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Therapists' perspectives on a new portable hand telerehabilitation platform for home-based personalized treatment of stroke patients

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Abstract. – OBJECTIVE: Patients who have sustained a stroke suffer from residual motor impairments. Stroke can limit their ability to employ their impaired upper limb properly. Hand function is particularly one of the most frequently persisting consequences of stroke. This paper introduces a new portable hand telerehabilitation platform (PHTP) for home-based personalized treatment of stroke patients. The aims of this study are (1) to document the iterative design and development process of the PHTP, and (2) to explore the therapists' perspectives on implementing home-based treatment of stroke patients.

MATERIALS AND METHODS: Local therapists were involved early in designing and developing the PHTP. We collected views of 84 therapists practicing in North America via an online survey.

RESULTS: Therapists' perspectives on the introduced prototype support the use of the PHTP to provide home-based telerehabilitation for stroke patients. The System Usability Scale score was 70 for the PHTP, indicating that the platform is usable. The rest of the qualitative results obtained from custom questionnaires showed consistency in the platform design, high perceived usability and good acceptability among the therapists' community.

CONCLUSIONS: In sum, the results encourage and support fine-tuning of the PHTP, commercializing it, and conducting prospective clinical studies.

Key Words:
Telerehabilitation, Stroke, In-home, Portable platform, Co-design, Development, Acceptability, User perspective.

Introduction

Patients who have sustained a stroke are often left with residual motor impairments that limit their ability to engage in meaningful occupations such as self-care, leisure activities, or work. Impaired hand function is one of the most frequently persisting consequences of stroke[1]. Paralysis of the upper limb or hand occurs acutely in up to 87% of all stroke survivors[2,3], affecting independence in daily life activities and quality of life. Although patients appear to benefit from substantial time spent in practice[4,5], studies show that they may not be practicing enough. Compared with other patient populations, patients who have sustained a stroke spend a lot of time alone and inactive or less active in rehabilitation units, more likely because of reduced sensorimotor capacity[6,7]. Thus, there appears to be a practice gap between the amount of training these patients need and the amount they receive. It is of benefit to investigate ways to increase the frequency, consistency, and efficacy of practice.

Therapists who work with patients with stroke use approaches to optimize motor behaviour to restore function and occupational performance. Treatment interventions such as materials-based occupations[8], task-related[9,10] or task-specific training[11,12] are common methods for remediating impairments and restoring function in the upper limb. These training methods stress the person's active participation, manipulation of goal-oriented tasks or environmental characteristics to drive motor behaviour, and practice of the whole task or components of the task under varying conditions. Patients often know how a movement should be performed but are physically not able to do so[13]. This activity has traditionally been used in athletics[14,15] intuitively, to review or reinforce the se-

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quence of movements that make up the action to be performed. The mental practice has shown to be effective in reducing impairment and improving functional recovery[16]. Literature shows that mental practice is an effective intervention when added to physical practice[16]. However, generalizations are difficult to make. Although functional imaging has shown that mental practice produces similar cortical activation patterns to those of movement, the clinical effectiveness of such methods in rehabilitation and functional recovery has yet to be demonstrated[16]. It is also complex to gauge the dosing required, the most effective protocols, whether improvements are retained, and whether mental practice affects function and perceived occupational performance.

The current state of knowledge in post-stroke hemiparesis neuro-rehabilitation is now ripe for research and therapy practice using technology-assisted interventions. However, technological advances are no longer an obstacle to developing rehabilitation technology for hand therapy[17-30]. Since stroke incidence is rising, the need has arisen for technology to support the treatment and relieve the therapists' workload.

The next step in hand rehabilitation seems to be home-based rehabilitation based on a clinically approved telerehabilitation platform. A home-based approach to rehabilitation is pragmatic considering the inequalities in access to care between regions and communities and the occurrence of disasters such as the COVID-19 pandemic. . In addition to enabling access and timely treatment of patients, home-based hand rehabilitation could be an interesting modality of treatment that supports intensity and frequency of practice. The evidence suggests that the higher the intensity and duration of therapy, the better the patient's outcome[31]. This paper presents a new portable hand telerehabilitation platform (PHTP), designed and developed by Tactile Robotics, Canada, for home-based treatment of stroke patients. It also describes the multi-faceted collaborative process for its development and content validation.

