Clinician perceptions of a novel wearable robotic hand orthosis for post-stroke hemiparesis

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Abstract

Purpose: Wearable robotic devices are currently being developed to improve upper limb function for individuals with hemiparesis after stroke. Incorporating the views of clinicians during the development of new technologies can help ensure that end products meet clinical needs and can be adopted for patient care.

Methods: In this cross-sectional mixed-methods study, an anonymous online survey was used to gather clinicians' perceptions of a wearable robotic hand orthosis for post-stroke hemiparesis. Participants were asked about their clinical experience and provided feedback on the prototype device after viewing a video.

Results: 154 participants completed the survey. Only 18.8% had previous experience with robotic technology. The majority of participants (64.9%) reported that they would use the device for both rehabilitative and assistive purposes. Participants perceived that the device could be used in supervised clinical settings with all phases of stroke. Participants also indicated a need for insurance coverage and quick setup time.

Conclusions: Engaging clinicians early in the design process can help guide the development of wearable robotic devices. Both rehabilitative and assistive functions are valued by clinicians and should be considered during device development. Future research is needed to understand a broader set of stakeholders' perspectives on utility and design.

Keywords: stroke, rehabilitation, upper limb, stakeholder engagement, wearable devices, assistive technology, clinician perceptions

Introduction

Stroke affects over 795,000 individuals each year in the United States and is a common cause of long-term disability [1]. Upper limb (UL) weakness has been reported in the majority of stroke survivors, which can limit use of the affected side in activities of daily living (ADLs) [2–4]. While UL use can improve with therapy, more than half of individuals with hemiparesis affecting the UL still lack functional hand use after six months [5–7]. As persisting UL impairments are associated with decreased quality of life [8], continued efforts aimed at developing assistive and rehabilitative technologies to improve UL function are warranted. Robotic devices that are designed to improve UL function can be broadly classified into two types based on primary function: assistive or rehabilitative [9]. Assistive robotic devices are intended to be used in the home or community environment to assist the user during participation in ADLs. Rehabilitative robotic devices are designed to improve motor function by remediating underlying deficits through practice and repetition and may be used in either clinical settings or the home/community [9]. Meta-analyses and clinical trials show that outcomes with available robots are comparable to standard and intensity-matched stroke rehabilitation and significantly improve motor control outcomes with low to modest improvements in ADLs [10–13].

Wearable robotic devices under development for UL rehabilitation are growing in diversity and capability [14–16]. These devices can assist finger movements with motorized linkage-based or cable-based mechanisms such as HERO Glove [17], Exoglove [18], HX [19], and the commercial MyoPro [20]; or, alternately, by using soft structures and actuators [21]. For example, multiple pneumatic-based gloves with inexpensive, battery-powered compressors are now available on the market for home use. As opposed to workstation devices, the portability of wearable devices offers them the potential to be used in an assistive capacity for ADLs [22]. Wearable devices also have rehabilitative promise, as potential for

improvement in UL motor function could be achieved through regular engagement in functional activities [9]. However, assistive versus rehabilitative uses of wearable robotic devices pose different design demands [14]. For example, an assistive robotic device may need to be waterproof, lightweight, low profile, and have an aesthetically pleasing look to be satisfactorily integrated into daily activities [23]. In contrast, a rehabilitative robotic device should support motor learning principles to elicit mechanisms of neuroplasticity during practice, such as appropriate challenge, feedback, repetition, intensity, and specificity [24–27]. Some devices attempt to meet both assistive and rehabilitative demands. The RELab Tenoexo is a low-profile, lightweight exoskeleton designed for users with low muscle tone and low residual force that offers both an ipsilateral control method via surface electromyography (sEMG) and button-based user or remote-control methods [28,29]. Determining the intended therapeutic use of a device can help developers make design-related decisions that improve the device's ultimate functionality in real-world and clinical settings [15].

Clinicians play an important role in the adoption of technology for rehabilitation and assistance, as they can recommend new devices and technologies based on the unique needs of the individual. Through collaboration with device end-users, clinicians can help ensure that these devices are perceived favorability and are well-suited to individual preferences, reducing the risk of device abandonment [30–33]. Clinicians have reported positive views of rehabilitation robotics, including their ability to provide increased practice opportunities and to treat more severe UL impairments [34–37]. However, many clinicians may not have access to new robotic technologies, resulting in low levels of adoption in clinical practice [38,39]. Reported barriers for implementation include the need for organizational support, lack of training, set-up time, and cost [34,36,37,39]. Additionally, clinicians are more likely to accept

new technology when it matches the needs of the patient, improves outcomes, and increases motivated engagement in therapy [36,40,41].

The incorporation of clinician perspectives within a user-centered design process can inform the development of robotic prototypes so that their functionality matches end-user needs [15,18,19]. Clinician insights, including perspectives from clinicians with no prior experience with specific devices, can provide direct guidance for certain aspects of designs, such as facilitating key joint movements and setting bounds for minimum grasp strength and maximum device bulk [42]. Although previous studies have gathered extensive end-user perspectives on wearable UL robotics to determine general device usability for key populations such as stroke and spinal cord injury survivors [17–19,43–46], little is known about the contexts in which clinicians may choose to use wearable robotic UL orthoses in rehabilitative versus assistive capacities. Limited evidence suggests that while clinicians may choose to use wearable UL devices to improve motor recovery, individuals with stroke may prefer a device that simply assists them during their ADLs [18,43]. However, further investigation into the perceptions of both clinicians and end-user populations is needed to guide device development.

Our research group is currently developing a prototype device called MyHand (see Figure 1), which is a wearable robotic orthosis that provides finger extension assistance during functional arm use for individuals with minimal hand function after stroke [47,48]. The device uses a motor and a cable transmission system attached to finger splints that simultaneously extends all digits when the intent to open the paretic hand is detected. Intent detection is determined through measurement of muscle activation using eight sEMG sensors that are evenly distributed around an armband at the proximal forearm of the paretic limb. A machine learning algorithm is then used to predict intent (open, close, or relax) based on sEMG signals. When a "relax" intent is predicted, the device maintains the previous

open/close command; this reduces the exertion effort required for the user to maintain a given hand pose. For those who do not have adequate sEMG signals, a contralateral shoulder harness system can be used. Activating a switch via shoulder shrugs commands the device to change open/close state. The current prototype device, which is still in the development stage, must be donned and doffed by the research team, and the amount of time needed for set-up and training varies based on the components being tested. The device was developed for individuals with chronic stroke, and previous research has demonstrated its potential for both assistive and rehabilitative uses [47].

In this study, we surveyed a large national group of occupational therapy (OT) and physical therapy (PT) clinicians to explore their perceptions of the MyHand prototype in order to guide future development of this device as well as other wearable robotic orthoses for stroke rehabilitation. Our aim was to learn how clinicians perceive the device and how they would choose to use it during treatment, specifically regarding assistive versus rehabilitative uses. Additionally, while the device is currently being developed for individuals with chronic stroke in outpatient or home settings, we were interested in other settings where clinicians believe the device could be deployed as well as its potential use with acute and subacute phases of stroke. Finally, we wanted to learn about clinicians' perceptions related to the cost of the device, including both time and monetary cost, in order to set engineering goals that would make clinical use of the device feasible [49]. This included the initial monetary cost of the device, acceptable amounts of set-up time, and the amount of training time therapists would be willing to spend learning to use the device.

