Assessing Self-Rehabilitation Strategies for the Visually Impaired in Denmark

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SUBMITTED TO:
On-site Liaison: John Heilbrunn, Vice President of the DAB
Project Advisors: Frederick Bianchi, and Susan Jarvis

SUBMITTED BY:

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John Mastroianni

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Taryn Loomis

____

Michael Wray

____

Victoria Semple

Abstract

Self-rehabilitation technology has been developed to reduce healthcare costs and provide a convenient, reliable method for patients to recover from a physical injury. Sponsored by the Danish Association of the Blind, the following report summarizes a project exploring self-rehabilitation technologies that can accommodate blind or visually impaired patients. Potential strategies to increase awareness of such devices throughout municipalities in Denmark were evaluated as well. The data collected in this project were used to recommend that the Danish Association of the Blind advocates for further development of several rehabilitation technologies and the education of healthcare professionals about these technologies throughout Danish municipalities.

Executive Summary

Due to changing and expanding demographics, countries throughout the world are burdened with rising healthcare costs. In Denmark, the total social expenditure on healthcare increased by 19% from 2007 to 2014. In this same time span, the municipal rehabilitation expenses increased by 143%. Due to an increased demand for rehabilitation, as well as an emphasis on independent living, the Danish Government is encouraging more home-based healthcare practices. The use of self-rehabilitation technologies is one method to reduce healthcare costs by moving some rehabilitation from training centers to patients' homes.

Self-rehabilitation technology is relatively new and the devices available are not in widespread use. The Danish Association of the Blind sponsored this project with an interest in identifying which technologies were currently being used in Denmark and making these technologies accessible to individuals who are visually impaired. This project began with a review of current literature related to self-rehabilitation and studies on new technologies. A methodology was developed and centered around the mission to assist the Danish Association of the Blind to determine how to implement at-home rehabilitation programs for people with visual impairment by assessing self-rehabilitation technologies within Danish municipalities. Three main objectives were used to guide this project:

Objectives

1. Evaluate healthcare infrastructure in municipalities throughout Denmark.
2. Explore existing home-based rehabilitation technologies.
3. Evaluate potential implementation methods for these devices/treatments for visually impaired patients.

Once in Denmark, extensive interviews with a variety of key stakeholders including members of the DAB, technology developers, and a physiotherapist were conducted. These interviews, as well as a site visit to a technology showroom, were used to identify existing rehabilitation technologies used throughout Denmark. Due to how relatively new this field is, very few technologies were identified. MITII (Move it to Improve It) and Virtual Training are two programs utilizing Microsoft Kinect technologies for exercise programs. ICURA and Bandcizer are sensor-based rehabilitation devices that use a smartphone application to track movements during exercises. FysioMeter is a device that uses a Wii Fit Balance Board for monitoring strength, balance, and reaction time. The Total Range EXercisers (TREX) and the Mobile Virtual Enhancements for Rehabilitation (MOVER) are two technologies are being developed in the United States, but were identified as possible solutions based on their potential to be adapted for visually impaired patients. TREX units utilize robotics for patients to individually and precisely complete exercises. MOVER technology tracks movements of patients using a webcam and a virtual skeleton.

While none of these technologies are currently accessible for use by a visually impaired individual, information from the interviews and further research were used to identify potential adaptations for these devices. Due to the lack of precise motion tracking of Kinect technology, as well as the dependency on visual cues, it was determined to be very difficult to modify MITII and Virtual Training to accommodate visually impaired patients. However, with the addition of audio cues and voice control, ICURA and FysioMeter have greater potential to be accessible to visually impaired patients. Due to time constraints, Bandcizer, TREX Rehab, and MOVER technologies were identified as potential solutions as well, but further discussion with the technology developers is needed to determine if they are willing to adapt their devices to accommodate for the visually impaired.

Information from these interviews were also used to identify issues with implementation, including resistance from physiotherapists to prescribe such programs to patients. This resistance comes from a lack of knowledge of how self-rehabilitation technologies work and an unwillingness to change their rehabilitation practices. Implementation is further complicated by the lack of awareness of existing devices. Interviews with various stakeholders revealed that there is no centralized way to learn about new technologies, and knowledge of available devices varies greatly between healthcare professionals.

Based on this information, recommendations were made to further investigate, adapt, and implement self-rehabilitation technologies. The recommendations to the DAB were as follows:

1. Collaborate with ICURA to develop adaptations to the device to accommodate blind and visually-impaired patients.
2. Collaborate with FysioMeter to develop adaptations to the device to accommodate blind and visually-impaired patients.
3. Establish contact with Bandcizer and discuss how the device can be made accessible to visually-impaired patients.
4. Establish contact with TREX and discuss how the device can be made accessible to visually-impaired patients.
5. Establish contact with MOVER and discuss how the device can be made accessible to visually-impaired patients.
6. Continue to research new technologies that have the potential to be made accessible to visually-impaired patients.
7. Improve patient and physiotherapist awareness about modern self-rehabilitation technologies.

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Introduction

Rising healthcare costs are causing a significant burden on national economies throughout the world. In the European Union, six member states spent more than 10% of their gross domestic product on healthcare in 2012 (Eurostat, 2016). Across the European Union, hospitals are the largest source of healthcare expenditures ranging from 25.8% to 49.4% of total healthcare costs (Eurostat, 2016). The increase in healthcare costs is the result of an increasing aging population that often requires additional treatments and services (United Nations, 2010). In addition, medicine has become increasingly dependent on technologies, which contribute to the continuing increase in healthcare costs (Kumar, 2011). Countries are addressing these high costs by pursuing new technologies and strategies to maintain affordable healthcare.

Denmark is similarly facing this increase in healthcare costs. Total social expenditure on healthcare-related services has increased by 19% from 2007 to 2014 (Statistics Denmark, 2016). Over 57% of healthcare costs are derived from curative and rehabilitation services (Eurostat, 2016). From 2006 to 2014, there were 20% more patients receiving physiotherapy related rehabilitation services (Statistic Denmark, 2016). These rising healthcare costs and rehabilitation visits are of increasing concerns for taxpayers.

Self-rehabilitation through assistive technologies is one approach to reducing healthcare costs related to rehabilitation. Assistive technologies are devices that are used to improve an individual’s functional capabilities. Self-rehabilitation technologies can alleviate healthcare costs by reducing the length of time an individual requires personal assistance (Hoenig, Taylor, & Sloan, 2003). In addition to decreasing session time, annual costs can be significantly reduced, as compared to facilitated therapy (Imms *et al.*, 2015).

While these studies have demonstrated the potential of cost-reductions with self-rehabilitation methods (Wagner et al., 2011; Taylor et al., 2006), the degree of the cost-effectiveness remains unclear. Denmark's healthcare infrastructure is organized into 98 municipalities, each of which independently selects technology and programs to offer its residents. Because of this, any new technology or program needs to have a clear cost/benefit value in order to convince as many municipalities as possible to acquire it. There is also a lack of rehabilitation programs and technologies currently in use that are designed for the visually impaired. An immediate solution will require existing technology to be adapted to fit the needs of blind patients.

This project had two areas of focus. The first focus was to identify technology that could be adapted or developed in order to make rehabilitation more accessible for visually impaired patients. The second focus was to identify challenges with implementing rehabilitation technologies into municipalities and patients' homes. The final product is this report, which details the projected effectiveness of specific rehabilitation technologies and outlines recommendations to increase awareness of these devices to healthcare professionals. The DAB will be able to use the information in this report to advocate for the recommended technologies.