Description of PHTP

The PHTP allows users to engage in hand rehabilitation practice remotely. The PHTP consists of a pair of smart gloves, a patient's mobile app and a therapist's desktop interface with their companion app (Figure 1). The glove is passively actuated with rubber band tensioners with various elasticities to help users regain control over their hand when extending their fingers. The glove is equipped with two kinds of sensory systems that allow the rehab expert to gauge the user's performance metrics. Each sensory system includes 5 flex sensors, which measure the angle of each finger, and one inertial measurement unit (IMU) that measures metrics of the palm's section of the hand's motion.The mobile app is a cross-platform application that is compatible with both iOS and Android smartphones. The mobile app allows the patient to record a video of their rehab task while wirelessly connected to the sensory system attached to TR-Gloves (TR stands for Tactile Robotics). The patient can receive key performance indices of their rehab tasks on the mobile app. Having performed the rehab task, the patient can upload the performance results, along with the recorded video, to the database and let the rehab expert monitor their progress.

The patient receives a pair of smart gloves at home with additional single-user rehabilitation tools included in the box, and a code to activate their account on the smartphone application. The app is initiated by the patient when they wear the gloves. It provides the patient with a comprehensive program that includes tasks assigned by the therapist. Short video demonstrations allow the patient to practice as needed. All the information is instantaneously uploaded to the cloud and saved in a server so the therapist can analyze the performance and provide the patient with feedback, synchronously or asynchronously.

This study aims to describe the role of local therapists in the co-design of the PHTP and examine the perspectives of a larger group of therapists on the PHTP prototype collected in support of PHTP manufacturing and commercialization. Involving therapists early in the design and development from the ideation to market-ready stages has been extensively documented in the literature[32-36]. Many conceptual models recommend using various technology development phases[37-39]; however, these models often prescribe stages that appear linear and not pragmatic. In this project, developing a rehabilitation technology is conceived as a dynamic approach that requires early assessment by the stakeholders, known as early health technology assessment (EHTA). IJzerman and Steuten's (2011) model[36] is one EHTA model that has been extensively adopted in health product development. IJzerman and Steuten[36] (2011) describes three main phases of health technology assessment (HTA) to refer to evolving research stages: (1) "very early HTA" or first stage, which is basic research; (2) "Early HTA" or second