<insert figure 1>

Methods

Study Design

This cross-sectional mixed methods study is part of a larger project to gather perspectives from both clinicians and stroke survivors on a wearable robotic hand orthosis in the development phase. We collected information on clinician perceptions using an anonymous online survey that was deployed via Qualtrics and was developed by our multi-disciplinary research team. Approval for the study was granted by the Columbia University Institutional Review Board (AAAT3351) with a waiver of written consent. Participants provided consent within the online survey platform by checking a box indicating that they agreed to participate in the study in lieu of in-person informed consent procedures.

Participants

Participants were screened for inclusion through a self-reported question at the beginning of the survey. The screening question asked if they were occupational therapists (OTs), occupational therapy assistants (OTAs), physical therapists (PTs), or physical therapy assistants (PTAs) with more than one year of experience working with stroke survivors and some experience with assistive technology (even low tech). Participants were recruited via listservs, newsletters, blogs, and social media. We contacted OT and PT associations and other groups on social media for permission to post recruitment notices. The survey was reposted on social media pages approximately 6 weeks after the initial posting.

Survey

Survey items were generated through review of the available literature and discussion within our research group, which included expertise in OT, stroke rehabilitation, robotics, and physiatry. Four members of the research team generated the initial survey, based on concepts addressed in focus groups by Elnady et al. [43], including rehabilitative versus assistive uses of the device as well as factors related to cost, such as set-up and training time. Iterations of the survey were reviewed and revised by the full research team. Before distribution, an

external OT with expertise in stroke rehabilitation reviewed the survey for clarity and readability.

The first half of the 31-question survey included four questions on participants' demographic information, six on clinical practice and experience, and five on technology and robotics experience. Participants then viewed a video explaining the MyHand system. After viewing the video, the second half of the survey focused specifically on the device. Participants were asked seven questions about their interest in using the device, rehabilitative versus assistive uses of the device, settings where the device could be implemented, and phases of stroke recovery that may benefit from the device. Two questions asked participants to write activities they would choose when using MyHand as an assistive or rehabilitative device. Seven additional questions asked about cost of the device, set-up time, and training time (see supplemental material for the complete survey).

Video and Robotic System

Participants viewed a video describing the MyHand system as a powered user-driven hand orthosis for individuals with chronic stroke and significant hand weakness. The video can be accessed via this link: https://www.youtube.com/watch?v=Ey9tUkIVQpU. The MyHand device is a robotic hand exoskeleton that consists of plastic finger splints attached to the distal ends of the digits and a motorized metal forearm splint with fabric straps securing it to the hand and forearm. Assisted collective finger extension is accomplished by the motor pulling on cables connected to the dorsal side of each finger splint. The user can close the hand under self-power when the motor is deactivated; however, the device does not assist finger flexion. We informed participants that we were seeking input on how the device should be used for patient treatment and described the two methods through which the user could control the device. The video explained that the device uses surface electromyography (sEMG) signals from the affected arm to detect the user's intent to open their hand, or if there

are not adequate sEMG signals, a shoulder harness system on the contralateral limb can also control the device. The video depicts individuals with poor to limited UL capacity due to stroke [50] using the device that allows the hand to open during activities involving reach, grasp, and release of basic objects (e.g., tennis ball, cube, and cup). The video also shows the role of the device in assisting with the performance of bimanual tasks such as opening a bottle or toothpaste tube with the weaker hand being used to stabilize the object (see figure 2). Both sEMG and shoulder harness control methods were shown in the video.

<insert figure 2>

Data Analysis

SPSS Version 28.0 (SPSS, Inc., Armonk, NY, 2021) statistical software was used to analyze quantitative survey data. Descriptive statistics were calculated for multiple-choice questions. Kruskal-Wallis tests were used to determine if there were statistically significant differences in responses to Likert Scale questions between different groups of participants (i.e., roles, primary practice settings, and prior experience with robotic technology.) A Pearson Chi-Square test was used to determine if there was a significant relationship between treatment session length and amount of time deemed acceptable for device set-up.

Conceptual content analysis was used to examine free-text responses for rehabilitative and assistive uses of the device. This method can be used to describe qualitative data by condensing words and phrases into progressively smaller categories to summarize a given topic [47]. We used a process described by Elo and Kyngäs, which is flexible and is adapted to meet the needs of a specific research question [47]. For our study, each participant's individual responses to questions 22 and 23 of the survey were analyzed separately. Because little is known about the types of activities therapists would choose to use with a wearable robotic device within rehabilitative and assistive contexts, we selected an inductive approach. In an inductive approach, the text is first analyzed using open coding, where concepts are

freely labeled without the use of predetermined categories. The goal of this approach is to create the fewest number of categories that are also cohesive and rational [47]. For our study, co-first authors first independently coded the type of activities listed by each participant for both rehabilitative and assistive items by hand (LW used NVivo 12 software, and AC used Microsoft Excel software). Similar codes were grouped into categories through an iterative process [51]. Co-first authors then met to discuss initial subcategories and created revised categories based on discussion. These categories were then discussed with the full research team, and final categories were determined. Co-first authors then independently re-coded all items according to the final categories using Microsoft Excel and resolved any discrepancies through consensus meetings. Coded responses were tallied and analyzed in SPSS for frequencies and percentages to concisely communicate the categorized data.

Results

Anonymous online surveys were collected between April and August 2021. Of the 201 participants who consented to participate, 154 completed the survey. Incomplete surveys were excluded from analysis. Participant characteristics can be found in Table 1. Most participants were OTs (n=94). Participants reported a variety of primary practice settings with the greatest representation in outpatient (n=38), acute care (n=32), and acute rehabilitation (n=30). While all participants were required to have more than one year of clinical experience working with stroke patients to be included in the study, nearly all (n=144) also had experience working with individuals in the chronic phase of stroke recovery (more than 6 months since diagnosis), which is the intended population for the MyHand device.

<insert table 1>

Experience with robotic systems

Only 29 of 154 participants (18.8%) reported having experience with robotic technologies. While experience with environmental control systems was also low (20.8%), participants reported higher levels of experience with other types of technology (survey question 11 [Q11]; see table 2). Overall, participants reported low use of robotic systems in their clinical practice. Most reported that they rarely or never use robotic systems as an intervention (85.1%) or as an assessment tool (95.5%). Additionally, 94.2% of participants reported that they rarely or never prescribe robotic systems for home use (Q13-15; see figure 3).

<insert table 2>

<insert figure 3>

Interest in the device

After watching a brief video about MyHand, participants were asked about their interest in using the device (Q16; see figure 4). Scores were rated on a 5-point Likert Scale (1 = extremely interested; 5 = not interested at all). On average, participants were moderately to very interested in using the device (M = 2.6, SD = 1.1). Kruskal-Wallis tests revealed that there were no significant differences in interest in using the device between roles, χ^2 (3) = 0.666, p = 0.881; primary practice settings, χ^2 (6) = 4.729, p = 0.579; or those with or without prior experience with robotics, χ^2 (1) = 0.179, p = 0.672.