Background

Increasing Demands on the Public Healthcare Sector

The Danish healthcare system has two sectors: primary healthcare and the hospital sector (University College Lillebaelt, 2016). Primary healthcare includes services from general practitioners, physiotherapists, and other professionals. The hospital sector serves patients who require specialized medical treatment, such as intensive care (University College Lillebaelt, 2016). Both primary and hospitalized care are provided through a single-payer system, financed primarily through taxes with about 17% of costs being paid through patient copayments (Pedersen, 2012).

Given Denmark's expanding and aging population, the Danish government is burdened by rising healthcare costs. Total social expenditure on healthcare-related services has increased by 19% from 2007 to 2014 (see figure 1, Statistics Denmark, 2016). Due to the nature of the single-payer universal coverage healthcare system, increasing healthcare costs put significant strain on the Danish government. More taxes are needed to cover rising costs, or alternative healthcare delivery approaches need to be considered to reduce costs.

Figure 1: Total Social Expenditure on Healthcare in Denmark from 2007 to 2014 (Statistics Denmark, 2016).

One area of the Danish healthcare system that is being assessed for revision is rehabilitation. Rehabilitation can take many forms, including pharmaceuticals, exercises, and physiotherapy. The World Health Organization (WHO) defines rehabilitation as "...a process aimed at enabling [patients] to reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels. Rehabilitation provides people with disabilities the tools they need to attain independence and self-determination," (WHO, 2016). Conditions requiring rehabilitation services include neurological and musculoskeletal injuries, which are either temporary, such as injuries sustained from sports, or permanent, such as blindness (APBMR, n.d). The WHO definition places emphasis on the human aspect of rehabilitation, with confidence and independence as the end goal rather than objective medical recovery.

Current rehabilitation strategies are costly. Between 2006 and 2014, there was a 20% increase in the number patients receiving physiotherapy rehabilitation services (Statistic Denmark, 2016, see figure 2). Statistics Denmark predicts that the number of patients requiring physiotherapy will increase beyond 2014, further inflating healthcare costs (Statistics Denmark, 2016). Without adjustments, current rehabilitation strategies will continue to burden healthcare financing.

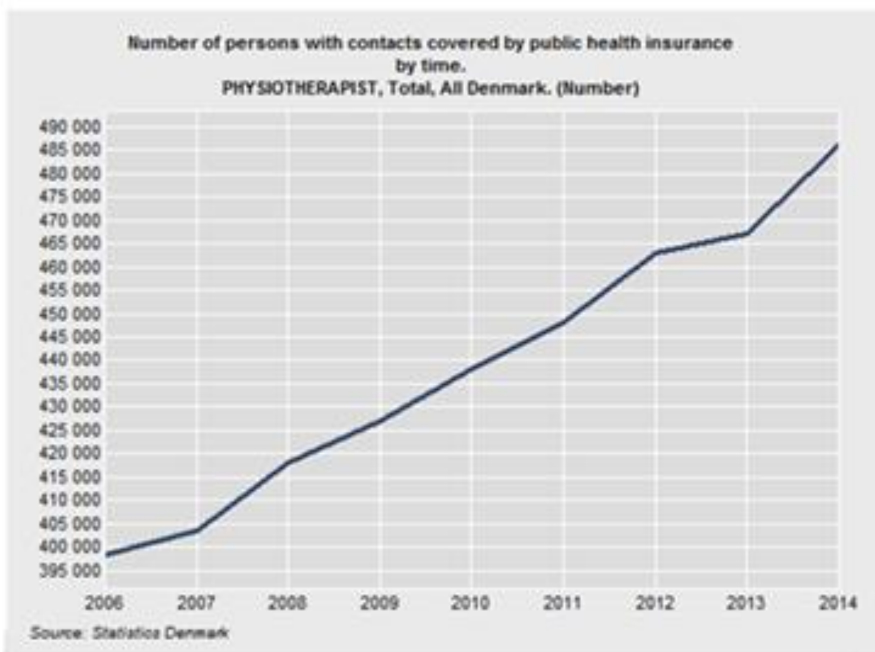

Figure 2: The Number of Physiotherapist Patients Covered by the Danish Public Healthcare System (Statistics Denmark, 2016).

These rising healthcare costs and rehabilitation visits are of increasing concerns for various populations that are prone to injuries and hospital visits. The visually impaired are at higher risk for physical injuries, such as fractures due to falls, compared to the fully sighted population. This increases their chances of being put into a rehabilitation program. In a study of 76 elderly participants with various degrees of visual impairment, Wood *et al.* (2011) found a positive correlation between the degree of visual impairment and falling. Those who were visually impaired were almost twice as likely to experience a fall as opposed to the fully-sighted elderly. Legood, Scuffham, and Cryer (2002) found similar statistics, reporting that the visually impaired were 1.3 to 1.9 times more likely to have a hip fracture, an injury that often requires rehabilitation. This study found the visually impaired were at greater risk of pedestrian injuries, including automobile and bicycle accidents. In addition, children with visual impairment were four times more likely to be injured than their fully-sighted peers (Legood *et al.*, 2002). Due to the increased risk of injury of the visually impaired, it is essential that rehabilitation programs do not ignore visual impairment when addressing physical injuries.

Self-Rehabilitation: A potential solution to rising healthcare costs

Healthcare professionals facilitate the majority of current rehabilitation programs. This directed care contributes to high treatment costs (Wagner *et al.*, 2011). In a six-week study performed in England, Taylor and colleagues (2006) analyzed the costs of home-based cardiac rehabilitation and hospital-based rehabilitation methods (Taylor *et al*., 2006). The hospital-based rehabilitation included services from a specialist nurse, physiotherapist or exercise therapist, and an assistant clinical psychologist who attended eight to ten sessions of treatment. The hourly cost of the physiotherapist and staff nurse were £38 (54 USD) and £32 (45.77 USD), respectively (Taylor *et al*., 2006). Other significant costs for hospital-based rehabilitation include patient travel costs, which were estimated at £0.60 (0.86 USD) per mile of travel from the patient’s home to the hospital (Taylor *et al*., 2006). Healthcare and patient expenses can be reduced by decreasing the time patients stay in hospitals or reducing staff travelling costs. Another cost-reduction strategy is to implement rehabilitation methods that require less involvement from healthcare professionals and focus on treatments that can be executed individually.

These financial issues can be addressed with alternative approaches to rehabilitation, such as self-rehabilitation. The concept of self-rehabilitation has changed over the last few decades. In the past, it has described support groups, workshops and seminars, or independent symptom monitoring. In 2009, the World Health Organization defined self-rehabilitation as “the ability of individuals, families and communities to promote health, prevent disease, and maintain health and to cope with illness and disability with or without the support of a health-care provider” (Barlow, 2010). This definition emphasizes the ability of citizens to direct their own care without the assistance of a specialist healthcare provider.

One promising method of self-rehabilitation is the use of assistive technology. Assistive technology (AT) is defined as “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities” (Scherer, 2005). These devices can be as simple as a magnifying glass or an alarm clock, but due to the complexity of some injuries and illnesses, more sophisticated solutions are sometimes necessary.

