostatic charges from friction, both of which are studied for their impact on cutaneous conditions [11, 12]. While CoF measures resistance between surfaces, affecting smoothness or irritation, electrostatic charge refers to the build-up of electricity on fabric, which can cause static cling and discomfort, especially in those with sensory sensitivities [13].

Clothing properties have long been an important focus in dermatology, with much of the attention centered around textile or clothing dermatitis, a condition in which an individual’s skin reacts to certain components of fabric, including fibers, dye, or chemicals, causing irritation, itchiness, scaling, and redness or an allergic reaction [14]. While understanding the role of clothing in dermatological conditions like textile dermatitis has been well-established, less focus has been given to sensory conditions like hyperesthesia, where clothing does not cause visible skin irritation but rather increases cutaneous sensitivity. This distinction highlights the need for further exploration into how clothing properties, specifically the CoF, influence both physical and sensory comfort [14].

3.2. Selection Criteria for Evaluating Clothing Materials and Textures

Clothing comfort is influenced by material and design elements, including yarn type, fabric thickness, stitch density, garment fit, and fabric treatments [15]. A study on exercise clothing found that a smaller fabric contact area and lower sweat content reduced sensations of stickiness, while higher moisture saturation increased discomfort [15]. These factors play a key role in evaluating materials and textures for clothing comfort. Furthermore, fabric finishes and treatments greatly affect garment comfort. Cotton, commonly used in textiles, is highly flammable and often treated with flame retardants to reduce risk, but these treatments can cause discomfort for sensitive skin [16]. To address this, Moula *et al.* introduced vitamin E to

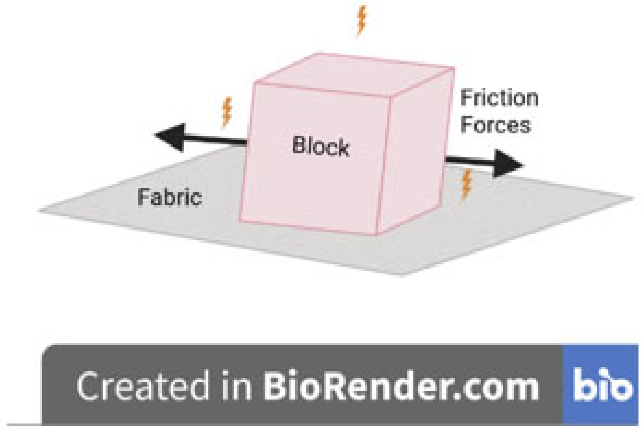

Fig. (1). Schematic representation of friction force and electrostatic charge generation between a textile surface and a sliding block.

fabric finishes, significantly enhancing moisture management, comfort, and strength, with a 43% improvement in moisture control and a 23% increase in tear strength [17]. Other studies have explored silk protein coatings to reduce skin irritation and fabric softeners to decrease stiffness and friction, further improving comfort [18-20].

3.3. Impact of Fabric Texture and Finish on Coefficient of Friction

Fabric texture and finish significantly impact the Coefficient of Friction (CoF). Fouly *et al.* studied various textiles' friction against hair and skin in chemotherapy patients, focusing on electrostatic charges and rubbing loads [11]. Six fabrics (acrylic, chiffon, cotton, dantel, and two polyester types) were tested. Results showed that weave and stitching influence both CoF and voltage (Table **1**). Chiffon had low friction but high voltage, while cotton, acrylic, and dantel exhibited moderate friction with lower voltage. Cotton, acrylic, and polyester blend produced the highest friction and lowest electrostatic charge [11].

3.4. Role of Friction-reducing Technologies in Clothing Design

Identifying factors contributing to skin friction aids in designing fabrics for specific needs. In athletic contexts, excessive movement increases skin susceptibility to shearing against clothing. Athletes wearing tight garments during prolonged activity experience heightened friction at the fabric-skin interface, which can lead to blisters and pressure ulcers. Therefore, fabric type, material, and design should be carefully selected to minimize skin damage [9].

Efforts to study friction-reducing technologies in clothing design include instruments assessing fabric smoothness and research on electric charges from textile friction, making these technologies increasingly common [12, 21, 22]. Both the mechanical properties of fabrics and the sensory perception of the user are essential in these studies. Hu *et al.* examined the neuromechanical aspects of fabric softness, showing how slowly adapting type I mechanoreceptors in human finger pads respond to tactile stimuli. These receptors detect mechanical interactions between fabric and skin, influencing the perception of softness and friction, which informs clothing design to enhance comfort and reduce friction [20]. Understanding these physiological mechanisms helps manufacturers create smoother, friction-reducing fabrics.

Advances in both the physiological understanding of fabric perception and technological innovations in fabric testing have greatly contributed to the design of friction-reducing clothing. For example, instruments like handheld probes now allow for the precise measurement of the CoF at specific anatomical points, offering detailed insights into how different materials interact with the skin. In a

Table 1. Comparison of friction coefficient (to the nearest thousandths) and electrostatic charge of various textile materials against skin (anwar *et al.*, 2018).