Assistive vs. rehabilitative use of the device

Participants were asked if they would prefer to use MyHand as an assistive device to compensate for lack of hand function, as a rehabilitative device to improve motor function, or both (Q19). The majority of participants reported that they would use the device for both rehabilitation and assistance (64.9%), compared with those who would use the device for only rehabilitation (28.6%) or assistance (6.5%). Participants also expressed a similar likelihood of using the device for assistance and rehabilitation separately: 67.5% reported that they would be somewhat or extremely likely to use MyHand as an assistive device, and 76%

reported they would be somewhat or extremely likely to use it as a rehabilitative device (Q20-21; see figure 5). Kruskal-Wallis tests again found no significant differences in likelihood of using MyHand as a *rehabilitative device* between roles, χ^2 (3) = 1.247, p = 0.742; primary practice settings, χ^2 (6) = 9.071, p = 0.170; or prior robotics experience, χ^2 (1) = 0.052, p = 0.820; or as an *assistive device* between roles, χ^2 (3) = 4.619, p = 0.202; primary practice settings, χ^2 (6) = 8.744, p = 0.188; or prior robotics experience, χ^2 (1) = 0.031, p = 0.860. Additionally, when using the device for assistive purposes, the majority of participants (80.5%) reported that it was very or extremely important that their patient be able to use the device independently (Q24).

<insert figure 4>

<insert figure 5>

Activities to use with the device

Participants were asked to describe the activities or interventions they would use with the device for rehabilitation (Q22) and assistance (Q23). Many participants offered a list of activities within each response. Responses were categorized as 1) exercise activities (motor skills including grasp/release, motor learning techniques such as repetitive task practice, strengthening, and range of motion), 2) functional activities (task-based interventions, ADLs, instrumental ADLs, leisure, work, client-selected goals, and mobility), 3) exercise and functional activities (both types of activities were listed), or 4) none or unsure (no activity was listed in the response.) See table 3 for examples of how activities were categorized. Functional activities were chosen at the highest frequencies for both assistive (69.5%) and rehabilitative (42.9%) objectives. However, when focusing on rehabilitation, more participants selected exercise activities or suggested combined tasks than when focusing on assistance (see figure 6). No significant relationship was found between the type of activity and role according to Pearson Chi-Square tests for either assistive or rehabilitative uses.

<insert table 3>

<insert figure 6>

Use with different clinical populations

The majority of participants responded that MyHand could be appropriately deployed in outpatient (85.1%), acute rehabilitation (61.7%), and subacute rehabilitation (57.8%) settings. Only 37.5% indicated that the device could be used in home care settings. The majority of participants also indicated that the device could benefit individuals at all phases of stroke (Q17-18; see table 4).

Cost of the device

Responses for the acceptable initial cost of the device can be found in figure 7 (Q25, 26, 28). The majority of participants (85.1%) felt that it was very or extremely important that the device be covered by insurance (Q27), and 90.3% felt that a reasonable out of pocket expense for patients should be less than $500 or no out-of-pocket expense. The amount of acceptable set-up and training time for the device that participants selected can be found in table 4 (Q29). Responses for amount of set-up time were not related to treatment session length according to Chi-Square tests. Just under half of participants (48.7%) were willing to spend 2 to 5 minutes for device setup within their session, while only 13% were willing to spend 11-15 minutes. Most participants (69.5%) also preferred a single device that could be used for multiple patients rather than one that was customized to each patient (30.5%; Q30). The majority of participants (55.8%) were willing to spend 1 to 2 days getting trained to use the device (Q31).

<insert table 4>

<insert figure 7>

Discussion

The purpose of this study was to investigate how clinicians perceived a novel wearable robotic hand orthosis in the development stage with regard to their interest in using the device, potential clinical applications, and factors related to the cost of the device. Our aim was not to evaluate the utility of the device through expert opinion but rather to gather perceptions of the device from a broad group of clinicians. As prior experience may affect these perceptions, it was important for us to determine the level of robotics experience in our sample. Less than 20% of our sample had experience with robotic technology, and the majority never use robotic systems for intervention, assessment, or as a prescription for home use. Previous research suggests that technology use among clinicians may be low due to lack of access; Langan et al. [38] found that more than 80% of the clinicians they surveyed did not have access to robotic technology, and none of six clinicians interviewed by Boser et al. [42] had experience with portable robotic devices capable for use in the home. Interestingly, we did not find a difference in the perceptions of those with and without robotic experience on their interest in the device or its potential rehabilitative and assistive uses. This is consistent with previous literature that found therapists both with and without experience with wheelchair mounted robotic arms expressed similar levels of interest in using the technology [52].

Previous studies have found that therapists have favorable interest in using robotic interventions to supplement traditional rehabilitation [34–36]. Similarly, we found that, on average, our sample expressed that they were moderately to very interested in using the device. Wearable robotic hand orthoses have the potential to function in both rehabilitative and assistive capacities; that is, they may be able to both improve underlying impairments in the limb and also increase the user's independence during ADL performance [9,47]. However, little is currently known about how clinicians would use such a device in practice. Focus groups by Elnady et al. [43] suggested that therapists may prefer rehabilitative devices

while individuals with stroke may prefer assistive devices. In contrast, our results suggest that, when given the option, most clinicians preferred a wearable robotic device with both rehabilitative and assistive functions; the majority of participants in our study reported that they were somewhat or extremely likely to use the device in both assistive and rehabilitative capacities. This is consistent with evidence that devices that assist with hand function can also reduce UL impairment when used within the context of task-specific training [53].

We asked participants to list activities that they would use with the device in both rehabilitative and assistive capacities to gain insight into necessary design requirements. Devices that are designed for exercise have different features than those that are intended to be used in a functional real-world context [54]. To engage in exercise, the device should be able to increase the level of challenge as the user improves and offer modes/mechanisms that allow for high intensity of practice (i.e. repetitions at just the right amount of challenge) [25]. Portability and form factors are less important design considerations for these devices [55]. To engage in functional activities, the device should be responsive to user intent and allow interactions with real-world objects rather than contrived activities such as grasping blocks [54]. Portability, weight, wearability, water resistance, and other practical concerns become greater design priorities for these devices that are expected to operate in real-world tasks [55].

The majority of participants preferred deploying the device in supervised clinical settings (acute rehabilitation, subacute rehabilitation, and outpatient) over home care. This finding may have been influenced by the video of the prototype, in which the device is clearly too complex for unsupervised home use in its present stage of development. Like many robotic prototypes that explore initial device feasibility with impaired users, this device is limited to standing or seated tabletop tasks since it is tethered with wires and cables to fixed electronics and computers. Additionally, 91% of participants listed areas of practice other than home care as their primary practice area, which may have biased responses

towards other settings. We found that, for assistive use of the device, functional activities were strongly preferred by participants. For rehabilitative use, a combination of exercise and functional activities were listed, although more than forty percent of participants still only listed functional activities. Thus, functional activities were important for both assistive and rehabilitative contexts. This makes sense from a rehabilitative perspective because motor learning principles include engaging the limb in task-specific activities that are relevant to the individual [53,56].

