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Athletic Wear Design and Disability: Exploring Needs and Values of Consumers with a Self-Described Upper Limb Impairment or Difference

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Abstract

Despite a growing focus on disability inclusion within apparel design research and practice, disabled consumers remain limited in clothing choice. In addition to impeding disability representation, a lack of appropriate clothing can hinder individuals' senses of self and social participation. Even with the global impact of the athletic wear industry, disability inclusion is lacking in this apparel sector, and there is little

scholarly research on design practice for adaptive athletic wear. In response, this paper presents a practice-informed exploration of barriers, needs, and values for athletic wear inclusion of consumers with a self-described upper limb impairment or difference. For this pragmatic design research, a participatory design methodology was applied for participant-led results framed by the social model of disability. Virtual semi-structured interviews, design ideation workshops, and feedback sessions were conducted for experiential results. The findings offer guidance to better understand and support certain disabled athletic wear consumers, revealing needs like easy grip, one-handed dressing, and variable sleeve lengths in performance garments. While different design approaches (e.g. adjustable, mass-customizable) are suggested, an inclusive approach is highlighted for commercial athletic wear that is accessible for a wider base of consumers. The implications support broader disability inclusion within apparel design, research, and education.

KEYWORDS: adaptive apparel, athletic wear, inclusive design, disability, fashion inclusion

inclusion, her research relied on participatory design approaches to understand existing barriers to apparel inclusion and ideate user-led solutions. Dr. Poage is interested in exploring inclusive and flexible design research tools and methods to support both disabled researchers and participants. Her previous experience working in the US apparel industry included athletic wear technical design for men's and women's training, high-performance, and athleisure apparel.
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Introduction

This practice-informed design research paper presents an exploration of athletic wear and disability inclusion needs with results relevant to adaptive apparel researchers, athletic wear design professionals, and inclusive fashion educators. Over one billion individuals experience disability worldwide (WHO 2022) with 28.7% of adults in the US and 24% of people in the UK reporting living with a disability in 2024 and 2022–2023, respectively (CDC 2024; Department for Work & Pensions 2024). Despite the prominent presence of disability in our lives, however, representation within the apparel industry is still greatly lacking, meaning a large segment of the population is without full choice and access to clothing that meets fashion and function needs. Furthermore, in addressing the long-standing fashion exclusion of disability, Foster et al. (2021, 225) writes, "underrepresentation and erasure of people with a disability carry significant implications for the reproduction and maintenance of [social] inequality." Highlighting this market gap, Kosinski, Orzada, and Kim (2018) claim that most apparel designers do not have training in adaptive apparel, leaving disability invisible in much of the apparel industry (Foster et al. 2021). Esmail et al. (2022, 78) state:

> The slow uptake of adapted clothing in the fashion industry may be due to a lack of understanding of the importance of clothing in the lives of persons with a physical disability and of their specific needs in terms of clothing design.

While growing awareness has mounted in recent years for fashion brands to address disability inclusion (Annett-Hitchcock 2023), adaptive and inclusive apparel (and athletic wear in particular) remain emerging and critical areas of research. Equal visibility and availability of clothing choice are essential for inclusion, allowing everyone the opportunity to construct and express their identity through what they wear (Lipovetsky 1994, quoted in Rocamora and Smelik 2015; Woodward 2007). Social participation, group belonging, and a sense of self can all be affected by the clothes one wears—or what is available to wear (Chang, Hodges, and Yurchisin 2014; Kabel, Dimka, and McBee-Black 2017). Experiences with apparel-related barriers, like inadequate fit, cumbersome donning and doffing, or limited choice of styles are more likely to affect individuals with disabilities and can perpetuate social exclusion (Kabel, McBee-Black, and Dimka 2016).

The athletic wear market is an expanding global industry and is expected to grow to $356 billion by 2032 (Pastore 2023), and by 2026 the adaptive apparel market is estimated to reach nearly $400 billion (BoF Team, McKinsey & Company 2020). Yet adaptive athletic wear is still lacking, which means certain consumers remain underserved in this sector. Engagement in sports can bolster feelings of belonging, acceptance, and cooperation (Hall 2012), but these benefits to well-being, along with needs for rehabilitation or community participation through sport, can be impeded by limited appropriate athletic gear for many individuals with disabilities (DePauw and Gavron 2005). Both athletic wear and adaptive apparel are often discussed in the literature as functional apparel design, where form (trends, aesthetics, values) and function (built-for-purpose construction) are considered (Lamb and Kallal 1992; Watkins and Dunne 2015). While athletic wear is designed for the demands of sport and fitness activity (Gupta 2011), adaptive apparel addresses design needs specific to consumers with various disabilities, such as trousers shaped specifically for wheelchair users (McBee-Black and Ha-Brookshire 2020). Though many disability sports organizations (e.g. Move United, Invictus Games Foundation) promote adaptive sports (e.g. wheelchair basketball, para swimming, hand cycling), adaptive athletic wear is limited both in research and on the market. This area of apparel design is crucial to fostering athletic wear inclusion that supports consumers with a range of disabilities, health conditions, or body diversity in following sports fashion trends, participating in team sports, completing rehabilitation, or maintaining fitness for wellbeing (Poage 2022).

To address this gap, the aim of this paper is to investigate barriers, needs, and values for athletic wear inclusion, focusing on a range of consumers with an upper limb impairment or difference. An underexplored area of apparel research, this scope includes individuals with limb loss, a limb difference, or conditions like arthritis, muscle or nerve damage, spinal cord injury, a stroke, or a short-term injury if the shoulder, arm, or hand is affected. Terminology used within this paper

follows the social model of disability and UK inclusive language guidelines (Disability Unit 2021; Shakespeare 2018). With a pragmatic design research framework in support of athletic wear industry disability inclusion, two research questions were addressed:

1. What are specific needs and values in athletic wear for consumers with an upper limb impairment or difference?
2. How can the results contribute to further disability inclusion within the athletic wear industry?