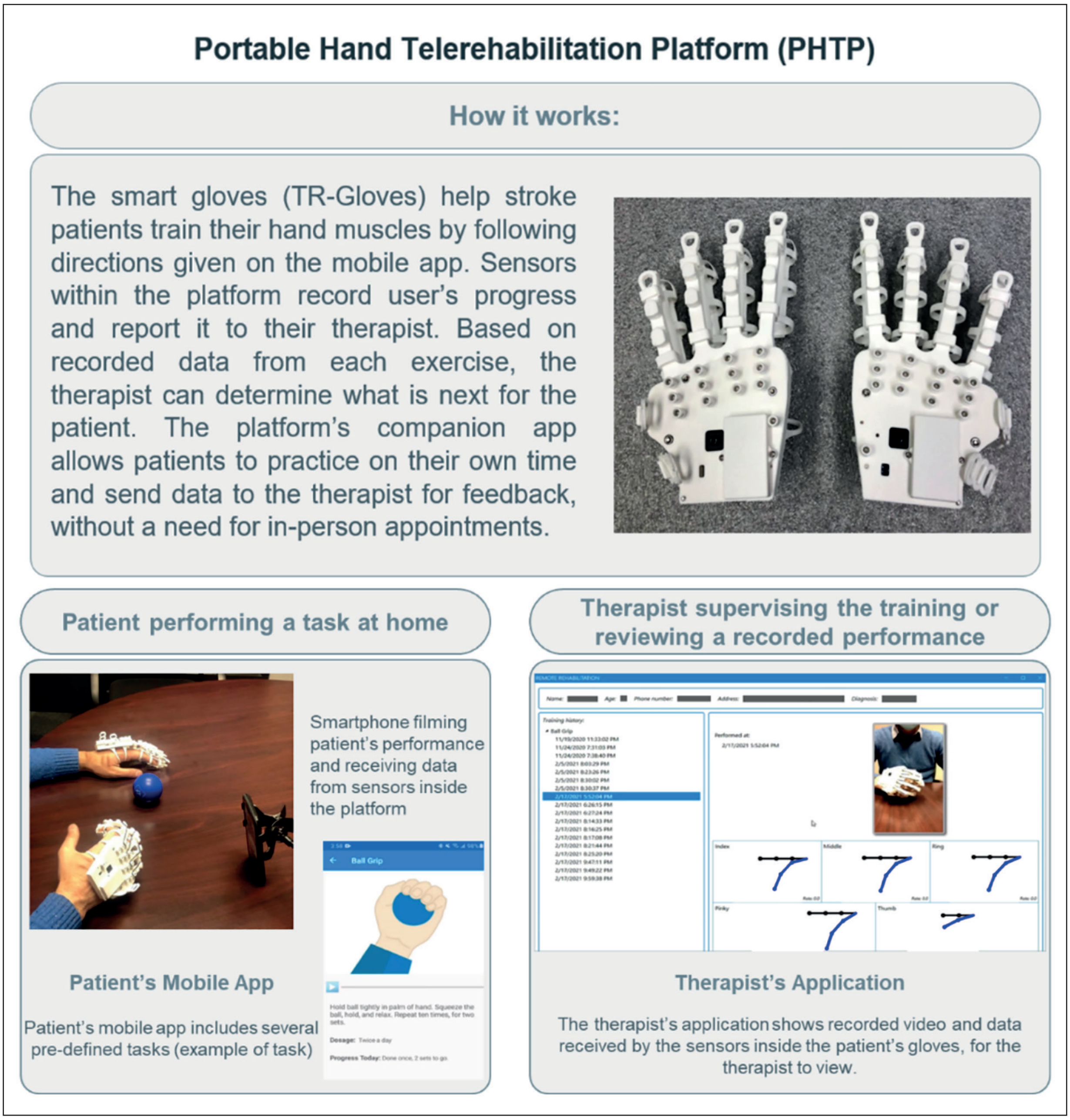

Figure 1. An overall picture of PHTP.

stage, which involves translational research; and (3) "mainstream HTA" or stages three and four, referring to clinical research and marketing. This study[36] presents the process, and outcomes from phases 1 and 2 of the EHTA, which involve four stages according to IJzerman and Steuten (2011): (1) "basic research on mechanisms", (2) "targeting for specific product", (3) "proof-of-principle" and (4) "prototype product development".

Materials and Methods

The PHTP was developed following a reiterative co-design process and evaluated at the early stages of development, as recommended in the literature[40]. Nine individuals were involved in developing and validating the first PHTP prototype: four occupational therapists (OT), one physiotherapist, two engineers, one computer scientist, and the principal investigator. A total of 138 therapists participated in the PHTP prototype evaluation.

Basic Research on Mechanisms

The PHTP concept was designed iteratively, involving discussions with four OTs, three women and one man. OT1 has 28 years of experience in both outpatient and community-based stroke treatment. OT2 has been practicing specifically with stroke patients for 2.5 years. OT3 has been practicing for 27 years, 11 of which were in the inpatient stroke rehabilitation unit, including full-time treatment of stroke patients for the past 2 years. OT4 worked for 8 years with stroke patients. In addition to the principal investigator and a physiotherapist, a group of OTs assisted in the design and content validation of the PHTP. Preliminary prototypes, drawings, and demonstration videos served as the foundation for all discussions. The areas of development discussed with the therapists covered the different parts illustrated in Figure 1, namely the smart gloves, the therapist web application, the patient mobile application, the tasks list, therapeutic program options, and the equipment provided as part of the platform. Therapists were gathered for a 1.5-hour discussion facilitated by a teleconference platform. The therapists were provided with initial thoughts and designs of different parts, presented as videos and images with the moderator's comments. The physiotherapist then presented the pre-defined therapeutic tasks and program options for further discussion. The two-way communication and information flow between the therapist and the remote patient were also discussed. All discussions were audio-recoded and transcribed post-session. Transcribed material has undergone an inductive thematic analysis. Emerging themes made it possible to provide a clear map for technical development iterations and program improvement. This phase guided and informed the final prototype.