Clinicians' clinical reasoning when choosing treatment approaches for UL hemiparesis may be guided by the phase of stroke. Acute and subacute phases have the highest potential for neural plasticity to occur, and clinicians may prioritize interventions designed to elicit motor recovery during these phases [57]. In the chronic stage, although motor recovery can still occur with intensive, focused practice [27], there is less recovery as time progresses, and therapists may focus more on compensatory strategies that improve ADL independence without improving underlying motor capacity [58,59]. While MyHand was originally intended for use in the chronic phase of stroke, participants indicated that the device may be useful during all three phases after stroke. Use of the device in acute and subacute stages suggests rehabilitative aims, as the greatest amount of motor recovery occurs during this time period [57,58].

The cost of the device, both in terms of the initial price as well as the amount of time it takes for set-up and training, is an important factor in the adoption of robotic technology in clinical settings. Our findings that insurance coverage and affordability are critical for device adoption are similar to previous research [34,39,41]. The mismatch between out-of-pocket costs that are considered affordable by our participants (< $500) and the prices or projected prices of devices that are labeled *low-cost* ($1000 − $30,000) is a barrier to clinical acceptance [11,18]. Another factor that can influence whether clinicians are willing to use a

robotic device is the amount of time it takes to set-up, as clinical schedules are often demanding [23,34,39,40]. While Lo et al. [34] found that therapists reported UL devices usually take about 10 to 15 minutes to set-up, we found that only 13 percent of our sample was willing to spend more than 10 minutes setting up the device, presenting a barrier for device adoption. However, we did find that the majority of participants in our study were willing to spend 1 to 2 days to get trained to use the device. Lack of training and organizational support have been identified as barriers to device adoption in previous work [34,36,37,39]. While our finding indicates some willingness on the part of clinicians to learn to use the system, it does not address other organizational barriers that may limit clinician access to training, such as time and financial support.

Implications for Device Developers

Our findings emphasize a desire for versatile and quickly-reconfigurable devices that can cover the broad spectrum of recovery goals and individual impairments. Participants perceived that the MyHand device could be useful in their clinical practice for engaging stroke survivors in functional tasks for both rehabilitative and assistive purposes. Many of the suggested functional activities, such as manipulating fabrics when dressing or stabilizing a pan when cooking, require a baseline level of dexterity that is often out of reach for stroke survivors without assistance. A portable robotic device, even at an early stage, can provide motivation by enabling real-world interactions in a clinical setting. However, further development of the current device is needed to enable use in unsupervised home environments.

The majority of participants were sensitive to both financial and temporal costs associated with adopting new robotic technologies, and when presented with an early-stage prototype such as in this study, strongly preferred deploying a single device in a supervised setting for which the same device could be customized for multiple patients. These

preferences may be due to factors specific to this device, such as concerns for whether the device complexity, which is needed to support the breadth of desired activities, would prevent users from being able to independently don, doff, or use the device in an unsupervised setting. Developers should balance clinicians' competing desires for a wide range of adjustable settings and a short (10 minutes or less) setup time. Participants also are moderately-to-very interested in trying even early-stage prototypes, which highlights an opportunity to obtain impactful feedback from clinicians, end users, and other stakeholders. As an example, future design research directions for the MyHand prototype presented here include: 1) making customization of control parameters (speed, total extension angle, activation thresholds) more transparent and accessible to clinicians who wish to vary difficulty, 2) improving the ease of swapping components to preserve the balance of accommodating individual users and reducing overall device complexity, and 3) reducing don/doff and alignment times in order to work towards a design that can support unsupervised, independent use by stroke survivors. We are optimistic about these design directions due to our finding that participants were willing to spend 1-2 days to get trained on the device usage and capabilities, and, in future work, the amount of acceptable training time should be factored in when determining the system complexity. However, it remains a challenge to meet the dual needs of improving flexibility and reducing complexity.

Limitations

The exploratory nature of this study presents several limitations. The choice to base the survey on an early-prototype device provides valuable feedback at a point where impactful changes can still be made to broad aspects of the design; however, participants' perceptions were based only on video clips of an incomplete device. Because the device is in early stages of development, this study did not evaluate device usability or effectiveness. The prototype contains many wired connections and velcro-based attachments that preclude use in the home

or other unsupervised settings, which may have influenced responses. The video focused on manipulation of objects and did not include setup time or initial training. Future in-person studies in multiple practice settings are needed to collect comprehensive feedback on device usability. This study was tailored to provide feedback using one specific device, and merely represents a starting point for investigating contexts of use and factors for developing assistive and rehabilitative devices. Future studies with additional devices are required to generalize design implications to other UL robotic exoskeletons.

The choice to collect perceptions anonymously from a national group of clinicians created additional limitations. The self-selected survey population may have been predisposed to favor robotic technology. Screening was based on self-reported and anonymous responses, which prevented confirmation of credentials. The sample over-represented clinicians in the Midwest and from a relatively young (25-34 years) age group. Lastly, dissemination of the survey via mostly digital means may not be representative of all OT or PT practitioners who treat individuals with UL hemiparesis post-stroke.

Conclusions and future steps

This study focused on gathering clinicians' perceptions of potential applications and challenges for clinical implementation early in the design cycle, at a time point where barriers can be clearly identified but major device changes are still possible. This study highlights the general interest of OT and PT practitioners in a novel robotic UL orthosis for post-stroke hemiparesis as well as the need for collaboration between designers of robotic devices and clinicians. While interest in both rehabilitative and assistive uses of the device was clear, integrating too much complexity into the design could also increase set up and training time for clinicians, limiting deployment in practice settings. These opposing priorities must be balanced so that planned design goals are in line with desired clinical uses. Incorporating practitioners' perspectives early in the design cycle of robotic devices for stroke is crucial for

identifying appropriate clinical uses and design requirements as well as barriers to clinical implementation.

Future studies are needed to determine the efficacy of wearable robotic devices for the UL in a variety of practice settings for both rehabilitative and assistive uses. With regard to the MyHand device, specifically, further refinement of the prototype is needed. This study has highlighted that advancements in portability and ergonomics, such as developing a wireless design and minimizing device footprint, are critical engineering research directions that are needed to enhance the clinical utility of the device. Future work is needed to test the safety and efficacy of the device for individuals with different levels of UL impairment and different stages of chronicity. This work should also investigate the development of efficient training paradigms to make the use of the device intuitive. Additionally, it will be important to conduct implementation studies that investigate clinician needs for training and technical support. Finally, the perspectives and priorities of stroke survivors and their care-partners are crucial for guiding the development of rehabilitation devices. We are currently investigating the perspectives of individuals with stroke on the device, and future work should also elicit the views of care-partners and other relevant stakeholders, such as healthcare institutions. This work is needed in order to ensure that robotic devices for the UL are acceptable, accessible, and beneficial.

Acknowledgements

We would like to thank Morgan Starkey, OTS, for help distributing the survey and Carly Goldberg, MS, OTR/L, for reviewing the survey.

Declaration of Interest Statement

The authors report there are no competing interests to declare.

Funding

This work was supported in part by the National Institute of Neurological Disorders and Stroke under Grant R01NS115652 and the Eunice Kennedy Shriver National Institute of Child Health and Human Development under award F31HD111301.