For example, in 2009, a team of engineers and medical professionals in Taiwan developed a wearable sensor network that could measure the range of motion of a patient and report the data via Bluetooth to the patient’s smartphone (Pan, 2013). The data recorded by the sensors can be reviewed by both the patient and the physiotherapist to ensure that the exercises are performed as intended. Patients who suffer injuries are typically assigned stretching regimens to complete regularly at home, but patients often fail to perform these stretches properly or forget to do them all together. This sensor technology could be employed to a wide variety of individuals, including the visually impaired, to allow physiotherapists to review patients' movements to ensure they are performing exercises correctly (Pan, 2013).

The ARM Guide is another example of assistive technology used in rehabilitation. Developed by a team from Kagawa University in Japan, the robotic exoskeleton is worn around the arm and is used to either support the user's motion or add resistance to improve muscle function (Song, 2001). Both modes are useful for rehabilitating a patient with impaired motor function. The device is ambient, meaning it does not require direct interaction or operation, and therefore, can be used at home without regular professional consultation.

Self-rehabilitation extends beyond physical recovery programs. Rabbitt, Kazdin, and Scassellati (2015) conducted a literature review of the use of socially assistive robotics (SAR) in several healthcare applications, which provide companionship, coaching, and motivation. This study concluded that SAR technologies can be used as an additive tool in therapy with specially trained professionals, rather than an overall replacement (Rabbitt, Kazdin, & Scassellati, 2015). These robots aid through social interaction and recognition of certain behaviors. Görer, Salah, and Akın (2013) analyzed an SAR robot used to assist the elderly with exercise. A physiotherapist programmed the robot to mimic exercise movements in a patient's home to encourage him or her to exercise. Overall, patients agreed that these robots were helpful, with an average rating of 3.625/5 on the Likert Scale measuring psychometric effects (Görer, Salah, & Akın, 2013).

To lessen the symptoms of neurological impairments, Dobkin (2007) studied the use of brain-computer interfaces to strengthen a patient's neuron function through repetition and increased independence by allowing patients to complete more tasks through this interface (Dobkin, 2007). Aziz *et al.* (2015) developed a robotic technology that recognizes anxiety and engages individuals in a supportive way to alleviate their symptoms. These studies demonstrate that self-rehabilitation technology can address multiple areas within the rehabilitation sector, allowing for a comprehensive solution as opposed to technologies that only address musculoskeletal injuries.

Table 1 summarizes existing self-rehabilitation technologies. While the methods of each program varies, each strategy offers a promising solution to increasing rehabilitation costs.

Table 1: Comparison of Existing Physical Rehabilitation Technologies

Rehabilitation Method	Disability/Injury Addressed	Key Characteristics
Robot Therapy	Upper extremity disabilities	Patient individually uses robotic technology
Assistive-Robotic Group Technology	Upper extremity disabilities	Group therapy sessions, robotic technology
At-Home Stretches	Upper extremity disabilities	Uses easily accessible materials, no technologies
Brain-Computer Interface	Neurological	Complete tasks independently
Socially Assistive Robots	Mental/Neurological	Provides social support, motivation
ARM Guide	Upper extremity disabilities	Patient individually uses technology, at-home exercises
Sensor Network	Musculoskeletal injuries	Detects movements, allows for monitoring of exercises
Tele-Rehabilitation	Variable	Video conference call with physiotherapist

Self-rehabilitation strategies also alleviate some of the social and personal stigmas associated with facilitated rehabilitation methods. Loss of privacy and dignity are two negative side effects associated with traditional rehabilitation and physiotherapy. Embarrassment or frustration from a lack of physical function can result in clashes between patients and healthcare practitioners over goals and activities (Stabell & Naden, 2006). Older adults value feelings of dignity and independence and have found that these feelings are often infringed upon in a hospital setting (Webster & Bryan, 2008). In a review of articles analyzing self-rehabilitation strategies in cancer patients by van Weert and colleagues (2008), self-rehabilitation was found to improve dignity among patients and promote feelings of independence. Transitioning away from methods that require dependence on health professionals could increase the autonomy of patients.

In addition to increasing patient independence, self-rehabilitation can reduce the high costs associated with current rehabilitation programs. In a study of three different rehabilitation methods, Wagner *et al.* (2011) found that adding robotic therapy in addition to usual care reduced total delivery care. The total cost averaged 140 USD for the robot therapy group and 218 USD for the intensive therapy group. The intensive therapy group participated in a treatment plan similar in intensity, frequency, and movement to the robot therapy with assistance of a physiotherapist rather than a robotic device. Study authors concluded that while these results reflected cost-benefits of self-rehabilitation, further work is needed to assess cost reduction offered by other robotic self-rehabilitation methods.

Technology used for self-rehabilitation alleviates healthcare costs by reducing the amount of time with healthcare professionals. In examining the use of assistive technology in disabled elderly, Hoenig, Taylor, and Sloan (2003), found that those who used assistive technology required an average of 4.1 fewer hours of personal assistance per week than those who did not use technology. Self-rehabilitation group therapy sessions have been established to further reduce time with healthcare professionals. Imms *et al.* (2015) established robot-assisted group therapy (RAGT) and compared it to individual therapy (IT) for upper arm injuries. Throughout the four-week study, the patients who only received IT completed two 30 minute sessions of therapy per work day. The patients receiving RAGT and IT completed 30 minutes per day of IT in addition to attending a RAGT sessions for 30 minutes per day. The annual cost for RAGT was 12,000 USD less than the individual arm therapy. Rehabilitation methods that incorporate at-home treatments with group sessions and a physiotherapist allow for further reduction of costs by reducing the time a healthcare professional is needed throughout the treatment and allowing for multiple treatments to occur at a singular time.

The indirect costs of rehabilitation methods cannot be overlooked, as these contribute to the overall costs on the individual and healthcare system. Self-rehabilitation reduces the financial weight of some of these indirect costs, such as recovery time and transportation, alleviating some of the burden on the healthcare sector. Not only does self-rehabilitation reduce the time with healthcare professionals, it can also improve recovery time, allowing individuals to save money by returning to work sooner. In interviews with nurses, Singleton (2000) identified that a common perception of self-care is that it reduces recovery time. One nurse was quoted saying “[patients] recuperate a lot faster when they’re able to do it for themselves” (Singleton, 2000). In a report on tele-rehabilitation, through which a physiotherapist or nurse uses video calls to instruct a rehabilitation session while the patient is still at home, Burdea (2002) reported a reduction in the length of sessions. An average tele-rehabilitation session was found to last 20 to 25 minutes as compared to 30 to 60 minutes for an in-home visit, with additional time for travel. This reduction in time caused the cost of one session with a nurse to drop from 75 USD to 30 USD (Burdea, 2002). Implementing self-rehabilitation exercises for upper limb injuries in Benin, Natta (2015) quantified the results using a Box and Block test, a type of rehabilitation assessment for upper limb functionality. Participants’ test scores increased by 32%, indicating that over the two-week study, the functionality and dexterity of the injured limb improved significantly (Natta, 2015). Patients improved the functionality and dexterity of their injured arm faster than those who participated in traditional rehabilitation. This self-rehabilitation program enabled successful physical recovery without travelling to medical facilities as well as improved recovery time. The reduction in recovery time and travel is beneficial in reducing costs associated with rehabilitation.

Self-rehabilitation reduces the need to travel to a medical facility, potentially saving an individual significant money on transportation costs. Transportation to a healthcare facility can add additional financial and physical strain on a patient. Self-rehabilitation methods reduce the need to travel to a healthcare facility as often, reducing the cost on the individual patient. Wagner *et al.* (2011) included transportation costs in the final analysis, which resulted in the robotic therapy costing less than the group that did not use these technologies despite higher initial delivery costs. In semi-structured interviews with 24 stroke victims, Logan, Dyas, and Gladman (2004) found that the cost of transportation deterred some individuals from attending rehabilitation at a remote facility. Alleviating the need for transportation to a medical facility reduces some of the financial burden on the individual during his or her rehabilitation period.