Targeting for a Specific Product

We determined that the PHTP should provide hand telerehabilitation services, which are COVID-19 compliant, to assist with current needs and the needs of rural, remote, and underserved populations for a post-COVID-19 era.

Proof of Principle

We determined that the PHTP should be not only a teleconferencing platform adapted to the needs of telerehabilitation, but rather a comprehensive platform that enables the therapist to set up the program in a flexible manner, the patient to be actively engaged in therapy, and both parties to act synchronously or asynchronously.

Prototype Product Development

This phase included an early feasibility study, including the elicitation of therapists' needs for development, an early system usability assessment, and a cost-effectiveness evaluation.

Survey Design

We created an online survey using Qualtrics (2020, Provo, UT, USA). The survey focused on therapists' perceptions regarding the usability of the PHTP using the System Usability Scale (SUS)[41] and an additional custom questionnaire. Internal consistency of SUS is high The SUS has a high internal consistency ($\alpha = 0.91$), and a moderate concurrent validity ($r = 0.81$, $p < .001$)[42]. The SUS scale includes 10 items that are positive or negative statements regarding the following aspects of usability: effectiveness, efficiency, and satisfaction. The items were rated on a 5-point Likert scale ranging from "1" indicating "complete disagreement" to "5" indicating "complete agreement". The SUS score ranges between 0 and 100[43,44]. Scores equal to or above 68 are considered "good". Scores below 50 are considered to be "very weak" (45). This study's custom questionnaire had 16 questions, each including a positive statement. These questions were also rated on a 5-point Likert scale ranging from "1" (strongly disagree) to "5" (strongly agree). Additionally, participants' background information was collected, such as experience as clinician, experience with hand therapy in particular, experience and training in telerehabilitation and work setting. The study was approved by the University of Manitoba Health Research Ethics Board. The survey was circulated digitally, being a COVID-19 compliant methodology. The current development is timely to continue the much-needed provision of hand therapy at home during the pandemic and beyond.

The following is a list of custom questions used in this study. Answer options range from 'strongly disagree" to "strongly agree" on a five-point Likert scale. *Instruction to participants was "For each of the following statements, mark one box that best describes your reactions to the platform".*

– The platform is easy for therapists to learn.
– The platform is quick and easy to start and adjust settings.

- The platform is portable and can be used both at patient's home and/or in typical therapy areas.
- The platform would be easy for patients to use.
- The platform can be used independently by patients.
- The platform provides clear feedback and instructions to patients.
- The platform should not take more time than standard therapy.
- The platform should make it possible to treat more than one patient at a time.
- The platform functions reliably and has accessible tech support.
- The platform is adjustable to various task-related variables.
- The platform can measure, track and document patient progression.
- The platform is adaptable to between-patient differences.
- The platform is adaptable to within-patient changes.
- The platform alone would not be enough for rehabilitation.
- The platform meets infection control guidelines (e.g., can be cleaned and shared).
- The platform meets privacy guidelines (e.g., storing personal information on devices and the cloud).

Therapists were also asked a COVID-19 specific question to understand their perception of the usability of the PHTP in the particular context of the pandemic and in the long-term post-pandemic. Participants were asked to imagine if they had the platform in their current work and to say if they "would prefer to use it over traditional sessions when there is an outbreak only" or "would prefer to use it over traditional sessions at all times".