Literature Review

Athletic wear and adaptive apparel

"Evolve[ing] at a faster pace than ready-to-wear," athletic wear is an innovative field that relies "heavily on research and development" (Bramel 2005, 25), leading to advancements in smart textiles, wearable technology, and material properties like moisture management, thermal insulation, compression, and UV protection (Ahmad et al. 2023; Watkins and Dunne 2015). These garment enhancements and in-depth research work to support the body, increase performance, or aid recovery—in short, maintain a nuanced connection with body function during sport or fitness (Gupta 2011). Beyond the necessity of function in athletic wear, this apparel segment intersects with contemporary lifestyle and fitness cultures. Self–image, for instance, has become affiliated with athletic wear (Basant, Gahlot, and Mehtab 2013), and this type of apparel takes on a fashion status when associated with social fitness trends or pop and sports icons' style choices (Loschek 2009). As such, athletic wear "is available with many leading fashion brands showcasing the latest trends" (Bairagi and Bhuyan 2021, 1062). Innovation for new features and technology are highly valued, and economic interests in this segment are significant (Bielefeldt Bruun and Langkjær 2016). Basant, Gahlot, and Mehtab (2013), finally, stressed the importance of choosing clothing appropriate for the sport practiced. They emphasized that clothing that does not allow the body to perform as it should could possibly impact a wearer's health. Greater focus on adaptive and inclusive athletic wear design and development can support health, identity, and participation in fitness culture.

It has been argued that disability has largely remained outside the apparel industry's scope due to lesser awareness of clothing concerns for different consumers with disabilities (Esmail et al. 2022) and, as suggested by Watkins (1995), possible misunderstandings of how to effectively use mass-manufacturing and distribution systems to address commonalities in clothing-related barriers for people with physical disabilities. While disability is experienced differently by everyone, Watkins (1995) wrote, certain situations are shared by many, which may provide

some direction for adaptive apparel design. In their section on adaptive apparel, for example, Watkins and Dunne (2015) recommended fastening systems for easier donning and doffing, varied and contoured fits, and accommodation for medical devices or braces.

Research on clothing for people with physical disabilities in the twentieth century began with a focus on rehabilitation needs and independence in dressing, but towards the end of the century, adaptive apparel design also began to address psychological and expressive needs in clothing (Carroll 2010). Acknowledging that clothing like adaptive apparel and athletic wear must include aspects beyond functional needs, Lamb and Kallal (1992) developed the functional, expressive, and aesthetic consumer needs model (or FEA model) to balance fashion and function in functional clothing. Addressing expressive (e.g. roles, status, self-esteem) and aesthetic (e.g. design principles) needs in functional clothing avoids unappealing or even stigmatizing results. Lamb (2001) also stressed the importance of involving disabled consumers in the design process to act as agents for change and to contribute knowledge from experience.

A small number of mainstream ready-to-wear brands have started offering adaptive apparel with an aim towards broader disability inclusion. Tommy Hilfiger has seen success with Tommy Adaptive, selling ready-to-wear garments that are designed to that make dressing simpler and more comfortable for different consumers with disabilities, like wheelchair users (McBee-Black 2022). M&S and Target each offer adaptive apparel for children with clothing lines that prioritize comfort for sensory sensitivities and hidden openings for feeding tubes or abdominal access. In 2024, Adidas launched a set of adaptive joggers and t-shirts for wheelchair users with longer back rises and hems and seam placement comfortable for seated athletes. Under Armor previously launched selected styles of jackets and hoodies with MagZip (Regenold 2014)—a magnetic locking zipper for one-handed use—but these were since discontinued. Nike's Go FlyEase trainers, marketed as universal design, have hands-free access and are available in a selection of styles, but while the accessible design received praise, some criticized the high price point and claimed there was a lack of disability representation in marketing (Tesfaye 2021). Research that has been published on adaptive athletic wear recommends functional features like seamless garment construction for comfort and unrestricted ease-of-movement (Bairagi and Bhuyan 2021; Bragança et al. 2018). Acknowledging the complexity of adaptive apparel design, athletic wear, disability sport, and the wide variety of disability experiences, much room is left for research on more comprehensive athletic wear inclusion needs for specific athlete or consumer communities.

Apparel design research for disability inclusion

To assess barriers to and needs for clothing inclusion of often marginalized disabled consumers, human-centered frameworks and methods are

recommended for research in this emerging area. Hobbs-Murphy, Morris, and Park (2024), for instance, published a case study covering the design and development of a custom Paralympic shooting jacket. After applying Lamb and Kallal's (1992) FEA model to assess athlete needs and design the jacket, the authors' recommendations for best practice included increased collaboration with the athlete, consideration of intersectional needs, and a deep understanding of the cultural context. Other approaches to mass-market disability inclusion involve inclusive apparel design. Inclusive design widens the scope of consumers by addressing many complex consumer needs through more accessible design features (Carroll and Gross 2010; Carroll and Kincade 2007). Carroll and Gross (2010) and Carroll and Kincade (2007) explored design features and mass-market production of work attire that could suit a wide range of both disabled and non-disabled women. While suitable designs features were identified, these authors concluded that certain industry biases (e.g. that the inclusion of disabled consumers is too costly or that it conflicts with existing apparel lines) were present and must be countered to reach meaningful inclusion.