References

[1] Virani SS, Alonso A, Aparicio HJ, et al. Heart Disease and Stroke Statistics—2021 Update. Circulation [Internet]. 2021;143:e254–e743. Available from: https://www.ahajournals.org/doi/10.1161/CIR.0000000000000950.

[2] Gebruers N, Vanroy C, Truijen S, et al. Monitoring of Physical Activity After Stroke: A Systematic Review of Accelerometry-Based Measures. Arch Phys Med Rehabil [Internet]. 2010;91:288–297. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0003999309009289.

[3] Guidetti S, Ytterberg C, Ekstam L, et al. Changes in the impact of stroke between 3 and 12 months post-stroke, assessed with the Stroke Impact Scale. J Rehabil Med [Internet]. 2014;46:963–968. Available from: http://www.medicaljournals.se/jrm/content/?doi=10.2340/16501977-1865.

[4] Lawrence ES, Coshall C, Dundas R, et al. Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population. Stroke [Internet]. 2001;32:1279–1284. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11387487.

[5] Franck JA, Smeets RJEM, Seelen HAM. Changes in actual arm-hand use in stroke patients during and after clinical rehabilitation involving a well-defined arm-hand rehabilitation program: A prospective cohort study. PLoS One [Internet]. 2019;14:e0214651. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30934015.

[6] Houwink A, Nijland RH, Geurts AC, et al. Functional recovery of the paretic upper limb after stroke: who regains hand capacity? Arch Phys Med Rehabil [Internet]. 2013;94:839–844. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23201317.

[7] Kwakkel G, Kollen BJ, van der Grond J, et al. Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke.

Stroke [Internet]. 2003;34:2181–2186. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12907818.

[8] Franceschini M, La Porta F, Agosti M, et al. Is health-related-quality of life of stroke patients influenced by neurological impairments at one year after stroke? Eur J Phys Rehabil Med [Internet]. 2010;46:389–399. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20927005.

[9] Khalid S, Alnajjar F, Gochoo M, et al. Robotic assistive and rehabilitation devices leading to motor recovery in upper limb: a systematic review. Disabil Rehabil Assist Technol [Internet]. 2021;1–15. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2021.1906960.

[10] Hesse S, Mehrholz J, Werner C. Robot-Assisted Upper and Lower Limb Rehabilitation After Stroke. Dtsch Arztebl Int [Internet]. 2008;105:330–336. Available from: https://www.aerzteblatt.de/10.3238/arztebl.2008.0330.

[11] Johnson MJ, Rai R, Barathi S, et al. Affordable stroke therapy in high-, low- and middle-income countries: From Theradrive to Rehab CARES, a compact robot gym. J Rehabil Assist Technol Eng [Internet]. 2017;4:205566831770873. Available from: http://journals.sagepub.com/doi/10.1177/2055668317708732.

[12] Lo AC, Guarino P, Krebs HI, et al. Multicenter randomized trial of robot-assisted rehabilitation for chronic stroke: methods and entry characteristics for VA ROBOTICS. Neurorehabil Neural Repair [Internet]. 2009;23:775–783. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19541917.

[13] Mehrholz J, Pohl M, Platz T, et al. Electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength after stroke. Cochrane Database Syst Rev [Internet]. 2018;9:CD006876. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30175845.

[14] Chu C-Y, Patterson RM. Soft robotic devices for hand rehabilitation and assistance: a narrative review. J Neuroeng Rehabil [Internet]. 2018;15:9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29454392.

[15] Veale AJ, Xie SQ. Towards compliant and wearable robotic orthoses: A review of current and emerging actuator technologies. Med Eng Phys [Internet]. 2016;38:317–325. Available from: https://linkinghub.elsevier.com/retrieve/pii/S135045331600031X.

[16] Vélez-Guerrero MA, Callejas-Cuervo M, Mazzoleni S. Artificial Intelligence-Based Wearable Robotic Exoskeletons for Upper Limb Rehabilitation: A Review. Sensors (Basel) [Internet]. 2021;21. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33803911.

[17] Yurkewich A, Kozak IJ, Hebert D, et al. Hand Extension Robot Orthosis (HERO) Grip Glove: enabling independence amongst persons with severe hand impairments after stroke. J Neuroeng Rehabil. 2020;17:33.

[18] Proulx CE, Higgins J, Gagnon DH. Occupational therapists' evaluation of the perceived usability and utility of wearable soft robotic exoskeleton gloves for hand function rehabilitation following a stroke. Disabil Rehabil Assist Technol [Internet]. 2021;1–10. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2021.1938710.

[19] Almenara M, Cempini M, Gómez C, et al. Usability test of a hand exoskeleton for activities of daily living: an example of user-centered design. Disabil Rehabil Assist Technol [Internet]. 2017;12:84–96. Available from: https://www.tandfonline.com/doi/full/10.3109/17483107.2015.1079653.

[20] McCabe JP, Henniger D, Perkins J, et al. Feasibility and clinical experience of implementing a myoelectric upper limb orthosis in the rehabilitation of chronic stroke

patients: A clinical case series report. PLoS One [Internet]. 2019;14:e0215311. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30978249.

[21] Proietti T, Nuckols K, Grupper J, et al. Combining soft robotics and telerehabilitation for improving motor function after stroke. Wearable Technologies [Internet]. 2024;5:e1. Available from: https://www.cambridge.org/core/product/identifier/S2631717623000269/type/journal_article.

[22] Martinez-Hernandez U, Metcalfe B, Assaf T, et al. Wearable Assistive Robotics: A Perspective on Current Challenges and Future Trends. Sensors (Basel) [Internet]. 2021;21. Available from: http://www.ncbi.nlm.nih.gov/pubmed/34695964.

[23] Babič J, Laffranchi M, Tessari F, et al. Challenges and solutions for application and wider adoption of wearable robots. Wearable Technologies [Internet]. 2021;2:e14. Available from: https://www.cambridge.org/core/product/identifier/S263171762100013X/type/journal_article.

[24] Kleim JA, Jones TA. Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage. J Speech Lang Hear Res [Internet]. 2008;51:S225-39. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18230848.

[25] Maier M, Ballester BR, Verschure PFMJ. Principles of Neurorehabilitation After Stroke Based on Motor Learning and Brain Plasticity Mechanisms. Front Syst Neurosci [Internet]. 2019;13:74. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31920570.

[26] Roby-Brami A, Jarrassé N, Parry R. Impairment and Compensation in Dexterous Upper-Limb Function After Stroke. From the Direct Consequences of Pyramidal Tract Lesions to Behavioral Involvement of Both Upper-Limbs in Daily Activities. Front

Hum Neurosci [Internet]. 2021;15. Available from: https://www.frontiersin.org/articles/10.3389/fnhum.2021.662006/full.

[27] Mawase F, Cherry-Allen K, Xu J, et al. Pushing the Rehabilitation Boundaries: Hand Motor Impairment Can Be Reduced in Chronic Stroke. Neurorehabil Neural Repair [Internet]. 2020;34:733–745. Available from: http://www.ncbi.nlm.nih.gov/pubmed/32845230.