Data Collection

A pool of 250 therapists was targeted in North America using Prolific.co, a convenient and reliable crowdsourcing platform that has been used successfully in sensitive research contexts such as behavioral science[46], and psychology[47,48]. Eligibility criteria for this study were that participants included were healthcare professionals from Canada and the USA. 138 participants completed the study successfully. The rest of the participants who completed the survey partially were excluded. Out of 138 participants, 84 practicing clinicians were included based on their expertise (occupational therapists and physiotherapists). All participants received GBP 2.5 as compensation for their time after completing the survey. On average, participants spent 9.2 minutes (±2.3) to complete the survey.

Results

PHTP Co-Design

PHTP Functions

Therapists expressed that clinical needs are for functional exercises to be part of training programs embedded in the PHTP and daily living tasks. OT4 mentioned, "*That's pretty much how we measure our outcomes and assess progress*". After viewing the PHTP demonstration video, OT3 commented, *"There was some allowance for functional outcome measurements as well; I think from my perspective that would be a beneficial tool."* OT1 added, *"One advantage now that we are looking at doing more therapy remotely is being able to have some objective outcome; we are looking at objective measurements of improvement hopefully. Maybe this can help us with that piece".* OT2 focused on the outcomes presented in the therapist's app and suggested that *"... it measures range of motion (ROM) in numbers and statistics, but also in percentages compared to the other hand, the healthy hand I mean."* OT3 said, *"...it is essential to measure the change and the relationship between the sensors..." having the change in either the ROM or the percentage of overall movements would undoubtedly be helpful for us, and the patients."* Overall, PHTP was described by the group as a goal-oriented platform, as emphasized by OT1:

"*I think that's where you're going to get people to buy in more if it's related to a goal that they want to achieve with that arm, whether it's brushing their teeth again or holding their phone or something that's where you're going to see more buy-in to work in these things right instead of just, I mean, the exercises*".

PHTP Characteristics

As discussed by the group, the PHTP should fit all hand sizes, and should *"open from the side",* as suggested by OT1. It was determined that three sizes needed to be developed: small, medium, and large. As OT2 detailed, *"Some people are in between for sure or some people... their hand is a little tighter; they can't put the small glove on* *even if the small is the right size for them so I will often go up a size just to have a little more space for them to get these tight fingers in, so, I think small medium and large could work.".* In addition to the glove size, the sensor sensitivity was also discussed. OT3 inquired about the sensitivity of the sensor to detect minor movements, wondering *"... how much minimum active movement would they have to have? I am thinking about their ability to get their hand into the glove, and what motor movement they can perform and what is the minimum requirement they would need?".* All the participating therapists said that the PHTP should be delivered with tools included in the package to be used during the exercises and activities, including as described by OT1, *"... small balls and other objects we usually use that are incorporated with the exercises and activities...".*

PHTP Target Users

All the participating therapists mentioned that the PHTP addresses stroke patients' needs, except for patients with high spasticity levels. OT1 said that the PHTP is to be used with "*pretty much all the patients excluding people with a significant amount of spasticity on the Ashworth scale.*" The group recommended the PHTP for use with stroke patients scoring 2 or less on the Ashworth Scale (49). Therapists also acknowledged that technology should be adapted to appeal to older adults. When asked about the interaction of therapists with patients during teleconference-based telerehabilitation sessions, OT4 was surprised by the quality of interaction, in particular with older adults, during the COVID-19 pandemic, stating that *"...there will be many people who would be great and keen to do it (telerehabilitation). I've been surprised by some people how well they are managing the virtual visits, so, I think the perceptions about technology are changing.*" OT3 added, "*I think there are always going to be some clients who maybe aren't open to that kind of device, but I know I've worked with some older adults who are very motivated and very tech-savvy. So, the short answer is yes.*"