Virtual garment design was examined by Paganelli (2021) as an emerging method for disability inclusion through the production of digital mass-customized garments. While he suggested this technique holds future promise, he described finding ableist biases embedded within some tools, such as the inability to scan asymmetrical body types. He, therefore, calls for greater diversity of participants within the apparel development process. Involving participants directly in the apparel design process for ongoing collaboration has been seen to facilitate relationship building, user empowerment, and more satisfactory results (Azher, Saeed, and Kalsoom 2012; Kidd 2006). In her case study of special occasion wear design for young women with spinal curvatures, Kidd (2006) suggested that facilitating ongoing collaborative engagement seemed to impart a sense of ownership to the participants, and the designer learned to look beyond traditional methods and pattern-fitting to find new solutions for the garment designs. Finally, in the case of Azher, Saeed, and Kalsoom (2012), garments were designed with the participation of women with rheumatoid arthritis for results that appeared to support more independence in dressing and increased self-confidence.

Adaptive apparel needs or values are often assessed to acknowledge context and goals for end-use, whether focusing on a specific disability type or addressing broader apparel industry inclusion. Exploring dress behavior of disabled women at university, for instance, Chang, Hodges, and Yurchisin (2014) found that themes unique to these participants were associating clothing with a sense of self-efficacy (perception of one's capabilities) and with markers of overcoming obstacles. Specific to sports apparel, Bragança et al.'s (2018) adaptive athletic wear study presented a needs assessment and design recommendations for wheelchair rugby player uniforms with the athletes identifying barriers in athletic

wear that is incompatible with wheelchair use and suggesting bespoke garments as an ideal solution. Taking into account that the mainstream apparel market is not conducive to selling bespoke options for operational reasons like manufacturing costs, Bragança et al. (2018) illustrated recommended design adaptations of existing mass-market athletic wear to better suit wheelchair users. Similarly, in her case studies of Tommy Hilfiger's adaptive apparel collaboration, McBee-Black (2022, 2024) indicated that user-focused design adaptations (magnetic closures, adjustability, varied entry points) to existing ready-to-wear styles facilitated a balance between industry and shared consumer needs for their successful mass-market adaptive apparel line. Accordingly, the research framework and results of this study on adaptive athletic wear build on the aforementioned adaptive apparel research in terms of needs assessments relevant to disability communities, direct engagement with participants, and balancing results with apparel industry practices.

Research Framework and Methods

Methodology

To explore adaptive athletic wear barriers, needs, and values, a pragmatic design research framework was applied. Pragmatism involves generating knowledge and evaluating results for real-world, applicable significance (Saunders, Lewis, and Thornhill 2012). A practice-informed design research context served to maintain a balance between user and industry needs for practical results for disability inclusion in both apparel research and practice (Chynoweth 2013; Koskinen and Krogh 2015). As such, this was a cross-sectional study, and through qualitative, inductive inquiry, localized knowledge was generated through an exploratory, iterative process (Saunders, Lewis, and Thornhill 2012). Rather than stemming from a set hypothesis, meaning was constructed through a user-led participatory exploration (Gaudet and Robert 2018). A participatory design focus guided the data collection and analysis with a mindset towards ideating with participants rather than for them to value knowledge through lived experience (Sanders 2002; Spinuzzi 2005).

To understand and position disability inclusion beyond purely functional design adaptations, aspects of constructivism were also relevant. As in the introduction, Foster et al. (2021) claim that underrepresentation of disability can perpetuate inequality, and Carroll and Kincade (2007), McBee-Black (2024), and Paganelli (2021) discuss observed misperceptions around consumers with disabilities as potential challenges to apparel inclusion. As Gaudet and Robert (2018, Choosing Qualitative Inquiry chapter) wrote, "we create social realities by naming, describing and interpreting them. Creating new understandings of social realities can sometimes help to deconstruct taboos and empower people." Accordingly, the social model of disability (Shakespeare 2018) provided a lens to decipher how garment-related barriers may be present for

certain athletic wear consumers, and once mismatches are recognized (Holmes 2018), inclusive practices and design solutions can be recommended.

For this study, the participatory design approach facilitated participants' reflections on their own experiences and needs for athletic wear garments and inclusive practice. Thematic analysis of the primary research data supported the pragmatic framework by identifying emergent themes (e.g. adjustable sleeves) applicable to designing adaptive athletic apparel. Findings were verified by users, the researcher, and additional apparel researchers and designers for practical results reflective of participant feedback, the disability studies underpinning, and industry parameters. The researcher's apparel design training and work experience in the athletic wear industry supported the practice-informed lens. The specific participant community was identified to meet a gap in the research. All research participants were adults who were provided with a participant information sheet before taking part in the study that covered the purpose of the research, details of engagement, data protection, and future use of contributions in academic reports or publications. Each participant either signed a consent form or gave verbal recorded consent (with choice provided for accessibility) before engaging in the research. The research followed the University of the Arts London's (UAL) ethical guidelines and had approval from UAL's Research Ethics Sub-Committee and College Research Degrees Sub-Committee.

Data collection

Data collection consisted of three phases—interviews, workshops, and feedback—with reflection and analysis following each stage to inform the subsequent one. All data collection was virtual to match the researcher's own disability-related needs and to continue research throughout the COVID-19 pandemic. A virtual format also served to fulfill sampling requirements by reaching individuals across the US and UK. Due to the purposive sampling needs to meet the study aim and the nature of exploratory inquiry, sample sizes at each phase were relatively small (Saunders, Lewis, and Thornhill 2012). Different participants were recruited for each data collection phase (Table 1), bringing the total number of user participants to 18. Recruitment was achieved through extensive distribution of notices for the research through Facebook and Twitter, disability organizations, adaptive sports foundations, and snowball through professional contacts. Engaging new participants at each phase provided triangulation, as did the choice of multimethods (Letts et al. 2007).