Debating the Potential of Self-Rehabilitation Strategies

There are many self-rehabilitation products available and motivations to pursue these strategies, but more exploration of applicability is needed. The push towards home-based care and self-reliance is dependent on the fact that the participants are capable of performing these actions independently and accommodations may need to be made in order to include individuals who are not self-reliant.

Self-rehabilitation relies on the ability of the patient to learn the prescribed exercises and to perform them correctly. Programs that rely on written and photographic instructions limit engagement of individuals with cognitive or physical disabilities (Browder, Wakeman, Spooner, & Algozzine, 2006). In a study of a mixed facilitated and self-rehabilitation strategy to improve the balance of visually impaired older adults, exercises were first introduced by a physiotherapist before sending patients home to routinely perform the exercises on their own (Cheung, Au, Lam, & Jones, 2008). It was concluded that this method of instruction, combining facilitated treatment with self-rehabilitation, effectively encouraged patients to complete the prescribed exercises successfully. Participants who performed at-home exercises had an increase of 9.4% on the Berg Balance Scale and an improved time on the timed up-and-go test, measuring balance and ability to stand up and walk quickly. There was no statistical improvement in the patients who did not perform these at-home exercises (Cheung *et al.,* 2008). These were simple exercises, but with more complicated technologies and exercises, continuous feedback and instructions may be necessary and must be accessible for patients.

While there is a wide range of assistive technologies available, and new devices being developed all the time, assistive technology is not always a perfect solution. Every patient is different, so devices do not work as well on some patients as they do on others. Devices are incapable of adapting to the patient’s needs as he or she improves, which can mean the device becomes less effective throughout the recovery process. By nature, assistive technology encourages reliance, not development. For some patients, this can cause them to feel less confident or independent. This reliance can also leave a patient vulnerable if the device breaks or malfunctions (UNC, n.d).

Many patients are also hesitant to adopt assistive technology. This has been especially observed among elderly patients, who often require more thorough training to use assistive devices and can quickly become frustrated as a result. If the device is unwieldy or too complex, many patients do not even try to adapt (Elliot, 1992). Even if the patient adopts a prescribed device initially, he or she may not use it for as long as it should be used. Patients may abandon their assistive device because it does not fit their lifestyle or environment, they may feel like it is no longer necessary, or they may feel embarrassed due to social stigmas (Gitlin, 1995). As many as 75% of assistive technology devices are abandoned within three years (UNC, n.d). Researchers have found that integrating assistive technology into the lives of elderly patients is much easier if the instructor is already familiar to the patient, and if the instructor explains the device to the family of the patient as well. Patience and positivity also help to prevent the patient from getting frustrated in the early stages of training (Elliot, 1992).

Even if a technology meets an individual's needs, it will only have positive results if the patient is adherent. Integration into one's lifestyle is important for adherence to self-rehabilitation programs. If a device is seen as a burden, then it decreases the likelihood that it will be used. Satariano and McAuley (2003) studied the determinants of exercise in older adults and found that adherence was reduced due to limited self-efficacy, fatigue, forgetfulness, and scheduling. Furthermore, an individual's belief that he or she can complete an exercise will influence his or her choice to participate and continue a self-rehabilitation program. Poortaghi (2013) found a positive correlation between home-based rehabilitation and increased reported self-efficacy. The participation in self-rehabilitation is likely to increase one's self-efficacy, improving the likelihood of one staying with the exercise program. In a qualitative study of visually impaired individuals participating in mobility training, Brouwer (2008) found that fear of obstacles and falling reduced the participants' independence and social interactions. As such, in order to promote adherence, a self-rehabilitation program must emphasize and improve an individual's confidence in his or her physical ability and in the potential positive outcomes.

Unique considerations need to be made when implementing self-rehabilitation for the visually impaired. One major consideration is mental health with regards to depression. Depression is characterized by feelings of sadness and hopelessness (Fried & Nesse, 2015). Increased depression leads to lowered self-efficacy, which presents a challenge for successful self-rehabilitation (Arnstein, Caudill, Mandle, Norris, & Beasley, 1999). A study was conducted by Evans, Fletcher, and Wormald (2007) to demonstrate potential links between visual impairment in the elderly and depression. The study was done with 13,900 patients, 75 years and older, from 49 different family practices in Great Britain. A randomized screening rated the patient's depression on the Geriatric Depression Scale (GDS). The results of this screening showed that 13.5% of the visually impaired patients scored high enough on the scale to qualify as depressed, with only 4.6% of the sighted patients screening as depressed (Evans, Fletcher, & Wormald, 2007). In order to have successful self-rehabilitation programs for the visually impaired, this susceptibility to depression needs to be considered.

One possible solution is to include services for depression in a rehabilitation program. A study by Horowitz, Reinhardt, and Boerner (2005) examined the effects of rehabilitation on depression in 95 visually impaired patients over two years. The study provided participants with several services, in addition to rehabilitation, with the goal of assessing how each service affected depression. Throughout the program, the amount of patients exhibiting severe depression symptoms decreased by 75% (Horowitz, Reinhardt, & Boerner, 2005). Counseling services were identified as a large contributor to this decrease. Using such a method to decrease instances of depression can help improve and maintain a patient's self-efficacy and lead to more successful self-rehabilitation.

Although depression can be addressed through the addition of counseling services, as part of the rehabilitation process, the stigma surrounding assistive technology can still limit its use in independent self-care. This stigma, if not addressed, can increase isolation as patients feel technological aids draw negative attention to their disability (Gitlin, Luborsky, & Schemm, 1998). Analyzing the reactions of non-disabled individuals as well as users of assistive technology, Shinohara and Wobbrock (2016) concluded that a technology's form can impact one's self-efficacy. Poor and unaesthetic technologies mark individuals as social deviants and negatively impact their social interactions (Shinohara & Wobbrack, 2016). Even in an individual's own home, feelings of insecurity and stigmatization can affect the use of a device. In a literature review of different factors influencing assistive technology use, Parette and Scherer (2004) found that social acceptability is integral to device usage, even in the context of familial relationships. Within his or her own home, an individual can still feel as if an assistive technology makes them an outcast or a burden, decreasing self-confidence and use of the device depending on how unusual or out-of-place the device appears. An individual user's social patterns within the context of using self-rehabilitation technology must be taken into account throughout the design process in order to increase use and social interactions.

While beneficial in reducing time spent traveling and the difficulty of travel when physically impaired, self-rehabilitation increases feelings of social isolation, which is already high among disabled individuals (La Grow, 2009). This stems from self-rehabilitation reducing the frequency of travel to facilitated rehabilitation sessions and subsequent interaction with others. Disabled individuals express a need to participate in society but have difficulties doing so given the required support needed for transport (Hersh, Johnson, & Keating 2015). For example, a study of deaf-blind patients found that those who joined social organizations, connecting them with people with similar disabilities, experienced less social isolation (Hersh *et al.*, 2015). Meeting with others in similar situations helped participants feel connected with others, while not worrying about negative attention due to the social stigma of their disability. Social interaction should be considered an important component of rehabilitation programs, and would be beneficial to integrate into self-rehabilitation programs for the visually impaired.