PHTP and Patient-Therapist Interaction

The group highlighted the importance of providing live cues to the patient when working synchronously. OT4 mentioned the relevance of providing feedback to patients *"...while they are doing the tasks so that we can give cues about certain ways of performing the tasks."* The use of videoconference was received positively by the entire group. OT2 said that *"It would be beneficial to be able to pop in every once in a while and see the client through the video interface."* Supported by OT1 and OT4, OT3 acknowledged that *"patients filming themselves is a good way of interacting and providing feedback"* even asynchronously (i.e., when the therapist is not present virtually via teleconference). *"Patients like that they are filming themselves, so they have to see what they are doing and how that compares to their other hand. They get more feedback that way without us being there to give back cueing."* OT3 added that *"The only requirement is that we are all aware of the PHIA* (Personal Health Information Act). *We are doing a lot of virtual therapy now and we are really being warned about the whole PHIA and we know we are not allowed to text patients. We will not text the clients, but we will be able to adjust the details of their program online and all they have to do is to follow instructions in the app. I think that's PHIA-compliant and beneficial to our clients."*

PHTP and Progress Monitoring

OT3 (supported by OT2 and OT4) suggested the reporting feature should be periodic or as-needed to enable a "before/after option"... OT4 sees a *"value in the client being able to see their difference and also have hard numbers."* OT3 added that "*...it's helpful to have even a weekly report of the total time that they are spending at it."* The report should also include functional and wellness questionnaires. According to OT3, *"It would be helpful to capture some functional information as well as patient comfort and pain, etc., with a fast questionnaire at the end of the session."* OT3 also added that *"...a weekly report would be enough. I would look at them even from my smartphone after hours. This is important to follow the progress, and we don't have such a platform now.".*

PHTP Evaluation

Therapist's Profile

A total of 84 participants were considered in our analyses, including 23 therapists from four Canadian provinces and 61 therapists from 25 states in the USA. 59.5% of participants (n=50) practice in private settings and 40.5% (n=43) in public setting. Participants had an average of 11.3 (±10) years of clinical experience ranging from 1 to 35 years of general experience and 6.2

(±4.4) years of experience specifically with hand therapy. Participants had 1.3 (±1) years of experience with telerehabilitation. 82.2% of participants (n=69) had no training in telerehabilitation, and 17.8% (n=15) followed a formal telerehabilitation course.

Therapists' Perception About PHTP

The SUS score in this study is 70, meaning that the PHTP has good effectiveness, efficiency, and participant satisfaction. The custom questionnaire statements were rated between 4.1 (±0.7) and 4.6 (±0.5), meaning that the PHTP is easy for therapists to learn and for patients to use. It can be used at the patient's home and/or in typical therapy settings and independently by patients (questions 1 to 5). The platform provides clear feedback and instructions to patients and takes no more time than standard therapy. It is adjustable to various task-related variables and allows for the treatment of more than one patient at a time. It functions reliably and has accessible tech support (questions 6 to 10). The PHTP can measure, track and document patient progression and is adaptable to between-patient and within-patient differences (questions 11 to 13). However, therapists confirmed that the PHTP would not be enough for rehabilitation (question 14). The PHTP meets infection control and privacy guidelines (questions 15 and 16). In terms of short-term versus long-term use of the PHTP, 70.2% of therapists (n=59) prefer to use the PHTP over conventional sessions only when there is an outbreak. 29.8% of therapists (n=25) would like to use the PHTP over conventional sessions at all times.