For the initial primary research phase, semi-structured, one-on-one interviews were conducted with five individuals who identified as having an upper limb impairment or difference and felt frustration with available athletic wear. The aim of the interviews was to explore the current

Table 1 Participant information for interviews, workshops, and questionnaire.

	Gender	Age range	Location	Self-description
Interviews:	Male	N/A	US	Partial paralysis of hand
	Male	N/A	US	Paralysis and muscle loss in arm
	Male	N/A	UK	Paralysis of arm
	Female	N/A	US	Born without one forearm
	Female	N/A	US	Shoulder surgeries, congenital condition
Workshops:	Male	26–35	US	Right below elbow amputee
	Female	18–25	US	Missing left hand and forearm
	Female	26–35	UK	Wears prosthetic arm
	Female	26–35	US	Quadriplegic, limited finger function and arm strength
	Male	46–55	US	Quadriplegic, C5-7
	Male	26–35	UK	Quadriplegic, C5, paralysis of hands, triceps, forearm
Feedback:	Female	26–35	US	Missing arm from 2cm below elbow
	Female	36–45	UK	Complex regional pain syndrome at left arm
	Female	56–65	US	No fingers on left hand, left arm is shorter
	Male	56–65	US	Above elbow
	Male	36–45	US	Left arm, below elbow
	Male	56–65	US	Right hand and arm, right leg
	Male	66–75	US	Left arm paralysis

scope of athletic wear design and disability accessibility related to user-specified goals, perspectives, and values. Interviews were conducted over Skype or by phone and lasted around 30 min each. Open-ended questions asked about mismatches with available athletic wear, solutions for improving designs, and practice for more meaningful athletic wear design inclusion. Discussions were open to any sport and type of athletic wear due to the exploratory nature of this emerging area of research.

For the following phase, one-on-one design ideation workshops were conducted with six new individuals who met the same parameters from phase one. The aim was to assess context and needs for athletic wear garments from users' perspectives. All workshops took place over Zoom with screen-shared ideation templates adapted in the online collaboration platform Miro v0.3.32; each session lasted about 1 h. Participants were guided through three design research exercises: (1) athletic wear use journey mapping (i.e. identifying key touchpoints of a user's experience to identify what works well and what needs improvement, as per Design Council 2015); (2) solutions ideation for desired athletic wear features; and (3) current market availability and prioritization of recommended design features. The workshops concluded with time for discussion on any resulting insights or thoughts about athletic wear inclusion.

The final feedback phase involved a questionnaire to evaluate the synthesized and visualized results from the interviews and workshops. Seven new participants completed this questionnaire, again matching the same recruitment parameters of the first two phases. Participants were given online access to the questionnaire through JotForm, where they viewed a range of athletic wear design strategies generated from the results of the first two phases. Questions asked which, if any, of the

results were preferable, and space for further feedback was provided. Finally, four senior or director-level industry athletic wear designers, an apparel technician, and a physiotherapist who also runs an adaptive apparel line provided feedback on the suggested design strategies through individual or two-person Zoom interviews.

Data analysis

Separate data analyses, as outlined below, were done after each data collection phase with findings applied to iteratively refine the final research output. Reflective journaling assisted in tracking emerging insights throughout the research project (Saunders, Lewis, and Thornhill 2012); reflexive notes aided in reflection on the researcher's role and interactions to prioritize the user-led insights (Barbour 2008). Following Stappers (2007), illustrations and mapping aided in visually making sense of significant design-related results and the intersection of user needs and athletic wear design practice.

For the first data collection phase, interviews were recorded, and transcripts were generated by a third party and checked by the researcher for accuracy. Transcripts were then loaded into qualitative analysis software Nvivo v12.6.1 for thematic analysis, following Braun and Clarke (2006). Initial codes were data-driven for user-led influence with emerging themes then evaluated and refined for relevance to the research aim of identifying athletic wear needs, values, and barriers. Thematic analysis was also applied to the workshops needs-related data, following the steps from Braun and Clarke (2006). As the final ideation boards for each user workshop were saved digitally, the thematic analysis was done visually within Miro. A collection of virtual Post-it notes showing participant ideation contributions were iteratively coded and clustered into themes—a method rooted in design thinking (Thoring and Müller 2011). The final themes found from the interviews and workshops were sent to respective participants for validation or feedback. Two responded from the interview set, agreeing with the findings; no participants responded from the workshop set. As previously noted, cumulative results from the interviews and workshops were visualized and evaluated through the user questionnaire, physiotherapist interview, and designers' feedback. Pertinent feedback and further recommendations were applied to refine the final results. Each data set was then re-reviewed to ensure no barriers, needs, or values conflicted with the final output and that all critical points had been considered.

Results

Phase 1: Interviews

Findings from each primary research phase were analyzed separately and then consolidated for the full set of results (Table 2). Data analysis from the first phase—the interviews—revealed three main themes:

Table 2 Athletic wear needs, design recommendations, and values for consumers with a self-described upper limb impairment or difference.

