Smooth Dynamic: Assistive Glove for Wheelchair User

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With the development of technology and the capability of product customization, more people with mobility issues, or the disabled, are seeking specialty assistive tools to help facilitate and manage their daily lives. Currently, the selections of mobility assistive tools have yet to largely improve the quality of life for effected individuals (Lunsford et al., 2016). The current market has yet to offer effective assistive tool suitable for many wheelchair users. There are some key variables, including discrepancies in anthropometry, the diverse degrees of the declines in physical body functions in adults, and the comfort ease in tool use. At the same time, the ergonomics and aesthetic factors have often been neglected by designers and in the mass manufactured products. Research have suggested that the hand rim wheelchair propulsion has a strong relationship with high physical strain in daily life, and may lead to fatigue and injuries in hands, wrists and shoulders (Janssen, van Oers, van der Woude & Hollander, 1994). It may cause chronic injury, such as carpal tunnel syndrome (CTS), and leads to hand, wrist, arm, event back pain, numbness. It thus reduces the user's hand overall function, particularly the grip strength. Consequently, the repeated and high strenuous wheelchair propulsion may lead to CTS, and the overuse of handling wheelchair pushrims often lead to wrist hyperextension in the coronal plane. There is limitation on research that focus on assistive tools that supports the wrist, finger, and hand's palmar side. Particularly, research gap exists in the use of 3D printing (3DP) technology and 3D computer-aided design (3D CAD) modeling tools in creating solutions for wheelchair operating challenges. .

This case study explores the workflow approach in developing wearable assistive glove for female wheelchair users using 3D CAD modeling program (Rhinoceros), 3D scanning, and 3DP technology (Fused Deposition Modeling or FDM). This case study was conducted using the qualitative approach and the research through design methodology, and reflexive journal for documentation. One live model is used for modification in the design development.

The assistive glove was developed using both traditional textile, medium weight Spandura knit, and 3D printed nylon filament. It consists of 2 portions: 1) the custom fit glove and 2) the wrist protection portion. The fitted glove portion allows the tip of the four main fingers to expose with the thumb closed. Each finger consisted of customized small friction pads to provide better grip and support in handling the wheelchair pushrims. The customized friction pieces on the palm side also further support the gripping motion. They are designed with 3 mm thickness. On the dorsal of the glove, a 3D printed textile design was incorporated to provide aesthetic value for the female users and provide additional heat dissipation. In the second portion, an articulating two-part wrist protection is 3D printed and designed with ergonomic curves. Due to common hand issues in operating the wheelchair, it is designed with two extended panels on the top part and mainly serves as splints to support user's potential wrist overuse, particularly in the palmer side, in the process. The bottom part design and the use of specialty nylon material in

3DP provide the appropriate level of flexibility and wearing comfort. For closure, this two-part articulating portion is secured at the wrist with a knit band that feeds through the bottom part of this wrist protection. It is secured with Velcro attachment at the band. Overall, consistent organic lines are incorporated, and colors and textures (light blue knit and semi-translucent 3D printed nylon) are coordinated into the assistive glove to keep cohesion in the aesthetic aspect of the design. Materials were chosen and designs decisions were made based on glove breathability, ergonomic, and the level of comfort for targeted user.

The assistive glove was through 7 key design processes: 1) developing 3D hand avatar for targeted user, 2) 3D modeling the 3D printed parts using the imported 3D hand avatar in Rhinoceros, 3) using live model hand and paint to define stress areas for glove fingers and palm to customize friction pads, 4) developing heat dissipating feature with aesthetic value (3D printed textile patterns), 5) developing flat patterns and sew-ups for the knit portion of the glove, 6) identifying 3D printing parts for sampling and fit/comfort evaluation, 7) applying traditional sewing construction. Three different prototypes were developed in this design research, and most of these processes were revisited based on the modification decisions made.

Key findings in this design research are mainly focused on the use and manipulation of 3DP materials for assistive tool development. The specialty 3D printed nylon material was unique in its resilient property; however, the FDM 3DP process is limiting in the minimal object thickness. Material cannot be prototyped with the ideal property. Further, material considering is heavily challenged during the closure design for the wrist protection. Additional challenges existed in accurately evaluating fitting ease between the 3D hand avatar and the 3D printed components in 3D modeling. Defining the stress areas between the hand and the wheelchair pushrims was also challenging as there are potential the shape interpretation discrepancy when translating from the paint to the 3D CAD model.

Overall, the research findings suggest that there is potential advantage in using 3DP in assistive glove development but also pose challenges with existing knowledge. For future, this design should be further surveyed with a bigger sample population to gain insightful user experience. Also, the glove closure design may be streamlined for wearing ease. Additional 3DP materials must be considered for assistive glove compatibility. The integrating of 3DP and traditional textile material should be further explored to meet functional and aesthetic needs. From the 3D modeling perspective, additional software/feature, workflow and cognition may be explored to ensure design efficiency.

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