Due to a wide range of disabilities and needs, individualization of assisted technology is required for success with patients. In a previous project sponsored by the DAB, Hill, Raymond, and Yeung (2013) developed a series of criteria to evaluate assisted living technology to determine if a device was appropriate for a specific patient. These assessment criteria included functionality and reliability, impact on user, safety and security, cost and benefits, feedback and control, and user rights. This criterion was ranked on a scale by the user or buyer of the device to determine if it met the needs of the patient. The study concluded that due to individual needs, abilities, and goals, one specific device cannot accommodate all these variables. Fuhrer, Jutai, Scherer, and DeRuyter (2003) developed a framework upon which to base assessment of devices with the stipulation that individual models must be created for specific device types. According to consumers and rehabilitation providers, the best results will be obtained by properly matching a device to an individual based on his or her capabilities, needs, and expectations (Scherer, 2005). These studies acknowledge the need to develop adaptable self-rehabilitation technologies that can be individualized.

In order to promote the implementation of self-rehabilitation technologies there must be a comprehensive assessment system to analyze the appropriateness of such technology in individual situations. A common method of evaluating assistive technology, including self-rehabilitation devices is use of the Human Activity Assistive Technology (HAAT) model to conceptualize the integration of assistive technologies into a user’s environment and activity. A user’s cognitive, physical, and emotional abilities are analyzed, along with the specific self-care activities that must be performed and the assistive technologies available, within the context of the injury to assess the best technology for that patient’s specific needs (Oishi, Mitchell, Van der Loos, & Machiel, 2010). Applying the HAAT model, Giesbrecht (2013) analyzed various studies finding that these concepts were applicable to self-rehabilitation but are often complex and lack clarity leading to poor analysis of assistive technology. Lenker and Paquet (2003) reviewed six different conceptual models for determining the outcomes of assistive technology use. The various models all had drawbacks and benefits, but each model is designed to match a device to an individual's needs and environment. In terms of assessing the functional outcome of self-rehabilitation technologies, there is a lack of standardization in measuring success (Skinner & Turner-Stokes, 2006). Haigh *et al*. (2001) in their review of outcome measurements in physical medicine found that in Europe there was significant heterogeneity throughout the use of rehabilitation measures even across one specific injury.

Given that self-rehabilitation technologies for the visually impaired would have to address at least two disabilities, the injury and the visual impairment, clear and detailed assessment methods analyzing the use of these technologies must be implemented to establish the impact of such technologies. These assessments must allow for determination of the benefits and drawbacks of a self-rehabilitation device for the use by a specific individual. Based on these difficulties, a list of necessary characteristics for a self-rehabilitation program to be successful was developed (Table 2).

Table 2: Successful Characteristics of Self-Rehabilitation Program

Characteristic	Description
Cost	Expenses related to device delivery, maintenance, etc.
Time	Length of exercises, time to recovery
Safety	Device must not pose harm to patient
Feedback/Accessibility	Must interact with patient. For example, a visually impaired individual may need audio feedback as opposed to visual feedback
Social Implications	Feelings of isolation or independence, acceptance of technology, interactions with others
Effectiveness	Restoration of injury, efficient recovery time
User Impact	Personal opinions on device, integration into lifestyle
Appearance	Appears “normal”, does not draw attention to disability

These criteria include important considerations such as cost, safety, feedback, and social implications. In order for a self-rehabilitation program to be an appropriate replacement for facilitated rehabilitation, it must address these characteristics in such a way that it proves beneficial over current methods. The availability of self-rehabilitation devices that will address these characteristics must be identified in order to pursue self-rehabilitation as a common healthcare strategy.

Methodology

Current assessments of self-rehabilitation indicate that while new technologies offer a promising solution to address concerns about healthcare costs and delivery, there remain uncertainties with regards to implementation and accessibility. This project was intended to assist the Danish Association of the Blind to determine how to implement at-home rehabilitation programs for people with visual impairment by assessing self-rehabilitation technologies within Danish municipalities. The following objectives guided this project:

1. Evaluate healthcare infrastructure in municipalities throughout Denmark.
2. Explore existing home-based rehabilitation methods and technologies.
3. Evaluate potential implementation methods for these devices/treatments for visually impaired patients.

Evaluate healthcare infrastructure in municipalities

While there is a push for more self-reliant healthcare solutions, the programs and services used throughout Denmark vary between municipalities. In order to explore the best self-rehabilitation devices, our team had to first understand how the healthcare system in Denmark is structured and how rehabilitation services are distributed.

Discussions with government officials and advocacy groups involved in healthcare policy formation aided in understanding the structure of municipalities and regions. This provided us with a basis to start our research into different self-rehabilitation programs and services. Our team posed questions in a semi-structured interview to a Copenhagen home-care project manager, Daniel Fragtrup. Sample questions are listed in appendix A.

Further evaluation and explanation of the healthcare infrastructure was acquired through unstructured interviews with the DAB members involved in the creation of this project including John Heilbrunn and Hans Rasmussen. As the DAB is involved in municipalities throughout Denmark, these discussions provided us with information about which municipalities to research further based on the varying resources throughout different municipalities. Consultants that work with the DAB to aid members in the application process for assistive technologies were interviewed in a semi-structured interview format. These individuals, Mette Pederson, Janni Hammershøi, and Helle Riley, were asked questions regarding the structure of healthcare throughout municipalities. See appendix A for our interview questions for these consultants.

Explore existing home-based rehabilitation technologies

Due to the push for at-home rehabilitation in Denmark, new technologies are currently being developed and put into use but do not accommodate for visually impaired patients. In order to understand which technologies could be applicable for the visually impaired, our team explored what is available for use and what is still being developed. This was done by conducting semi-structured interviews with developers of rehabilitation technology, and a site visit to the Aalborg welfare technology showroom.

Discussions with technology developers were used to collect information on the most current types of rehabilitation technology available. To further our understanding of the technologies, we conducted a site visit to a welfare technology showroom in Aalborg and identified current rehabilitation technologies. An employee at the company MITII Development, which produces a rehabilitation technology utilizing Kinect, was interviewed to learn more about this specific technology. See appendix B for our interview questions. Email communication with employees of FysioMeter, a company that developed a rehabilitation technology using a Wii Fit Balance Board, provided our group with more specific information about this device and potential adaptations to make it more accessible to the visually impaired. In addition, our team interviewed Berit Rask, an employee in the municipality of Gentofte, who worked on the development and evaluation of two rehabilitation technologies, ICURA and Virtual Training. This information was used to analyze how these technologies currently operate and the benefits and drawbacks of each technology. Our team learned what is necessary to develop technology that accommodates the specific needs of a patient or patient group through these interviews and site visit. This information allowed the team to make recommendations of which companies the DAB should collaborate with, and strategies for identifying new promising technologies for use by a visually impaired individual.

Evaluate implementation methods for devices and treatments

Our final objective was to evaluate strategies to implement self-rehabilitation methods and devices within municipalities throughout Denmark. Through semi-structured interviews with the DAB consultants, we gained insight on how some municipalities are successfully implementing self-rehabilitation technology. The interviews with consultants allowed our team to focus on the municipalities that have successful self-rehabilitation programs and make recommendations accordingly. The interview questions for the consultants can be viewed in appendix A.