Functional needs	Design recommendations
Grip	Loop in zipper pull
	Large zipper pull
	Thumbhole loops in sleeve, hems, or waistband
One-handed fastenings	Magnet or Velcro closures in place of zipper
	Magnetic zipper
	Avoid buttons or laces
Reach	Accessible pocket placement
	No back fastenings
Donning/doffing	Slick inner sleeve lining
	Flexible or no sleeve cuffs
	Looser fit on pull-over tops
	Front opening on tight top
Sleeve fit	Varied sleeve lengths
	Adjustable sleeves
Prosthetic use	Access points along sleeve or at back
	Appropriate sleeve fabric
	Sleeve with enough room to fit over
Brace use	Sleeve tight enough to fit under
	Sleeve with enough room to fit over
Values for inclusion (or expressive and aesthetic needs)	
Affordable cost	Less time spent on dressing
Choice of styles	Able to self-adjust garment
On-trend looks and materials	Big brand inclusion
Not too "adaptive" looking	Availability of varied fits
Inclusive marketing	

- Theme 1: Wider context of inclusion
  - Subthemes: Preferences in athletic wear, medical devices, barriers beyond athletic wear, and complexity of limb impairment
- Theme 2: Donning and doffing
  - Subthemes: Barriers with tight clothing, preference for front openings, one-handed dressing, and trim or closure function
- Theme 3: Personalized solutions

The first theme represents the broader context surrounding adaptive athletic wear design and what inclusion meant to the participants. When asked about preferences in athletic wear, many of the answers immediately referred to common styles (leggings or cycling tops) or material properties (sweat wicking) available at retail, and popular brands like Under Armor were mentioned. A holistic set of needs (style preference, sport-specific use, moisture management), many of which were not disability-specific but more generally around athletic wear function and appearance, were discussed which should remain fundamental considerations in adaptive athletic wear. Certain barriers to preferred athletic wear did emerge, however, for consideration regarding this participant group, one concern being the interaction of athletic wear with medical

equipment like arm braces. One participant discussed the time it took to put on multiple tops over and under two difference arm braces and expressed frustration at managing the right layers to accommodate this. Mentions of mismatches in accessibility unrelated to athletic wear (e.g. inaccessibility of a water bottle, gloves, bras, and jeans) also arose in the interviews unprompted, conveying the greater impact of design-related barriers when multiple areas of daily living are affected. A further crucial contextual point is that the label "upper limb impairments or differences" represents a complexity of people, varied experiences, and multiple perspectives. As one participant stated, "the more people I meet within the disabled world, the variations of… even just arm amputations within one arm is completely different." This reality is essential in maintaining an inclusive mindset and bears relevance on when inclusive or adjustable garment designs might be a feasible solution and if further design strategies (e.g. mass customizable) can be explored.

Although each participant had their own experience with athletic wear, some shared athletic wear barriers did emerge amongst multiple participants. Participants indicated that donning and doffing (putting on and taking off) athletic wear increased in difficulty with tight tops or leggings, generally designed to be pulled on with two hands. As one participant described, "that's hard to get off if it's tight, and then you have the sports bra which everyone has a problem with, but even more so for those with limb differences." Front openings were recommended for tighter tops, amongst other styles, because "if I unzip it, it's not hugging the skin. And it would just be easier to just get the whole thing off." Trims like drawstrings and buttons that also require two hands to manipulate were considered inaccessible. Due to these experiences, most participants had adapted store-bought clothing, leading to user-led experiential knowledge of what design features and materials suited their needs. One participant, for instance, had replaced his shoelaces with a hands-free "never tie" shoe fastening device and added loops to extend smaller zippers for easier grip. Another participant went through his own design process of testing and applying bungee cords and then seatbelt material to best secure his arm brace during sports. Adopting a participatory design framework for adaptive athletic wear, accordingly, could facilitate participants to express novel and effective solutions.

Phase 2: Workshops

From the second primary research iteration, the workshops data analysis revealed themes that intersected with the previously described interview themes as well as some new findings. Three workshop themes emerged:

- Theme 1: Trims and construction
  - Subthemes: Grip, accessible trims, and fit
- Theme 2: Adjustability
- Theme 3: Values for apparel inclusion

As in the interviews, barriers for donning and doffing due to required two-handed grip was mentioned repeatedly throughout the workshops. Design suggestions included adding thumbholes, loops, or rings at key leverage points to better grasp a garment or a zipper. Making trims accessible meant that features, such as pockets, needed be reachable and large enough to use. For instance, an arm pocket might be unusable for someone with limb loss, and small pockets could be inaccessible for someone whose fingers remain bent. Additionally, replacing zippers or buttons with fastenings for one-handed access was described as "good as idea, but needs to work." These fastenings need to be accessible but also "stay locked during a workout"—this particular statement being based on an experience of an adaptive garment closed with Velcro opening up during a workout. Finally, recommendations for fit involved clothing that felt secure on the body but not too tight, more varied fits for greater body diversity, and options to choose different sleeve lengths or fabrics.

While many of the above-mentioned design features represent similar experiences shared amongst multiple participants, the theme of adjustability reflects certain individual experiences that were at times referenced. Similar to the interview feedback, one participant stated, "I'd be curious with adaptive fashion how you can make a product work for a lot of abilities because each 'disability' is so different from one another." Some participants wanted options to self-adjust garments to suit their own needs. One participant suggested detachable and movable loops to connect to garments in strategic spots for better leverage in dressing. The notion of adjustability arose repeatedly in reference to sleeves with preferences including, "option to take off or put on sleeve" and "make sleeve easy to roll to certain length."

The concept of adjustability, while relating to functional garment design, also reflected critical values for apparel inclusion. As one participant noted, adjustability in a garment allows for the "ability to modify to fit personality." Built-in garment adjustments can also facilitate self-reliance and normalize options in clothing that may have previously been seen as disability add-ons or were described as requiring a trip to a tailor. Explained by one participant, "that's what I want at least, is like to be able to be in charge of my own stuff and not always have to ask for somebody to help me or… that it's like a special request. Just that it's normal to have options." A desire for mainstream brand inclusion was indicated with one participant stating, "I want to see big sports brands do more in this stuff," and on-trend aesthetics—or, "adaptive clothes that are still cute" as one participant put it—were considered very important. Reducing time and effort in dressing, along with reasonable cost, were also valued for athletic wear inclusion.