[28] Bützer T, Lambercy O, Arata J, et al. Fully Wearable Actuated Soft Exoskeleton for Grasping Assistance in Everyday Activities. Soft Robot. 2021;8:128–143.

[29] Ryser F, Butzer T, Held JP, et al. Fully embedded myoelectric control for a wearable robotic hand orthosis. 2017 International Conference on Rehabilitation Robotics (ICORR). IEEE; 2017. p. 615–621.

[30] Shore L, de Eyto A, O'Sullivan L. Technology acceptance and perceptions of robotic assistive devices by older adults – implications for exoskeleton design. Disabil Rehabil Assist Technol [Internet]. 2022;17:782–790. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2020.1817988.

[31] Sugawara AT, Ramos VD, Alfieri FM, et al. Abandonment of assistive products: assessing abandonment levels and factors that impact on it. Disabil Rehabil Assist Technol [Internet]. 2018;13:716–723. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29334475.

[32] Johnston P, Currie LM, Drynan D, et al. Getting it "right": how collaborative relationships between people with disabilities and professionals can lead to the acquisition of needed assistive technology. Disabil Rehabil Assist Technol [Internet]. 2014;9:421–431. Available from: http://www.tandfonline.com/doi/full/10.3109/17483107.2014.900574.

[33] Martin JK, Martin LG, Stumbo NJ, et al. The impact of consumer involvement on satisfaction with and use of assistive technology. Disabil Rehabil Assist Technol [Internet]. 2011;6:225–242. Available from: http://www.tandfonline.com/doi/full/10.3109/17483107.2010.522685.

[34] Lo K, Stephenson M, Lockwood C. Adoption of robotic stroke rehabilitation into clinical settings. Int J Evid Based Healthc [Internet]. 2020;18:376–390. Available from: https://journals.lww.com/10.1097/XEB.0000000000000231.

[35] Mashizume Y, Zenba Y, Takahashi K. Occupational Therapists' Perceptions of Robotics Use for Patients With Chronic Stroke. The American Journal of Occupational Therapy [Internet]. 2021;75. Available from: https://research.aota.org/ajot/article/75/6/7506205080/23067/Occupational-Therapists-Perceptions-of-Robotics.

[36] Flynn N, Kuys S, Froude E, et al. Introducing robotic upper limb training into routine clinical practice for stroke survivors: Perceptions of occupational therapists and physiotherapists. Aust Occup Ther J [Internet]. 2019;66:530–538. Available from: https://onlinelibrary.wiley.com/doi/10.1111/1440-1630.12594.

[37] Bower KJ, Verdonck M, Hamilton A, et al. What Factors Influence Clinicians' Use of Technology in Neurorehabilitation? A Multisite Qualitative Study. Phys Ther [Internet]. 2021;101. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33522582.

[38] Langan J, Subryan H, Nwogu I, et al. Reported use of technology in stroke rehabilitation by physical and occupational therapists. Disabil Rehabil Assist Technol [Internet]. 2018;13:641–647. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2017.1362043.

[39] Turchetti G, Vitiello N, Trieste L, et al. Why effectiveness of robot-mediated neurorehabilitation does not necessarily influence its adoption. IEEE Rev Biomed Eng

[Internet]. 2014;7:143–153. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24803207.

[40] Liu L, Miguel Cruz A, Rios Rincon A, et al. What factors determine therapists' acceptance of new technologies for rehabilitation – a study using the Unified Theory of Acceptance and Use of Technology (UTAUT). Disabil Rehabil [Internet]. 2015;37:447–455. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24901351.

[41] Chen CC, Bode RK. Factors influencing therapists' decision-making in the acceptance of new technology devices in stroke rehabilitation. Am J Phys Med Rehabil [Internet]. 2011;90:415–425. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21765257.

[42] Boser QA, Dawson MR, Schofield JS, et al. Defining the design requirements for an assistive powered hand exoskeleton: A pilot explorative interview study and case series. Prosthet Orthot Int [Internet]. 2021;45:161–169. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33118453.

[43] Elnady A, Mortenson W Ben, Menon C. Perceptions of Existing Wearable Robotic Devices for Upper Extremity and Suggestions for Their Development: Findings From Therapists and People With Stroke. JMIR Rehabil Assist Technol [Internet]. 2018;5:e12. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29764799.

[44] Dittli J, Meyer JT, Gantenbein J, et al. Mixed methods usability evaluation of an assistive wearable robotic hand orthosis for people with spinal cord injury. J Neuroeng Rehabil. 2023;20:162.

[45] Tanczak N, Ranzani R, Meyer JT, et al. A Novel Mixed-Method Approach to Identify Needs and Requirements for Upper Limb Assistive Technology for Persons after Stroke. IEEE Int Conf Rehabil Robot. 2022;2022:1–6.

[46] van Ommeren AL, Smulders LC, Prange-Lasonder GB, et al. Assistive Technology for the Upper Extremities After Stroke: Systematic Review of Users' Needs. JMIR

Rehabil Assist Technol [Internet]. 2018;5:e10510. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30497993.

[47] Park S, Fraser M, Weber LM, et al. User-Driven Functional Movement Training With a Wearable Hand Robot After Stroke. IEEE Transactions on Neural Systems and Rehabilitation Engineering [Internet]. 2020;28:2265–2275. Available from: https://ieeexplore.ieee.org/document/9186719/.

[48] Chen A, Winterbottom L, Park S, et al. Thumb Stabilization and Assistance in a Robotic Hand Orthosis for Post-Stroke Hemiparesis. IEEE Robot Autom Lett [Internet]. 2022;7:8276–8282. Available from: https://ieeexplore.ieee.org/document/9803858/.

[49] Babaiasl M, Mahdioun SH, Jaryani P, et al. A review of technological and clinical aspects of robot-aided rehabilitation of upper-extremity after stroke. Disabil Rehabil Assist Technol [Internet]. 2016;11:263–280. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25600057.

[50] Hoonhorst MH, Nijland RH, van den Berg JS, et al. How Do Fugl-Meyer Arm Motor Scores Relate to Dexterity According to the Action Research Arm Test at 6 Months Poststroke? Arch Phys Med Rehabil [Internet]. 2015;96:1845–1849. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26143054.

[51] Elo S, Kyngäs H. The qualitative content analysis process. J Adv Nurs [Internet]. 2008;62:107–115. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18352969.

[52] Bourassa J, Faieta J, Bouffard J, et al. Wheelchair-mounted robotic arms: a survey of occupational therapists' practices and perspectives. Disabil Rehabil Assist Technol [Internet]. 2021;1–10. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2021.2017030.

[53] Rozevink SG, Hijmans JM, Horstink KA, et al. Effectiveness of task-specific training using assistive devices and task-specific usual care on upper limb performance after stroke: a systematic review and meta-analysis. Disabil Rehabil Assist Technol [Internet]. 2021;1–14. Available from: https://www.tandfonline.com/doi/full/10.1080/17483107.2021.2001061.

[54] Sarac M, Solazzi M, Frisoli A. Design Requirements of Generic Hand Exoskeletons and Survey of Hand Exoskeletons for Rehabilitation, Assistive, or Haptic Use. IEEE Trans Haptics [Internet]. 2019;12:400–413. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31251193.