Our team met with a political consultant, Jeppe Kerchoffs, who works at Dansk Handicapp Forbund, an advocacy group for all individuals with disabilities. This interview was used to ask about health technologies for individuals with disabilities and gain more information into the process through which individuals can obtain these technologies. Sample questions are listed in Appendix A. Our team also met with Carsten Jørgensen, an employee at a regional communication center who helps with implementing new assistive technologies into individuals' homes. This meeting, sample questions listed in Appendix A, led to a discussion of individuals' resistance to new technologies and the best methods of implementing new technologies into individuals' homes. A meeting with Hans Jørgen Wiberg, creator of the application Be My Eyes, included questions related the development of technologies usable by the visually impaired and the process of getting such technologies into the hands of end users. See Appendix B for sample questions.

To understand the logistics of prescribing the available at-home rehabilitation technology we conducted semi-structured interviews with Lene Van der Keur, a visually impaired physiotherapist. This allowed our team to gain insights into the perceptions of self- and at-home rehabilitation technologies from a physiotherapist's perspective to understand how this may affect the implementation process. See appendix C for interview questions for the physiotherapist.

Through our interviews with rehabilitation technology developers, our team further learned how municipalities acquire devices for patients and the approximate cost of these technologies. Discussions with these individuals helped us understand how municipalities know which devices to purchase. This helped us make recommendations to the DAB on how to promote awareness of self-rehabilitation technologies.

Interview Logistics

All interviews began with an introduction, followed by a request for consent for the conversation to be recorded. In addition to the voice recorder, one team member took notes throughout the interview. Another team member facilitated the interview, loosely adhering to the predetermined questions but allowing the conversation to progress naturally. The other team members supported the facilitator by asking follow up questions or any of the predetermined questions the facilitator overlooked.

Results

Technologies

After conducting interviews and visiting the Aalborg Rehabilitation Technology Showcase, our team identified several self-rehabilitation technologies used in different municipalities throughout Denmark and other parts of the world. Each of these technologies, described below, have varying degrees of functionality and accessibility and have different approaches to facilitate at-home rehabilitation.

FysioMeter

Figure 3: FysioMeter strength exercise (FysioMeter n.d.)

The FysioMeter uses a Wii Balance Board to test strength, balance, and reaction time. The strength exercise is pictured in figure 3 where the patient sits with the board strapped to his or her feet via a harness worn around the waist. The patient pushes his or her feet against the board and the board measures how much force the patient is exerting.

Figure 4: FysioMeter strength exercise (FysioMeter n.d.)

For the balance exercise, a patient simply stands on the board for a period of time. During that time, the board detects how the patient distributes his or her weight and how much he or she shifts. These changes in balance are recorded by the device and this information can be displayed on the computer.

A patient can test his or her reaction time by placing the board on a table or desk in front of him or her. A color will flash on the left side or the right side of a computer screen, and the patient must tap the board on the corresponding side as quickly as possible. The time it takes for the patient to touch the board and the number of mistakes are all recorded.

All of the data collected from these exercises are recorded and saved in a chart that can be printed or emailed for review. The exercises are simple and easy to understand, and the data produced is comprehensive and informative. Physiotherapists can use FysioMeter to monitor muscular development remotely. The device is portable, lightweight and designed to be run on a home computer.

One concern with this device is the setup procedure required for the strength exercise. It may be challenging for a physically injured patient to put on the harness correctly and set up the rest of the hardware, and this process would only be more difficult if the patient was visually impaired. The strength exercise would likely require additional training in order for a visually impaired patient to operate the device independently.

Another potential issue with this device is the initial cost. In its current form, the cost for one unit is 25000 DKK, approximately 3800 USD. This includes the harness, hardware mount, software, and license, but does *not* include the actual Wii Balance Board itself. In addition, renewing the license for this device costs an additional 2500 DKK (400 USD) per year. This price point could be a deterrent for less wealthy municipalities, who may instead invest in more affordable alternatives.

ICURA

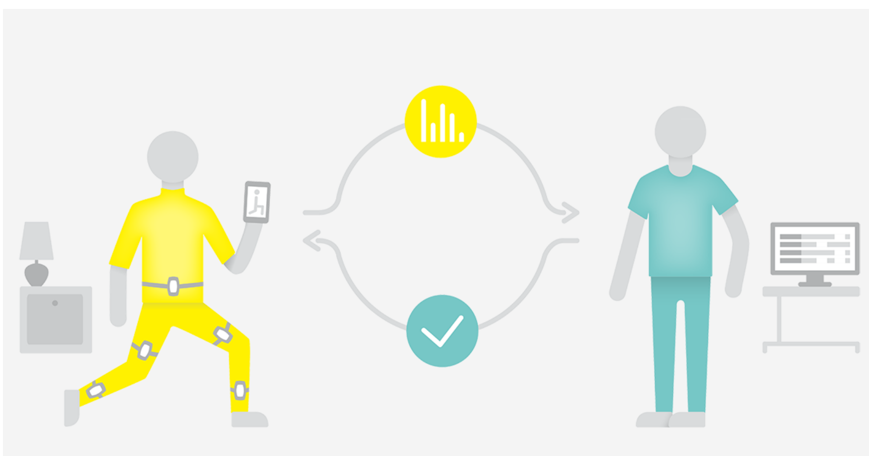

Figure 5: ICURA: Connection between patient at home and physiotherapist (ICURA, n.d.)

ICURA is a sensor based product that utilizes a smartphone application to allow physiotherapists to monitor patients' at-home exercise programs. Motion sensors on the patient's body detect movements and are used to monitor the quantity and quality of the exercises being performed. The sensors are connected to a mobile application used to guide the patient through the exercises and provide immediate feedback on the quality of his or her training. Patients can use this information to track their progress over time. The smartphone application encrypts and sends the data to a physiotherapist for expert review. A physiotherapist can monitor the data received to ensure the exercises are being performed correctly at home and adjust a patient's program based on individual needs such as changing the difficulty of the training program, as represented in figure 4. ICURA contains a bank with a variety of exercises that can be tailored to fit the individual needs of a patient. This database allows physiotherapists to upload new exercises as they are developed (ICURA, n.d.).

ICURA is currently being used in the municipality of Gentofte but has never been used by an individual who is visually impaired. It was implemented in the municipality after a randomized control study of 270 patients indicated that the sensors measured movements more accurately than physiotherapists' observations. Evaluation of ICURA showed that this training could be done up to five times faster and save 200 DKK (30 USD) per study (Rask, 2015). ICURA is a relatively new technology that is currently still being developed to improve its features. It was designed for Samsung Galaxy phones and as of now is not accessible for individuals to download on their own phone. Instead, they receive a phone containing solely the ICURA application for their training. ICURA was designed for rehabilitation after knee and hip replacement, but has the potential to be adapted to a wider range of injuries once the technology has been developed further. There is also an ICURA Activity application that works on the same principle but only uses one sensor to monitor day to day activity. This is not used for specific rehabilitation but rather monitoring everyday movements to ensure an individual is getting adequate exercise.

MITTI

Figure 6: MITII training (Gloria Mundi Care, n.d.)

Move It To Improve It (MITII) is a rehabilitation technology introduced to our team by Ditte Dangaard of MITII Development. MITII was designed for patients with Cerebral Palsy in need of neurorehabilitation (MITII, n.d.). As shown in figure 5, tasks are displayed on a screen and are to be completed by movements done by the patient. The movements are recognized with Microsoft Kinect technology and are tracked for review by a health professional. This training is done in the home of the patient but data from the sessions are automatically sent to a physiotherapist to be analyzed. This allows for tracking of the patient's progress and adjustment of the program as needed. These tasks are described as cognitive and are used to improve the strength of the patient as well as neuroplasticity.