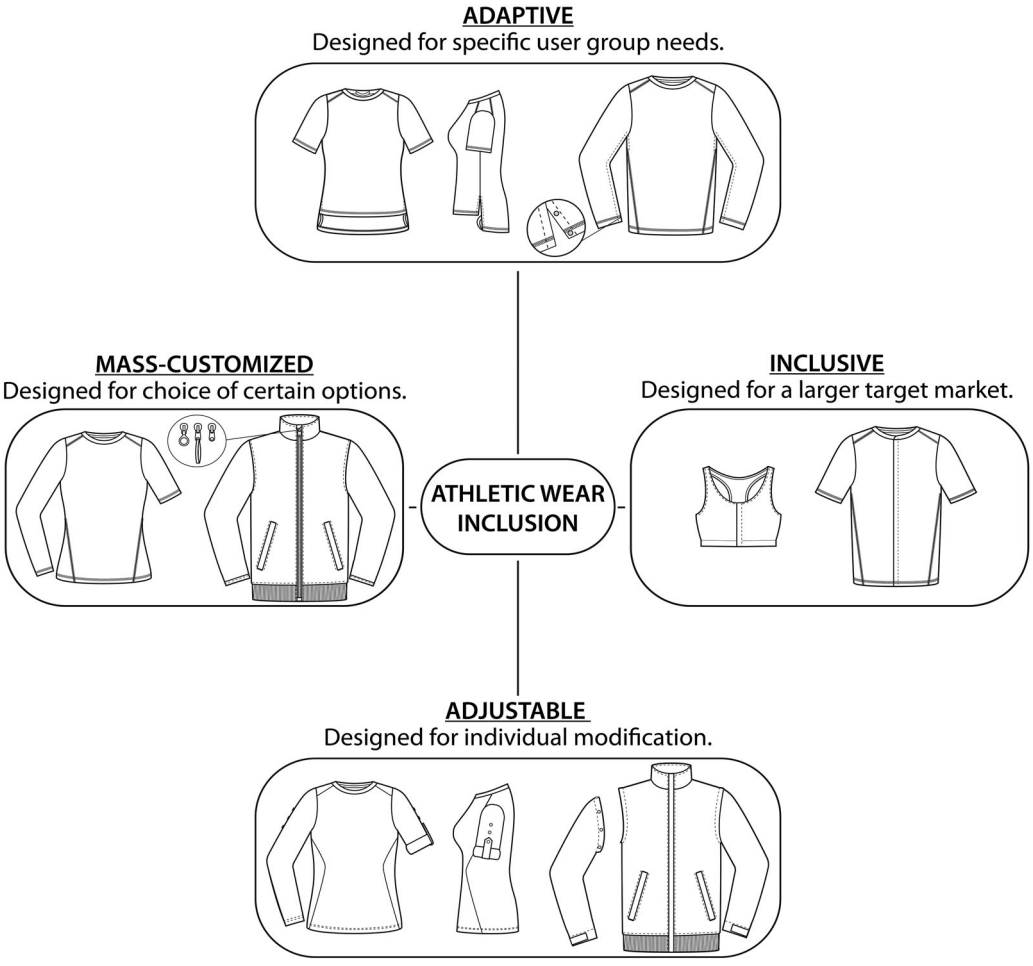

Figure 1
Athletic wear inclusion design strategies.

Final output: design strategies, needs, and values

In summary, while shared design recommendations emerged in both the interviews and workshops, emphasis was also placed on the individual and customization. Acknowledging the assortment of participant needs and the practice-informed context of apparel design, a range of design strategies for athletic wear inclusion were mapped (Figure 1) from the primary research results. Four options are shown: adaptive, inclusive, adjustable, and mass-customized. Ready-to-wear adaptive athletic apparel may address disability-specific preferences, such as added loops for donning and doffing. Strategies for mainstream athletic wear to meet more varied needs are: (1) mass-customization (e.g. options for choosing accessible zipper pulls); and (2) adjustable garment features, such as detachable or rollable sleeves. A further option is inclusive design, where

existing athletic wear is made more accessible to reach a wider scope of users. For example, adding a front opening to tight compression tops could simplify donning and doffing for many disabled and non-disabled consumers alike and serve to widen the market.

The athletic wear inclusion diagram was embedded in the feedback questionnaire sent to the final participants and reviewed by the athletic wear designers and physiotherapist. Each of the four design strategies received preference from different user participants, validating the need to explore a multifaceted view of apparel inclusion. From the designer reflection on the inclusion strategies, a question arose on whether to ideate from one branch of Figure 1 or to address the full scope for a larger focus; this designer indicated that non-disabled athletes could use certain features like customizable sleeves, suggesting that such inclusion efforts could reach a much wider consumer base. Two designers were familiar with garment adjustability but had not considered it specific to disability-related needs, and two designers thought it was important to clearly distinguish between adaptive and inclusive apparel. While three designers were intrigued about the idea of mass-customization for functional needs, they noted that mass level customization can be difficult due to costs and logistics. The physiotherapist offered construction recommendations: magnetic locking zippers and built-in sleeve openings to accommodate different types of braces. Further design recommendations also emerged from the user feedback, such as having fewer zippers and slick inner fabric for tops. Participants, as before, expressed values of affordable cost and garments not looking "too adaptive," with one respondent emphasizing the importance of appearance and belonging by stating, "specialized inclusive clothing needs to not make the individual look different! …I want clothes that are easier for me but I don't want to necessarily wear things that look different from other participants." Contributing to the broader context of disability inclusion, appropriately marketing to this consumer was indicated as a concern. The inclusion map was refined with this feedback, and needs and values, along with design recommendations, from all phases were consolidated. While the data collection and analysis were user-led and inductive, the emergent themes as listed in Table 2 align with Lamb and Kallal's (1992) FEA model, underscoring the significance of addressing function, expressive, and aesthetic needs in adaptive athletic apparel.