[55] du Plessis T, Djouani K, Oosthuizen C. A Review of Active Hand Exoskeletons for Rehabilitation and Assistance. Robotics [Internet]. 2021 [cited 2023 Apr 3];10:40. Available from: https://www.mdpi.com/2218-6581/10/1/40.

[56] Winstein C, Lewthwaite R, Blanton SR, et al. Infusing Motor Learning Research Into Neurorehabilitation Practice. Journal of Neurologic Physical Therapy [Internet]. 2014;38:190–200. Available from: https://journals.lww.com/01253086-201407000-00008.

[57] Joy MT, Carmichael ST. Encouraging an excitable brain state: mechanisms of brain repair in stroke. Nat Rev Neurosci [Internet]. 2021;22:38–53. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33184469.

[58] Kwakkel G, Kollen B. Predicting improvement in the upper paretic limb after stroke: a longitudinal prospective study. Restor Neurol Neurosci [Internet]. 2007;25:453–460. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18334763.

[59] Sánchez N, Winstein CJ. Lost in Translation: Simple Steps in Experimental Design of Neurorehabilitation-Based Research Interventions to Promote Motor Recovery Post-

Stroke. Front Hum Neurosci [Internet]. 2021;15:644335. Available from: http://www.ncbi.nlm.nih.gov/pubmed/33958994.

Tables

Table 1. Sample Demographic Characteristics.

Characteristic	N	%
Total Completed Responses	154	100
Age		
18-24	3	1.9
25-34	62	40.3
35-44	42	27.3
45-54	24	15.6
55-64	19	12.3
65-74	4	2.6
Region		
Northeast	37	24
Midwest	72	46.8
South	19	12.3
West	16	10.4
Outside United States	10	6.5
Setting[a]		
Urban	63	40.9
Suburban	73	47.4
Rural	33	21.4
Role		
Occupational Therapist	94	61
Physical Therapist	39	25.3
Occupational Therapy Assistant	10	6.5
Physical Therapy Assistant	11	7.1
Primary Practice Setting		
Acute Care	32	20.8
Acute Rehabilitation	30	19.5
Skilled Nursing Facility/ Subacute Rehabilitation	13	8.4
Skilled Nursing Facility/ Long-Term Residential Care	12	7.8
Outpatient Rehabilitation/ Community or Private Practice	38	24.7
Home Care	14	9.1
Other	15	9.7
Experience Working With Chronic Stroke Patients		
Yes	144	93.5
No	10	6.5
What Ages Groups Do You Generally Work With?[a]		
Less Than 18	12	7.8
18-40	59	38.3
40-65	105	68.2
65+	131	85.1

[a]Multiple responses could be chosen.

Table 2. Participant experience with technology.

Types of Technology[a]	N	%
Low-tech assistive technology (e.g., reacher, shoe horn, sock aid)	144	93.5
Durable medical equipment	147	95.5
Splints, slings, mobile arm supports	138	89.6
Computer or tablet technology	75	48.7
Environmental control systems/ adapted communication systems	32	20.8
Virtual reality or gaming systems	67	43.5
Robotic systems	29	18.8
Electrical stimulation or biofeedback	117	76.0

[a]Multiple responses could be chosen.

Table 3. Examples of interventions participants listed they would use with the device. Responses were categorized as “exercise activities” and “functional activities.”

Activity Categorization
Exercise Activities • “Block pick up, pegboard tasks.” • “Motor repetition.” • “Grasp, functional reach, prehension, repetitive task practice” • “Grip strength, wrist strength, ROM”
Functional Activities • “Bimanual ADL tasks, dressing, IADL’s such as putting away dishes, cooking etc” • “would train the affected arm as an assist for the primary arm within ADLs that the patient needs to perform at home.” • “ADLs...dressing (BUTTONS, PULLING UP PANTS), grooming (holding brush, makeup container)” • “eating, writing, teeth and hair ADLs”
Exercise and Functional Activities • “ADLs, functional mobility, therapeutic exercise, IADLs, leisure, work” • “Grasp and release repetitive task practice during functional tasks” • “Grooming, self feeding, dressing, cooking, strengthening for grasp and release” • “Bimanual tasks for neuro re-ed, ADLs to help facilitate independence while also working on neuro re-ed”

Table 4. Responses to survey items related to the clinical use of the MyHand system.

Survey Item	N	%
What locations do you think MyHand could be most appropriately deployed in?[a]		
Acute care	23	14.9
Acute rehabilitation	95	61.7
Skilled Nursing Facility/ Subacute Rehabilitation	89	57.8
Skilled Nursing Facility/ Long-Term Residential Care	46	29.9
Outpatient Rehabilitation/ Community or Private Practice	131	85.1
Home care	55	35.7
Other	10	6.5
What groups of patients do you think would most benefit from MyHand use?[a]		
Acute Stroke	91	59.1
Subacute Stroke	134	87
Chronic Stroke	111	72.1
How much time would you be willing to spend per session setting up MyHand on your patient prior to use?		
Less than 2 minutes	17	11.0
2 to 5 minutes	75	48.7
6 to 10 minutes	42	27.3
11 to 15 minutes	20	13.0
How much time would you be willing to spend to get trained in using MyHand?		
Less than 1 day	42	27.3
1 to 2 days	86	55.8
3 to 5 days	21	13.6
More than 5 days	5	3.2

[a]Multiple responses could be chosen.