MITII is currently being used in 15 municipalities by 40 people with a wide age range. To use this device a municipality can purchase a 52 week license and will be responsible for distribution, or a citizen can buy it privately. If bought privately MITII workers will teach the patient how to use the program and be responsible for adjustments as opposed to a municipality worker. The use of this device does reduce patient to physiotherapist one on one time by allowing the physiotherapist to check the data for only 20 minutes a week to adjust the program. There is also a survey sent out after 14 weeks to gauge the patient's view on the progression of his or her goals. There is no other direct contact with the patient beyond this. This also reduces travel time for the patient. With both the private and public methods of purchase, price has slowed the growth of this technology (Christensen, Personal Communication, March 29, 2016).

Virtual Training

Figure 7: Virtual Training Pro with Microsoft Kinect Camera (Welfare Denmark, n.d.)

A similar technology to MITII that our team found is called Virtual Training. This device uses a Microsoft Kinect technology, or a computer webcam in certain versions, to track and analyze a patient's movements while he or she completes prescribed exercises. Live exercise data are sent digitally to a physiotherapist, who can then review the patient's performance and even conduct a video conversation when necessary. The video communication platform allows for instant feedback from physiotherapists, who can also modify the prescribed exercise during an exercise session. Virtual Training transmits data between patients and physiotherapists through the mobile network, as opposed to using an internet connection that similar technologies use (Welfare Denmark ApS, n.d.).

Patients are given a computer in addition to the Microsoft Kinect device, on which therapists can remotely install custom rehabilitation exercises. On the computer screen, a sighted patient can watch his or her movements while also watching a video of a therapist demonstrating the exercise as a reference, as seen in figure 7. Therapists can track the progress of the patient, while also knowing if the patient missed any of the assigned exercise sessions (Welfare Denmark ApS, n.d.).

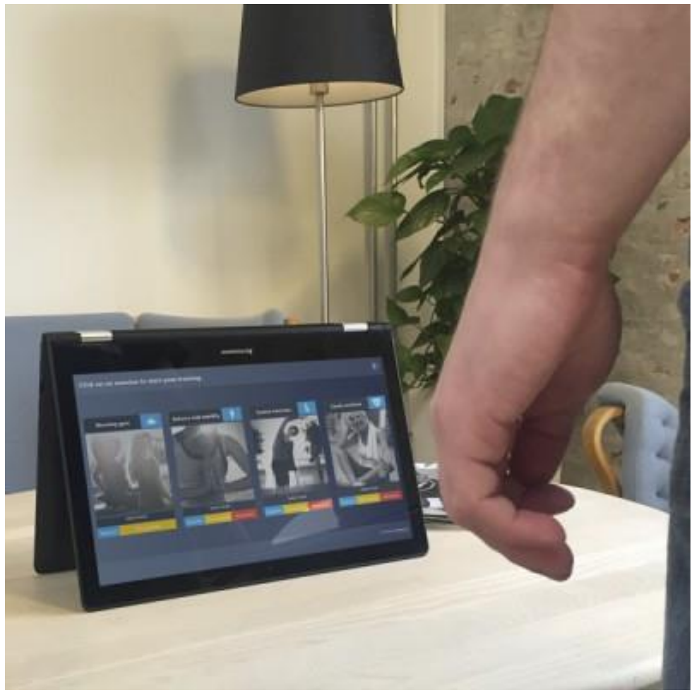

Figure 8: Virtual Training STD with predefined exercises (Welfare Denmark, n.d)

There are three models of Virtual Training: STD, Light and Pro, varying in complexity and features. The STD has four pre-defined rehabilitation programs, each equipped with three difficulties: beginner, intermediate and advanced, as shown in figure 8. While this version does not record the patient movements, the device is still used as a tool for completing exercises at home. The Light version is slightly more advanced using a webcam to send results to a physiotherapist. The Virtual Training Pro includes the live feedback feature and provides advanced data to the therapist (Welfare Denmark ApS, n.d.).

While many patients have successfully used Virtual Training for their at-home rehabilitation, others have experienced various reliability issues. Developers claim that using the mobile network is a major benefit to using Virtual Training, but patients often have difficulty connecting to the mobile network in Denmark. Without a proper connection to the mobile network, the program takes a long time to load on the computer and the patient and physiotherapist are unable to communicate (Rask, Personal Communication, April 18, 2016).

The installation process for Virtual Training is both complicated and expensive. To install the device, a technician must travel to the patient's home and manually set up the computer screen and Kinect technology. A municipality must have additional, specialized staffing to implement such a device. These costs would be in addition to the monthly license, which ranges between 70 and 140 Euro (approximately 80 USD and 160 USD) (Rask, Personal Communication, April 18, 2016).

Many patients who have used this device are displeased with the size of the equipment, complaining that the computer screen is too large. Virtual Training can be difficult to use in a smaller home because the patient must be standing two meters away from the Kinect camera for the camera to capture his or her full movements. If patients do not have enough space to complete their exercises, they may be more resistant to using the device (Rask, Personal Communication, April 18, 2016).

Physiotherapists have also demonstrated resistance towards prescribing this device to patients. The Microsoft Kinect camera is unable to precisely track movements from patients, making it difficult for physiotherapists to properly analyze the performance of their patients. Another common concern is that the interface for physiotherapists is very complex. Virtual Training contains a database with a wide variety of exercises, which can be useful when administering exercise but many physiotherapists found they were spending an excessive amount of time selecting exercises, as opposed to having direct patient interactions (Rask, Personal Communication, April 18, 2016).

Despite the above drawbacks, this device has been growing in popularity. As of January 2016, 350,000 exercises have been completed by patients using Virtual Training technology throughout 30 municipalities in Denmark.

Bandcizer

Figure 9: Bandcizer sensor attached on resistance band (Bandcizer, n.d.)

Bandcizer is a sensor technology that uses a resistance band to track exercises. The sensor is attached to a resistance band, as shown in figure 9, and is connected to a smartphone application via Bluetooth. The user interface of the application consists of three components including an administrative part to aid in planning exercise programs, a calendar to show the training schedule, and a tutorial section to demonstrate chosen exercises through videos and texts. Data collected from the sensor are sent both to the patient's smartphone and to a physiotherapist for review, allowing the patient to receive immediate feedback on the quality of the exercises. Developed within the Odense municipality, this product underwent a year-long scientific study in 2015 about the quality of the product and its programs, although results are not yet available.

TREX Rehabilitation Systems

TREX REHAB a company based out of Mount Pleasant, South Carolina that has developed "High Intensity Stretching" devices. This line of technologies, called Total

Range Exerciser (TREX), was designed specifically to break down scar-tissue and help patients improve his or her range of motion through at-home rehabilitation.

Figure 10: TREX Shoulder Rehab System (MedRep Resources, 2016).

The first device is called the TREX Shoulder Rehab System, as shown in figure 10, which uses a tri-actuator design. This unique device helps patients conduct exercises in all six ranges of motion (ROM). More specifically, this device was developed to treat patients who suffer from frozen shoulder and limited range of motion. Using this device along with regular physiotherapy visits can help patients avoid procedures including manipulation under anesthesia and lysis of adhesions. By presetting the ROM on the TREX technology, patients can prevent further injury during their rehabilitation, even if he or she is using the device alone. The device is simple and easy to use through a remote controller. A patient can precisely adjust the movement of the machine and their arm to make gradual movements at his or her own pace. TREX Shoulder Rehab is also equipped with a variety of safety features including seat belts and a chair that can be repositioned between exercises (MedRep Resources, 2016).