Textile Type	Friction Coefficient	Electrostatic Charge (V)
Poly. 1	0.07	68
Cotton	0.09	27.5
Chiffon	0.11	214
Dantel	0.15	84.5
Poly. 2	0.19	286.5
Acrylic + Cotton + Poly.	0.25	13
Acrylic	0.25	24.5

study by Ramalho *et al.*, friction values across various fabrics were evaluated, revealing that materials with lower CoF, such as polyamide and cotton, provided greater comfort and reduced friction, while wool had the highest CoF. Additionally, they observed that CoF varied depending on the area of the body, with polyamide showing a higher CoF on palms compared to other regions. Sensory feedback further revealed that wool and silk felt rougher and stickier, while polyamide and cotton felt smoother and more slippery [21]. Similarly, Parmar *et al.* developed devices to assess fabric surface smoothness, demonstrating that smoother fabrics reduce friction and improve wearability [22].

In addition to these mechanical evaluations, researchers have also explored the role of electrostatic charges in fabric-skin interactions. Al-Qaham *et al.* investigated the static electric charge generated by the friction between polymeric textiles and cotton. Their experiments examined how sliding distance, velocity, and load influenced the static charge between materials like wool, polyester, and rayon, tested on different hair types, including African and Asian [12]. Beyond everyday use, friction-reducing technologies are gaining prominence in the biomedical field, particularly in managing the skin's microenvironment. Personalized clothing is now seen as a potential tool for optimizing skin health. For instance, Salgueiro-Oliveira *et al.* developed a specialized pajama prototype designed to prevent pressure ulcers by reducing moisture, a key factor in pressure injuries. The innovative two-piece set incorporated features like fabric stretch and soft textures to enhance patient comfort during hospital stays, reflecting the growing role of friction-reducing technologies in healthcare [23, 24].

4. DISCUSSION - ROLE OF CLOTDHING INHYPERESTHESIA

4.1. Impact of Fabric Properties on Comfort in Hyperesthesia

The sensations from clothing-skin contact can greatly affect comfort, particularly in patients with hyperesthesia. Those with exaggerated neuropathic responses are sensitive to varying degrees of touch and thermal contact. As a result, the CoF of fabrics plays a role in clothing comfort for these patients. Selecting materials that reduce electrostatic charge, like cotton or silk, can improve comfort by minimizing friction and providing breathability and moisture-wicking properties [25].

4.2. Consideration of Clothing Elements for Hyperesthesia

In addition to fabric types, other clothing elements also play a crucial role in improving comfort for individuals with sensory processing disorders. Tags, seams, and labels can be particularly bothersome for those with heightened sensory perception, and many individuals benefit from increased comfort from tagless designs, flat seams, bonded edges, or seamless construction in their clothing [26].

Fabric finishes can also enhance comfort by altering the material's intrinsic properties. For example, adding a vitamin E finish to cotton can improve its softness, moisture management, and soothing properties. Similarly, friction-reducing technologies, such as silicone-based treatments or chemical coatings, can be applied to fabrics to reduce the risk of irritation and discomfort for individuals with hyperesthesia [27]. Fabrics treated with finishes or chemicals may alter their intrinsic properties, impacting comfort. Ongoing advancements in friction-reducing technologies and fabric treatments continue to improve comfort for individuals with hyperesthesia and other sensory sensitivities, such as silicon-based treatments or chemical coatings applied to fabrics to decrease friction and irritation. Research into fabrics designed to address skin conditions, such as atopic dermatitis, further highlights the importance of minimizing irritation and maintaining an intact skin barrier [28]. Innovations like Microair Dermasilk and DermaTherapy fabrics, which focus on breathability and moisture absorption, have been developed to reduce skin irritation and promote comfort, making them ideal for individuals with sensory sensitivities [29, 30].

4.3. Preliminary Considerations and Recommendations

For individuals with hyperesthesia, selecting fabrics with a low Coefficient of Friction (CoF) is essential in minimizing skin irritation and discomfort. Fabrics like polyamide, chiffon, and cotton are known for their smooth texture and low friction properties, making them ideal for reducing the frictional forces that can exacerbate hypersensitivity. In contrast, materials with higher CoF, such as wool or polyester, may increase discomfort due to their rougher surfaces [21]. Additionally, natural fibers that minimize electrostatic charge can improve comfort by reducing sensations of static cling and irritation.

Recent studies highlight the evolving nature of the textile industry, particularly with emerging blends of man-made fabrics derived from nature, such as plants and trees. Bio-based fabrics, compared to traditional cotton, offer enhanced comfort with less piling and abrasion, which is crucial as friction and piling can disrupt sensation and trigger hyperesthesia. Modal, a blend of beech tree cellulose and cotton, has demonstrated superior mechanical and comfort qualities, including better tensile strength and moisture-wicking properties, compared to a cotton blend alone. While cotton is often regarded as a comfort fabric, its short fibers tend to expand and contract, increasing friction and rubbing against the skin [31]. This has spurred advancements in fabric development, with a focus on breathability and moisture absorption to enhance comfort for individuals with sensory sensitivities like hyperesthesia.