Discussion

The first objective of this paper was to describe the PHTP development process, emphasizing the role of therapists in its co-design. Local therapists were involved early in design and development by providing feedback, asking questions and validating the concept suggested by the rest of the research team members. The usefulness of involving therapists in EHTA has been extensively documented in the literature[32-36] and was fruitful in this project, as reported by both the local therapists and the larger group of North American therapists. The role of the therapists has indeed been relevant to the interrelated phases of "basic research on mechanisms", "targeting for specific product", "proof-of-principle," and "prototype product development" as defined by the IJzerman and Steuten (2011) model[36]. The PHTP functions and characteristics were perceived as relevant to therapeutic needs in supporting hand rehabilitation in general and providing care remotely. COVID-19 has momentarily disrupted the management of this project in the short term; however, the research team benefited from the pandemic's impact on people's perception of remote care. Many health authorities have actually urged the strengthening of digital and data-driven solutions to support COVID-19 response[50], with calls to monitor patients remotely and safely to reduce the burden on health systems[51]. Interest is the same in the rehabilitation field. For example, a recent survey carried out with physiotherapists in Ontario, Canada, indicates that "there is substantial interest in continuing the delivery of telerehabilitation or a hybrid model of care, including a combination of care delivered in-person, and remotely where appropriate"[52]. Hand telerehabilitation is, however, a tiny field under the umbrella of telerehabilitation in general. Technology and practice are yet to be documented and discussed. The co-design approach followed in this study particularly helped facilitate interdisciplinary interactions between the technical development subgroups (3D design, mechanical engineering, electrical engineering, and computer science) and the therapist subgroup (occupational therapists, physiotherapists, and human kinetics). The main features discussed throughout the co-design process are every user's role and the data visualization for everyone. We determined that the patient platform will be straightforward to navigate and use to maximize practice time. The therapist's platform will be comprehensive, as illustrated in Figure 1. However, in terms of data visualization, the therapists provided many options, such as graphs and statistics of ROM without specifying which one would work best. Averaging ROM would be particularly challenging if we rely on mean values as the finger angles will fluctuate between positive and negative values resulting in biased mean values. To achieve reliable results, the root mean square (RMS) value of each finger's ROM is calculated. Relying on the RMS values to observe changes over time has been widely used in multi-articular task analysis and abnormalities detection in ecological movements[53-55]. RMS will be displayed in numbers and in graphs to satisfy therapists' desires to work with quantitative data, as expressed by the therapists who contributed to the PHTP co-design.

For the second objective of this study, we examined the perspectives of a larger group of therapists practicing in North America on the PHTP prototype that are collected in support of PHTP manufacturing and commercialization. The results are encouraging and are in favour of fine-tuning the prototype and commercializing the PHTP. The SUS score for the PHTP was 70, which is above the threshold of 68, meaning the PHTP is a usable platform[41,42]. Therapists' perceptions were also positive (over 4/5 on average) and were therefore in support of moving to the next steps of development: that of a commercialized version and moving forward to post-EHTA phases as recommended in the literature (pilot and larger scale clinical studies)[36]. Therefore, the next step in the PHTP development process is to conduct prospective studies to evaluate the clinical outcomes resulting from using the commercialized version of PHTP to provide hand telerehabilitation services with stroke patients scoring 2 or less in the Ashworth Scale[49]. The cost was not explored in this study as it was determined that presenting the cost to therapists at this stage would bias their opinions about the technology introduced. Also, we determined that therapists are not necessarily the target audience for cost-effectiveness analysis since not all therapists are involved in purchasing decisions in their units.

The cost-effectiveness of the PHTP-based intervention is key to the decision-making process on its implementation. This step will therefore be addressed in the next phase of the project. Although we do not have data on the unit cost and impact of using the PHTP on insurer budgets, it is expected that the PHTP will be offered at a competitive price comparable to that of many wearable devices. This will enable broader use of the PHTP in different clinical settings and increase access to telerehabilitation in other regions of the world, which is the first reason for this project. Beyond pricing a PHTP unit, future cost-effectiveness analyses will focus on demonstrating the economic value of this treatment option compared to the direct and indirect costs of standard in-person treatment to assess the impact on the insurance budget. This study allowed to come up with a comprehensive PHTP with a clear vision for its users' roles and information exploitation.

The PHTP includes a mobile app that can be downloaded from App Store or Google Play after the final release and can wirelessly communicate with the sensory system located in the smart gloves. The patients need to register on the mobile app to be connected to their respective therapist(s). The mobile app provides the patient with various rehabilitation tasks assigned by their therapists. They can watch a pre-recorded video of each task to learn how to conduct the task. Alongside the pre-recorded video, the patient can record themselves on a video when performing the task, using the front camera of their cellphone. This way, the therapists can see how the patient performs the task without needing to be there in person. Furthermore, the mobile app is equipped with a graphical representation of the sensory data demonstrating the patient's performance in layperson's terms.