Discussion

The results in this paper build on previous athletic wear and adaptive apparel design knowledge (Figure 2) and offer a set of needs, values, and design recommendations to support wider athletic wear inclusion. In response to research question one—What are key needs and values in athletic wear for consumers with an upper limb impairment or difference?—Table 2 shows a spread of participant-suggested functional adaptions related to grip, one-handed dressing, reach, simpler

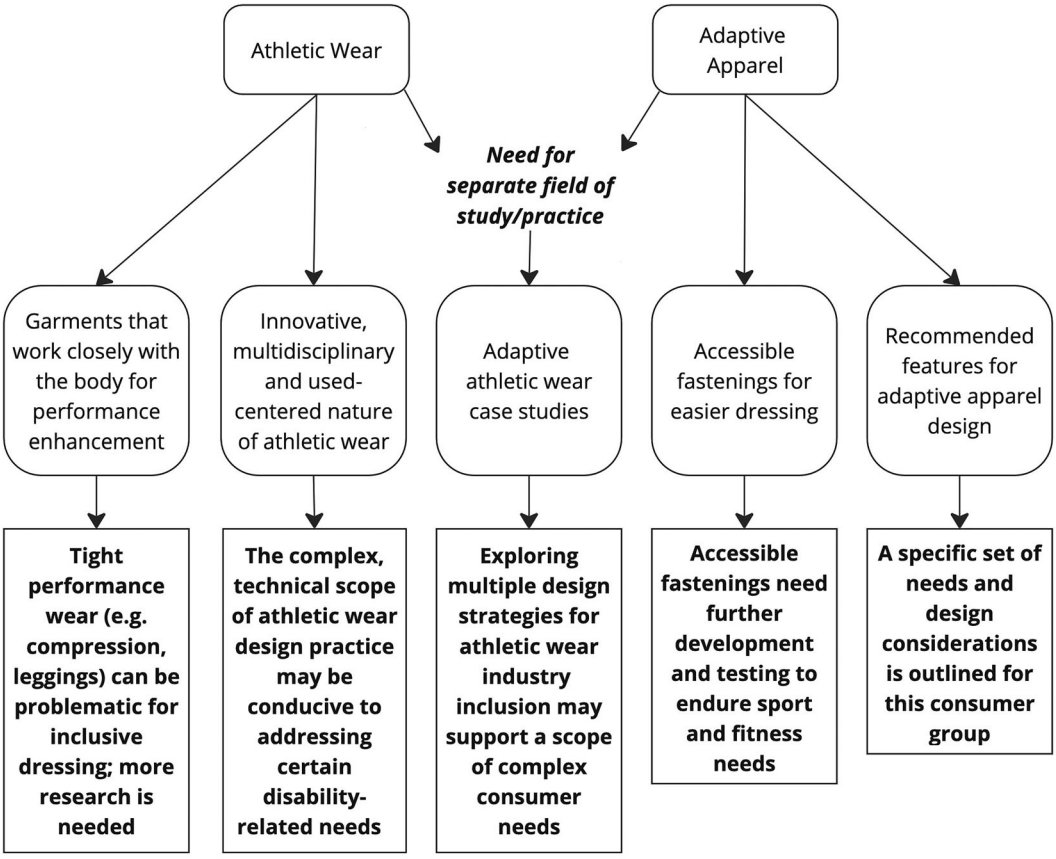

Figure 2
Path of adaptive athletic wear knowledge (with study results in bold).

donning/doffing, sleeve fit, and accommodation for medical wearables (e.g. arm brace). Along with further values for inclusion (e.g. affordable cost, varied fits, ability to make self-adjustments), these results point to a multifaceted scope of considerations for athletic wear inclusion of this potential consumer group, diverging from the previous studies on adaptive athletic wear design that focus on particular garment types for wheelchair users. A crucial finding emerging from this study was that multiple participants expressed dissatisfaction with the function of existing ready-to-wear adaptive clothing features when used on performance wear, a critical intersection (i.e. adaptive and athletic wear needs) that expands on but was not found in previous literature on types of functional apparel design (i.e. Gupta 2011; Watkins and Dunne 2015). On this point, several participants suggested that addressing both sports biomechanics and inclusive dressing needs were of particular concern in tight-fitting garments (e.g. compression pieces, base layers, leggings) that interact in very close contact with the body. Multiple participants also

shared experiences or concerns of accessible trims or fastenings on athletic apparel, like magnetic or Velcro closures, drawstrings, or front easy-clasps on sports bras, releasing during exercise, highlighting a need for adaptive or inclusive performance-ready accessories. It should be noted that while magnets were suggested by some participants and that NdFeB magnets are sometimes used as accessible fastenings in clothing, these come with potentially serious risks for some when worn close to the body, such as interfering with near medical devices like cardiac pacemakers or implantable cardioverter-defibrillators (Wolber et al. 2007); accessible features should be tested for any health-related impact.

