

Aging and Disability

Design of an Automated Finger and Toe Stretching Device for Quadriplegia J. Santos, N. Endale, K. Kumar, S. Shams, H. Sharma, R. Huang, Y. Vafi, M. Kan, M. Chung, A. Mishima, N. Swan, E. Piskacek, M. Leung, R. Flora, A. Uriza Enrigue, A. Ren. *Gerontechnology* 25(s)

Purpose Individuals with quadriplegia may require prolonged passive stretching of fingers, wrist, toes, and ankle to maintain range of motion and comfort. For some, these routines are entirely caregiver-dependent, limiting autonomy and making daily adherence difficult. This project aims to develop a user-centred, automated stretching device requested by an adult with incomplete quadriplegia due to Enterovirus D68, enabling hands-free, prolonged finger and toe stretching while the user multitasks. **Method** An iterative co-design approach was used with ongoing client consultations guiding each design cycle. Interviews were conducted to document functional limitations, mounting constraints (bed and wheelchair use), prioritized motions, preferred controls, and acceptable device bulk. A market review was performed to assess existing hand and foot stretching solutions, and a targeted literature review was conducted to identify feasible mechanical strategies for finger/toe mobilization. Findings were synthesized into a needs and engineering requirements document specifying motion priorities, including preliminary displacement targets of approximately ± 4 inches for finger flexion/extension and $+4/-3$ inches for wrist vertical motion, comfort and stability requirements, and safety features. An automatic shutdown feature is planned to trigger upon detection of abnormal forces or excessive joint rotation using integrated sensing. Design concepts were generated and refined with feasibility considerations for compact integration and extended duration use. Current concepts include a low-profile rack-and-pinion-based actuation platform for synchronized finger motion, and an alternative curved-rail sliding mechanism that guides individual digits along ergonomic trajectories to support comfort and alignment. CAD modelling is ongoing to evaluate mechanism packaging, manufacturability, and user/caregiver interactions. **Results and Discussion** Early needs-finding and market analysis identified an unmet gap for devices providing active assistive stretching (device-assisted motion) rather than resistance-based stretching alone, particularly for individuals with severe motor impairment seeking prolonged, automated stretching sessions with minimal caregiver involvement. Early design outcomes included quantified preliminary displacement targets for finger and wrist movement and a requirement for extended operation (approximately four hours) with comfort-focused interfaces and secure attachment. The client prioritized finger flexion and extension, followed by abduction–adduction, with wrist rotation identified as a lower-priority movement. Individual digit movement was explicitly highlighted as beneficial for sensorimotor mapping and rehabilitation-oriented engagement, reflecting the importance of maintaining digit-specific motor awareness during assisted movement [1]. Toe and ankle stretching were considered desirable but lower priority, informing modularity considerations. Planned prototype evaluation will assess motion repeatability, attachment stability (slippage), comfort and skin integrity during extended use, and indicators of user independence such as reduced caregiver involvement. While this device is being developed for a single individual, the design framework and requirements may be applicable to older adults and other populations who rely on caregiver-assisted stretching due to age-related or neurological motor impairment.

References

1. Edwards, L. L., King, E. M., Buetefisch, C. M., & Borich, M. R. (2019). Putting the “sensory” into sensorimotor control: The role of sensorimotor integration in goal-directed hand movements after stroke. *Frontiers in Integrative Neuroscience*, 13, 16.

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