Each patient is also provided with a pair of smart gloves to be worn during the practice of rehabilitation tasks. One glove (called: healthy glove) is worn on the healthy hand to provide the reference data from the patient directly. The patient conducts the rehabilitation task once using the healthy glove to collect the reference data. Afterwards, the same task is repeated by the impaired hand using the other glove. Both gloves are wirelessly connected to the mobile app for the collection of sensory data.

Each therapist registered on the platform has their page on the web application. The therapists can define and add the rehabilitation tasks and record a video of the task to be presented to their patients. A patient list enables the therapists to add new patients to the list and communicate with them remotely. A feature on the web application allows the therapists to assign and customize tasks for patients based on observation of their progress. On each patient's page, the training logs are available. This feature enables the therapist to review the history of the patient's activities over time. In each training log, the therapist can find the video of the task performed by the patient, at a specific time, along with the performance data.

Summary of the PHTP characteristics and features as considered for the commercialized version:

- A cross-platform mobile application compatible with both iOS and Android operating systems;
- A pair of smart gloves, shown in Figure 1, to be worn by the patient, one on the healthy hand and the other on the impaired hand;
- A web application to be used by the therapists to track patients' progress and prescribe the required activities to the patients;

- A local database to store patient data and transfer data/ videos to the therapists later when there is no access to the internet; and
- A cloud database for remote data transfer and communication between patients and therapists, as well as data storage.

Limitations

Opinions of therapists gathered in this study represent those targeted online via a specific crowdsourcing platform (Prolific.co). They may not represent clinicians' perspectives who are not used to participate in solicited online surveys. The study also focused on the evaluation of the PHTP by therapists. The results call for further studies with a sample of the rest of the stakeholders involved in hand telerehabilitation, such as stroke patients and their families, unit managers and insurers.

Conclusions

This paper aimed to provide an overview of developing a portable hand telerehabilitation platform (PHTP) involving local therapists and the research team and exploring the therapists' perspectives on the prototype as an approach to early health technology assessment. The results showed the co-design process's success, as assessed by clear deliverables to the engineering team on a well-needed platform and a ready-to-manufactured product. The study also identified the platform as usable with a high potential for successful implementation, as determined by the SUS scale and the custom questionnaire. In recognizing the potential benefits of this technology, it is essential to be aware of the likely need for therapists' training and increase patient awareness of the related telerehabilitation services. This study provides food for thought on successive hand telerehabilitation requirements, i.e., easy-to-use mobile apps, easy-to-wear gloves, adapted and progressive exercises, and data-driven patient-therapist interactions. Although we have not studied the implementation of the portable hand telerehabilitation platform, we would expect it to be successful in any healthcare setting because of the need for it and its ease of use. This paper aimed to have the experts' viewpoints on the newly developed platform. More technical details and clinical data are to follow in our next publications.

Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the study's design, in the collection, anal-yses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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Institutional Review Board Statement

The protocol of this study was approved by the University of Manitoba Health Research Ethics Board [Certificate # HS22607 (H2019:074)].

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Authors' Contribution

Dr. Ali Maddahi is a Postdoctoral Fellow in the Department of Occupational Therapy, College of Rehabilitation Sciences at the University of Manitoba. Dr. Maddahi is the principal developer of the PHTP technology. Jasem Bani Hani is a Master of Science student in the Rehabilitation Sciences Program, College of Rehabilitation Sciences, University of Manitoba, and has contributed to developing the tasks list. Ali Asgari is a Master of Science student in the Biomedical Engineering Graduate Program at the University of Manitoba. Asgari has contributed to the technical design of the smart gloves. Amir Mahdi Nassiri is a computer scientist and has contributed as a research associate to the development of applications. Dr. Mohamed-Amine Choukou is an Assistant Professor in the Department of Occupational Therapy, College of Rehabilitation Sciences, and an Adjunct Professor in the Biomedical Engineering Graduate Program and Research Affiliate in Riverview Health Centre and the University of Manitoba Centre on Aging. Dr. Choukou is the Principal Investigator of this project and senior author of this paper. All authors have read and agreed to the published version of the manuscript.

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