In addressing research question two—How can the results contribute to further disability inclusion within the athletic wear industry?—two aspects of the findings, in particular, were considered pertinent: (1) design strategies to meet a spectrum of inclusion needs, and (2) participant-led ideation to generate inclusion solutions. Throughout the data collection phases, it became apparent that multiple design strategies—adaptive, inclusive, adjustable, and mass-customized—reflected the complexities of participants' disability, fitness, and athletic wear needs and preferences. This selection bears similarity in concept to Black and Williamson's (2011, quoted in Grenier, Miller, and Black 2017, 53) inclusive sports model, which promotes a range of sports setups from separate modified activities to inclusive sports groups so all who want to engage in sport have an option to do so—a framework upon which Figure 1 was visually modelled for apparel inclusion options. While adaptive apparel research has often focused on single case studies or approaches (e.g. Paganelli's 2021 disability inclusion research on mass-customization through body scanning and digital knitting), which have been integral to this field of study, future research could further explore and intersect multiple design approaches to compare manufacturing, costing, and consumer inclusion implications.

Looking at these approaches within the context of this study, a novel take on mass-customization for choosing sleeve length, material combinations, or closure options emerged, supported by many research participants, and also seen as relevant, in the designer feedback, to a wider athletic wear consumer base. This option, it was noted, would need further development in logistics and cost for use in practice. In terms of more specific adaptive sportswear designs, Bragança et al. (2018) concluded that smaller-scale providers who can produce fewer quantities of specialized garments may be best set up to meet more individualized needs in athletic wear, which may suit certain design recommendations stemming from this study (e.g. adaptive athletic tops that can integrate with a prosthetic or arm brace). Differing from the previous adaptive-focused athletic apparel research, the option for inclusively designed athletic wear is intriguing for this study's scope as several design features recommended in the findings may also be usable by existing mass-market consumers to extend the reach of commercial athletic wear.

Suggested inclusive features, for instance, could facilitate reduced grip, one-handed (or quicker) dressing, and easier reach in athletic wear that could benefit a larger scope of wearers looking for streamlined garment function. From this study's results, such relevant recommended design features include looped zipper pullers, easy-grip high-performance trims, and fastenings (e.g. one-handed drawstrings), accessible (large, securely closing, and easy-to-reach) pockets, accessible front openings on tight tops, variable (modular, adjustable, detachable, or rollable) sleeves, and additional garment openings for simplified donning and doffing of performance pieces. While this approach builds on Carroll and Gross' (2010) and Carroll and Kincade (2007) exploratory design research on inclusive office attire development for a range of women by clustering shared clothing needs, the inclusive garment considerations from this study's scope and findings (like added openings, loops, or extra points of grip to don performance tops or leggings) are specific to athletic wear function and built-for-purpose design (i.e. biomechanics, ergonomics, material science, construction methods). Within this context, it is proposed that the innovative, multidisciplinary, complex user-centered nature of athletic wear design (Ahmad et al. 2023; Watkins and Dunne 2015) may well-support the development of more functionally inclusive commercial athletic wear with a focus on flexible wearability or streamlined dressing.

Consistent with the reasoning of collaborative and user-focused adaptive apparel design researchers like Azher, Saeed, and Kalsoom (2012), Kidd (2006), and McBee-Black (2022), this paper posits that participatory engagement with different people with disabilities can be integral to deeper understandings in adaptive or inclusive athletic wear research and design. Within this study, the participant-led explorations resulted in ideated solutions inspired by the participants' perspectives and lived experiences, like securing excess sleeve fabric during exercise or adding fabric loops to smaller zippers. Leaving space for open-ended feedback in all data collection phases also facilitated sharing of broader views and considerations for apparel inclusion, such as the needs for less time spent dressing or modifying clothing and not feeling differentiated by adaptive garments that are very distinctive in appearance. In addition to the needs assessments, this paper contends that these flexible discussion points iterated throughout the research journey led to a more comprehensive view of athletic apparel inclusion, building on Hobbs-Murphy, Morris, and Park's (2024) stance to seek understandings of disability cultural contexts for adaptive (or inclusive) athletic wear design.

Conclusion

This study's results call attention to the timely need for more research focused on adaptive and inclusive athletic wear design and for applying a comprehensive approach to understanding and assessing diverse

disability, sport, and garment-related user needs. The findings of this research exploring needs and values of consumers with an upper limb impairment or difference, in particular, highlight a specific need for the development of fastenings that are both accessible in design and can withstand high-performance demands during garment use. Additionally, a significant need for tight-fitting athletic garments that can provide necessary performance support for the wearer but can also be donned and doffed with less effort, along with versatility in sleeve design and function, was clearly expressed for this study's participant scope. Values like self-reliance through the ability to make necessary adjustments to garments or fitting in with on-trend accessible sports or fitness apparel, furthermore, point to a more holistic understanding of apparel inclusion. It is posited that certain recommended garments features from this study's results (e.g. easy-grip performance closures, adjustable sleeves) may be shared with a wider scope of commercial athletic wear consumers, supporting an inclusive approach. Resources like Microsoft's (2024) inclusive design toolkit with methods for defining, understanding, and contextualizing underrepresented user communities could further support fashion designers entering this area, although the development of more inclusive and participatory apparel design frameworks would also be beneficial.

Given that the research was conducted virtually due to the circumstances previously outlined, only those with online access and relevant technical skills participated, and as the purposive sampling required for this research scope necessitated a relatively small sample size in each data collection phase, there is space for future virtual, hybrid, and in-person observations with a wider set of user participants and industry partners. As the parameters of this study were limited to a needs and values exploration, future research is recommended to develop and wear-test specific adaptive and inclusive athletic garments with additional evaluations for user satisfaction, costing, and inclusive marketing. Further research on accessibility of different types of athletic wear (e.g. sports bras, swimwear) for more disability communities (e.g. wheelchair users, consumers with a visual impairment) is also recommended to understand broader inclusion frameworks. Finally, future research can investigate intersections of the research results for disability inclusion with other socially responsible areas of apparel research, like sustainability.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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