4.4. Exploring New Avenues in Pain Management Through Fabric and Texture Research

Research into different textures and fabrics for desensitizing the skin is opening new pathways for pain management. One study highlights that altered skin sensation can affect pain perception, suggesting fabric design as a potential therapeutic tool for conditions like hyperesthesia [32]. The challenge of managing friction and irritation in hyperesthesia underscores the need for innovative fabric technologies. Emerging textronics, which integrates textiles with electronics, offers promising solutions by embedding sensors that monitor vital signs and provide real-time feedback on friction and heat build-up, key discomfort factors for individuals with hyperesthesia [33]. Furthermore, recent advancements, such as the development of a textile friction analyzer capable of measuring skin-fabric interactions with a sensitivity of up to 0.01 CoF units, could have profound implications for designing therapeutic garments that minimize discomfort for individuals with chronic pain or hypersensitivity [34].

In addition to high-tech fabrics, natural materials like bamboo and hemp are gaining interest due to their low CoF, breathability, and hypoallergenic properties. Bamboo fabric, known for its smooth texture, moisture-wicking, and antibacterial qualities, may help relieve irritation, while hemp offers durability and resistance to microbial growth [31]. Beyond their benefits for sensory sensitivities, these materials are environmentally sustainable, increasing their appeal [35]. Future research should focus on further development of bio or synthetic fabrics more compatible with human skin, as well as integrating natural fabrics with advanced technologies to further reduce friction and enhance comfort. Long-term studies, including clinical trials with advanced textiles, are needed to assess the impact of both natural and synthetic fabrics on skin health and sensory perception. By identifying specific fabric characteristics that can reduce tactile discomfort, such as fiber type, weight, and finish, the field of biotextiles can move toward standardizing textile fabrics.

Furthermore, developing and utilizing a tactile discomfort scale or scoring system would provide deeper insights into fabric tolerability for individuals with hyperesthesia and help healthcare providers offer tailored recommendations for patients beyond hyperesthesia, including those with autism spectrum disorder, fibromyalgia, and neuropathies. As sustainable manufacturing practices and the use of alternative natural or biobased fabrics gain momentum, this field is already evolving. There is significant potential for impact through interdisciplinary collaboration, including partnerships between neurologists, dermatologists, occupational therapists, as well as textile companies. One proposed initiative involves establishing global standards, specifically ISO guidelines for “Sensory-Friendly Textiles,” to set international benchmarks for labeling and designing fabrics deemed safe for individuals with tactile sensitivities. Labeling criteria for “hypersensitivity-friendly” garments based on minimum friction and irritant thresholds, supported by standardized product testing and further research, could advance both clinical and commercial integration of inclusive textile solutions.

Presently, there is a specialized clothing industry that caters to individuals with physical disabilities, offering adaptive features, such as magnetic or Velcro closures, anti-slip socks, front-opening shirts, and side zippers. Within this category, a limited selection of adaptive clothing for people with sensory disabilities is available, including soft fabrics, tag-less labels, and seamless construction. While these designs address functionality, we propose expanding the focus to include the physiological and sensory properties of fabrics. By incorporating CoF measurements and sensory comfort research into fabric design, future garments could minimize irritation and significantly improve wearability for individuals with hyperesthesia [36].

CONCLUSION

A multifaceted approach is recommended for treating hyperesthesia, with clothing design playing a key role in enhancing comfort for individuals with sensory sensitivities. While limited studies exist on the role of clothing type, this review highlights the importance of fabric properties, particularly CoF, breathability, and moisture management, in reducing discomfort and irritation. Despite the significance of these factors, there are no standard guidelines for selecting appropriate clothing for hyperesthesia, leaving patients to seek advice from blogs and online communities for additional help. Understanding the sensory experiences of those with hyperesthesia is essential for developing garments that address both functional and emotional needs. Collaboration between designers and healthcare professionals can lead to more accessible and inclusive clothing options that improve comfort [25].

Future research should further explore sensory perception in patients and the factors influencing their discomfort. While pharmacological treatments are available, appropriate clothing choices offer significant potential to improve the quality of life for those with sensory sensitivities. Non-drug alternatives, such as compression garments and weighted blankets, have shown clinical promise in managing chronic pain. With advancements in textronics, there is potential for innovative solutions that combine comfort and pain management for individuals with hyperesthesia and related conditions [37-39].

AUTHORS' CONTRIBUTIONS

The authors confirm their contributions to the paper as follows: According to the CRediT contributorship taxonomy, SK contributed to conceptualization, data curation, formal analysis, methodology, validation, and writing (original draft, review, and editing). BK contributed to conceptualization, methodology, and writing (original draft, review, and editing). CB contributed to conceptualization, study design, methodology, and writing (editing). LG contributed to conceptualization and supervision. All authors reviewed the results and approved the final version of the manuscript.

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CONFLICT OF INTEREST

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