Figures

Figure 1

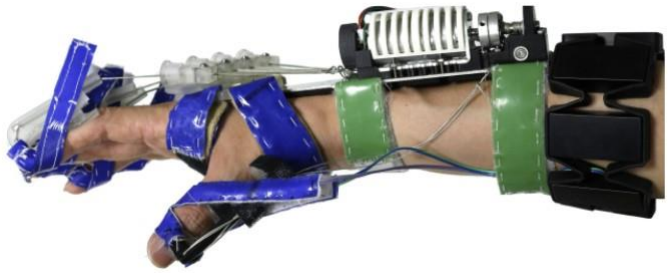

Figure 2

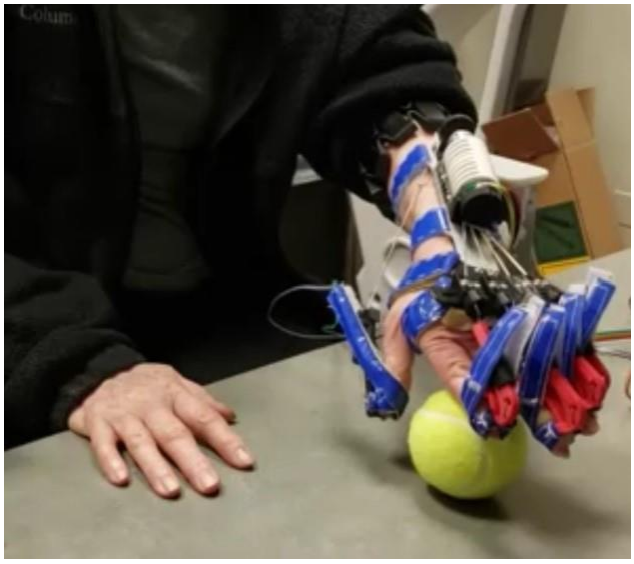

Figure 3

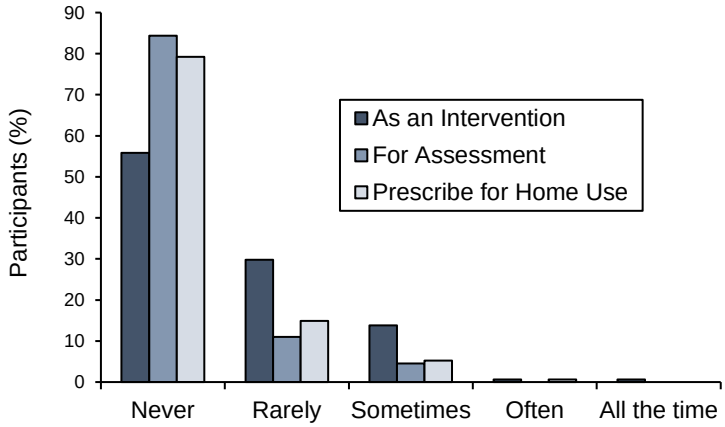

Figure 4

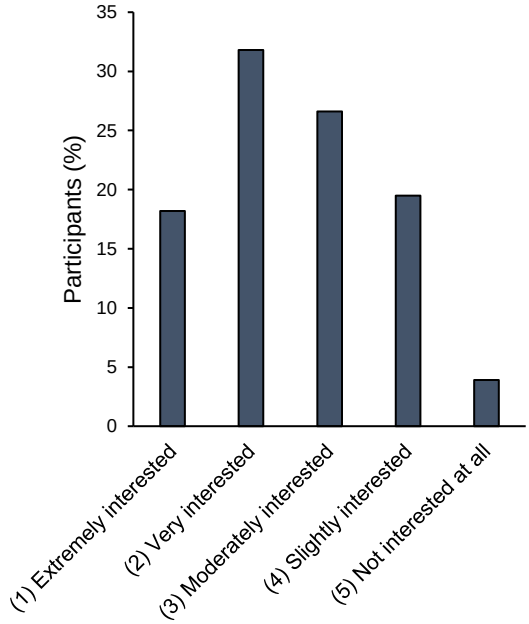

Figure 5

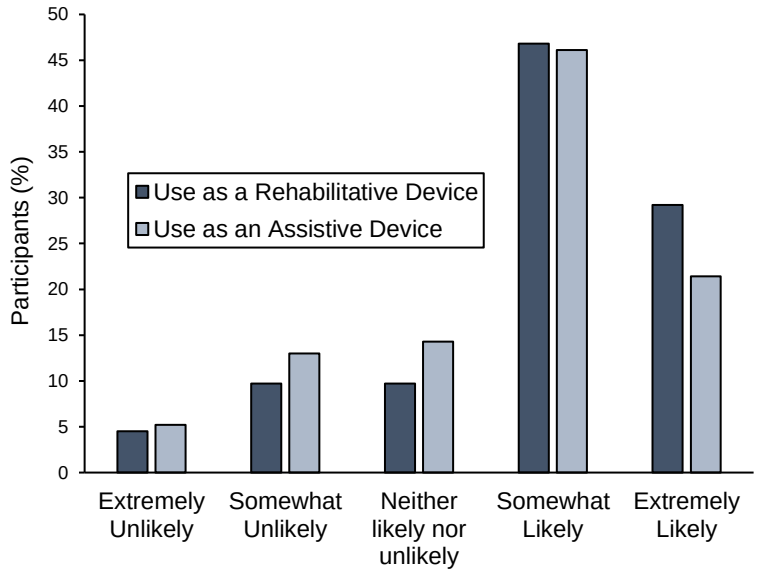

Figure 6

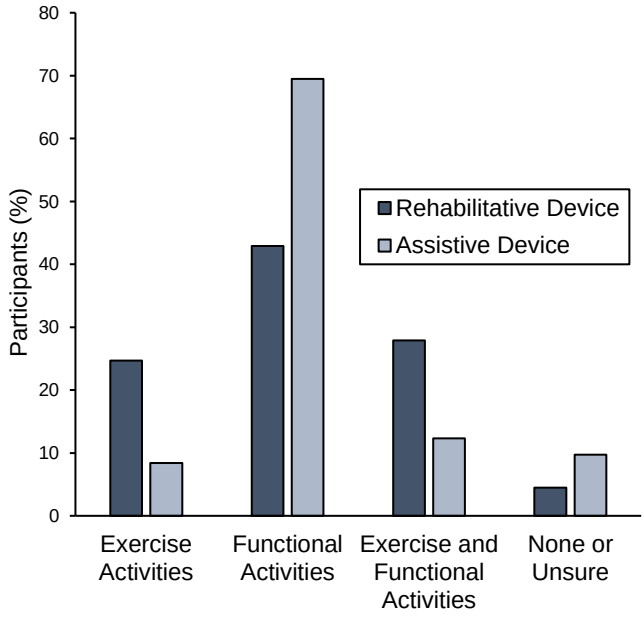

Figure 7

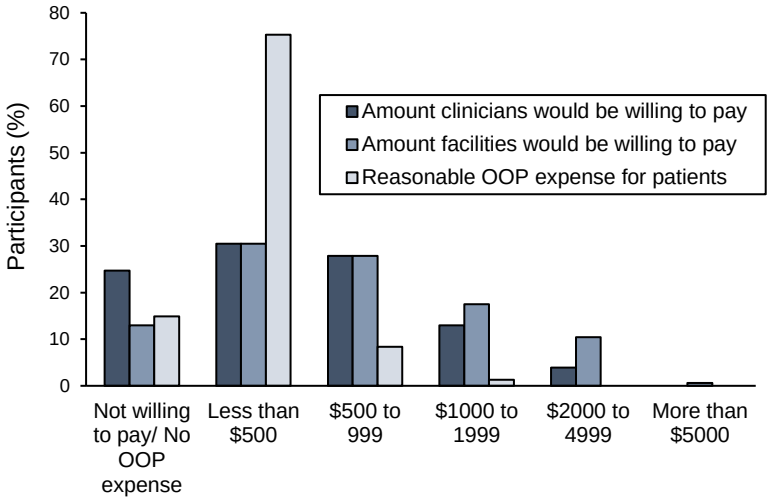
80
70
60
50
40
30
20
10
0
Participants (%)
Amount clinicians would be willing to pay
Amount facilities would be willing to pay
Reasonable OOP expense for patients
Not willing to pay/ No OOP expense
Less than $500
$500 to 999
$1000 to 1999
$2000 to 4999
More than $5000

Figure captions

Figure 1. The MyHand system.

Figure 2. Still image from the video viewed by participants depicting an individual with hand weakness from stroke using the MyHand system to grasp a tennis ball.

Figure 3. Clinicians' frequency of use of robotic systems.

Figure 4. Participants' responses to the question "How interested would you be in using the MyHand System?"

Figure 5. Clinicians' likelihood of using the MyHand system for rehabilitation and assistance.

Figure 6. Activities selected for the MyHand system as a rehabilitative device and as an assistive device.

Figure 7. Clinicians' perceptions of acceptable costs of the MyHand system. OOP = out-of-pocket.