Design of the Soft Ankle Support (SAS) for Children with Ankle Instability

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Introduction: Ankle-foot-orthoses (AFOs) are assistive devices that can provide lower extremity support by stabilizing the ankle for individuals with physical disabilities and ankle weakness (AliMed, 2014; Chang & Cardenas, 2000). Despite their functional application, AFOs are predominantly perceived negatively by users in relation to expression, accessibility, and aesthetics (Li, Orlando & Lobo, 2020; Lahoud et al., 2020). Traditional AFOs are made from hard materials such as heat-moldable plastics, metals, and carbon composites (Civil, 2020). The bulkiness of these materials restricts the use of footwear options typically worn during social activities such as formal events, dance, and sports (Civil, 2019). Compared to hard AFOs, a Soft Ankle Support (SAS) garment that is flexible and sleek may provide a novel, more appealing solution for users (Li et al., 2019). The purpose of this study was to implement a user-centered design process to develop the SAS, a soft ankle support garment to serve as a supplemental solution for children with mild to moderate ankle weakness who use AFOs. The Functional, Expressive, Aesthetic, Accessibility (FEA2) consumer needs model was used to guide the design process in order to develop a wearable that could meet the broad needs of end users (Hall & Lobo, 2018).

Method: Three children (3-14 years of age) who used AFOs daily due to mild to moderate ankle weakness participated in this study. The research team developed the SAS prototypes based on user needs reported in prior literature and by the current study participants and their parents. Participants and their parents provided feedback throughout the iterative design process. User satisfaction regarding the final SAS prototype and participants' AFOs (Figure 1) were assessed via participant ratings (1-5 Likert scale; 1= not satisfied, 5= very satisfied) for the following items: dimensions (bulk), weight, adjustability, safety, durability, ease of use, comfort, effectiveness, aesthetics, and fit.

Results: The SAS was inspired by ankle braces that are commercially available for the management of ankle injuries. The available products utilize a variety of lateral ankle support mechanisms and often a figure-8 wrapping to support the forefoot. While these solutions could provide design inspiration, they would not suffice as a solution for participants in this study, since they were made for temporary usage and therefore did not meet users' needs in terms of aesthetics, durability, or comfort. Furthermore, child sizes were limited or unavailable for

A B C

Figure 1. The AFOs used by (A) Participant 1, (B) Participant 2, and (C) Participant 3.

these products. Different types of performance fabrics were explored during the iterative design process. 5mm neoprene (Seattle Fabrics), heavyweight 4-way stretch Ponte de Roma in various colors (Spandex World Inc.), and knit interfacing for fabric stability (Pellon® SK135 Sheer-Knit™), were selected to make the final products (Civil, 2019). Each participant selected their preferred color and design for their SAS. They received two SAS prototypes: one SAS design utilized a figure-8 elastic wrap (elastic 9320W, Amazon); the other incorporated lacing (lace-Derby Lace, Amazon). Tunnels were incorporated to house corset wire (1/4" Wide Spiral Steel Corset Boning, Bias Bespoke) and/or 0.02mm feeler gauges (Brass Feeler Gage Strips, TBI) to provide different levels of lateral support. The final SAS prototypes are shown in Figure 2. Do-it-yourself manuals detailing the materials and methods necessary for fabricating the SAS were developed and openly shared online to increase accessibility (https://sites.udel.edu/move2learn/how-todiy/).

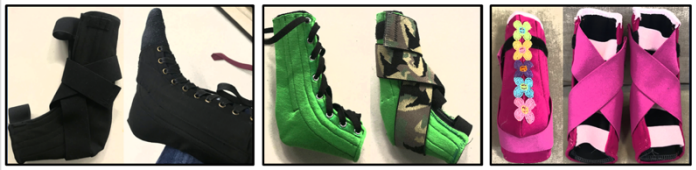

Figure 2. SAS prototypes for (A) Participant 1, (B) Participant 2, and (C) Participant 3.

Users' ratings of the SAS and their AFOs are shown in Table 1. Across all categories, the SAS was rated equal to or higher than participants' AFOs. The SAS and AFO had similarly high ratings for safety, durability, effectiveness, appearance, and fit. The SAS was rated higher than AFOs for its dimensions (bulk), adjustability, ease of use, and comfort. Participants reported that they especially appreciated that the SAS allowed them to utilize typical footwear to dress for formal occasions, sports (i.e., cleats), and dance (i.e. ballet shoes).

Table 1. Users' ratings of the SAS and AFOs.

	Bulk	Weight	Adjustability	Safety	Durability	Ease of Use	Comfort	Effectiveness	Aesthetics	Fit
SAS	**5**	5	**4.5**	5	5	**4.5**	**5**	5	5	4.5
	(0)	(0)	**(.7)**	(0)	(0)	**(.7)**	**(0)**	(0)	(0)	(.7)
AFO	3.2	4	2.3	5	4.7	3.2	3.3	4.7	4.5 (.5)	4.2 (.8)
	(1)	(1)	(.6)	(0)	(.6)	(1)	(.6)	(.6)		

Note: Mean (Standard Deviation). 5= very satisfied, 1= not satisfied. Orange shading: SAS rated higher.

Conclusion: This study developed the SAS to serve as a supplemental solution for children who use AFOs due to mild to moderate ankle weakness. The user-centered design process allowed our team to create a product that successfully met users' needs related to function, expression, aesthetics, and accessibility. Participants perceived the SAS as being similar to or better than their existing orthotic solution. This study serves as an example of how user-centered design efforts can be used to develop improved rehabilitation devices for people with disabilities. This work also highlights the need and potential to improve wearables used in rehabilitation.

Reference:

AliMed. (2014). AFOs or Ankle Foot Orthosis Article. Retrieved September 22, 2018, from https://www.alimed.com/afo-info-blog/

Chang, M. W., & Cardenas, D. D. (2000). Ankle-Foot Orthoses: Clinical Implications. *Physical Medicine and Rehabilitation*, 14, 435-454

Civil, D. A. (2019). Design and Development of a Soft Pediatric Support Garment for Ankle-foot Orthoses Wearers (Masters dissertation, University of Delaware).

Hall, M. L., & Lobo, M. A. (2018). Design and development of the first exoskeletal garment to enhance arm mobility for children with movement impairments. *Assistive Technology*, 30(5), 251-258

Klingbeil, F. T., Whitaker, B., & Dunn, C. (2000). Principles and Clinical Practice of Lower Limb Orthotics in Children. *Physical Medicine and Rehabilitation*, 14 (3), 515–532.

Lahoud, D., Teng, C. H., Nusem, E., Burns, J., Wrigley, C., & Cheng, T. L. (2020). Content analysis of child user and carer perspectives of ankle–foot orthoses. *Prosthetics and Orthotics International*, 0309364620952906.

Li, B., Greenspan, B., Mascitelli, T., Raccuglia, M., Denner, K., Duda, R., & Lobo, M. A. (2019). Design of the Playskin Air™: A User-Controlled, Soft Pneumatic Exoskeleton. In *2019 Design of Medical Devices Conference*. American Society of Mechanical Engineers Digital Collection.

Li, B., Orlando J. M., Lobo, M. A. (2021). User-Perceptions about Lower Extremity Orthotic Devices: A Systematic Review. *In 2021 Combined Sections Meeting (CSM)*. APTA.