Figure 11: TREX Knee Rehab System (MedRep Resources, 2016).

TREX Knee Rehab System provides a convenient opportunity for patients to complete rehabilitation exercises at home. This device focuses on improving the ROM for a patient's knee through extension and flexion exercises. Similar to the Shoulder Rehab System, the TREX Knee Rehab System can help patients avoid corrective surgery and will address conditions such as arthrofibrosis and limited range of motion. Patients can move their knee with up to 140 degrees of flexion and -20 degrees of hyper-extension. The Knee Rehab System is also operated with a remote controller. Other unique aspects of the device are that the patient can prevent "tibial translation" and "outward bending of the knee" when conducting flexion, allowing for proper anatomical alignment throughout movements (MedRep Resources, 2016).

TREX has a patent pending for software and firmware for SMART-REHAB, which would allow the rehabilitation units to be connected to the internet. Patients and physiotherapists will be able to use a phone application, Bluetooth, and Wi-Fi technology to exchange information. Healthcare professionals would access this information to ensure patients are complying with his or her exercise plan and track his or her progress. A web portal will allow therapists to set device end range limits and goals for the patients (TREX REHAB, 2014).

MOVER

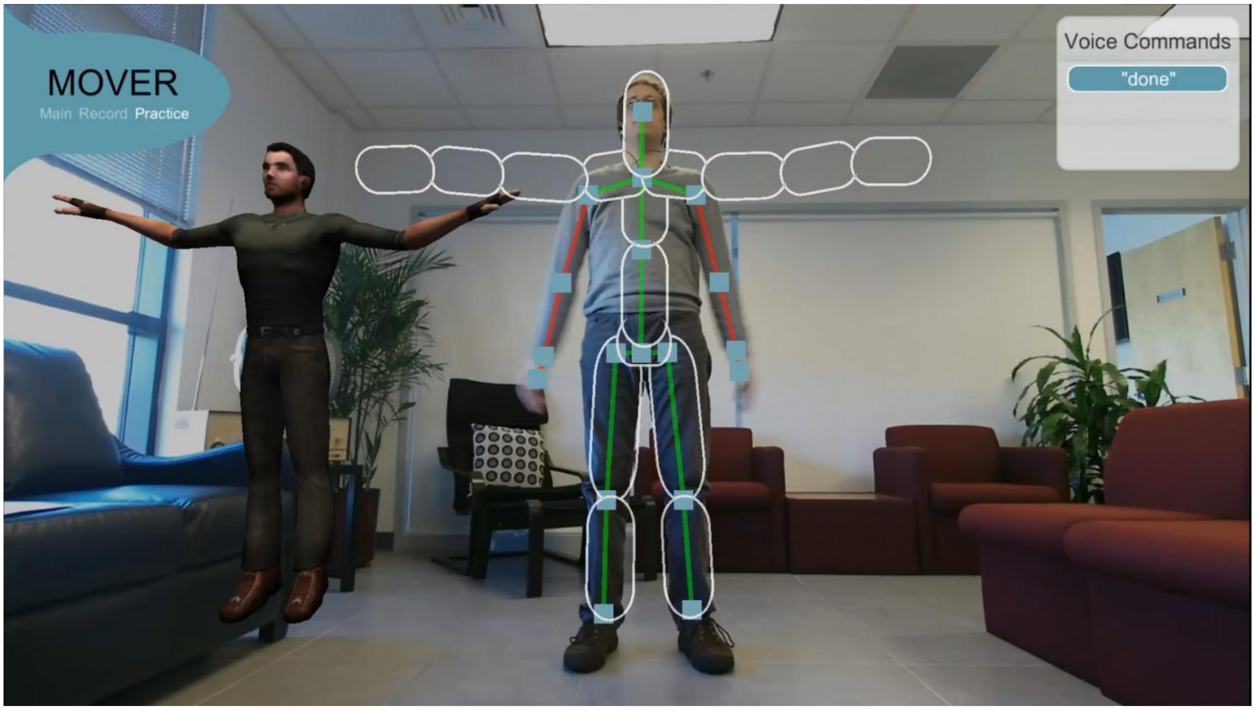

Figure 12: On-screen example of the MOVER in use (phys.org, 2015)

Charles River Analytics, an R&D company based out of Cambridge, Massachusetts, has developed an at-home rehabilitation device to support physically injured soldiers with head trauma. The device displays the profile of a human performing various stretches on a screen and uses a camera to detect the patient copying the exercise. If the patient moves outside the profile on the screen, the device will inform the user so he or she can make appropriate corrections. The exercise regimen can be customized by the user's physiotherapist as needed, and the device is able to record the patient's performance automatically.

Implementation Issues

Healthcare technology for private use is controlled by one of two systems. The social system manages assisted living devices, such as a walker or speech to text programs. In order to receive a device that falls into this category, a patient must send an application for the device to their local municipality. Officials at the municipality will then review the application, and approve or reject the application based on whether or not they deem the device necessary for the patient. There is no specified time frame in which officials are required to make a decision about an application, so while some patients may hear back from the municipality in a few weeks, others may not hear back for several months, forcing them to acquire the device directly from the technology developer and pay out of pocket.

The hospital system manages healthcare technology, such as ICURA. In order to receive a device which falls into this category, patients are prescribed the device as part of their rehabilitation program by the physiotherapist. The hospital makes a decision upon release of the patient as to whether or not the patient requires rehabilitation within the municipality. If the patient requires rehabilitation, it is up to the physiotherapist to decide if the device is a good fit for the patient’s rehabilitation program. Some healthcare professionals are hesitant to do this, as they may distrust the accuracy of the device or simply be uninterested in modifying their practice.

Additionally, for a physiotherapist to prescribe a self-rehabilitation technology it must be owned by the municipality. Many municipalities are not willing to invest in buying new technologies to offer their citizens due to the upfront costs. While most at-home technologies offer long term cost benefits, municipalities are often short sighted with their budget and will not make long term investments (Mette Pederson, personal communication, April 7th, 2016). Even if a municipality is willing to adopt and invest in new technologies there is a lack of knowledge about their existence. Through various interviews, it became clear that many individuals within the healthcare sector were only aware of one if any technologies.

Discussion

Self-rehabilitation technologies offer a new approach to physiotherapy that reduces costs and can be more effective than traditional rehabilitation methods. This is a relatively new and growing field, and there are not many existing technologies currently in place. All the technologies that do exist would need further development and adaptation for an individual with visual impairment to be able to use them. Some of the devices are more easily adaptable than others to accommodate for visual impairment. Even as new technologies arise, implementation of these technologies into different municipalities' rehabilitation programs and patients' homes is another issue for a variety of reasons including resistance to change and lack of knowledge.

Evaluation of Technologies

FysioMeter

In its current form, the FysioMeter is operated through software on a personal computer. Selecting exercises, reviewing charts, and printing or emailing results is all done through on-screen icons and buttons. Additionally, the reaction time exercise requires the user to see the left or right side of the screen flash green, indicating which side of the board to strike with their hand. Both of these aspects of the device make the FysioMeter extremely difficult for a visually impaired patient to use. The addition of a voice control system could allow a patient to navigate the menus and select exercises with spoken commands. Similarly, the visual cues in the reaction time exercise could be replaced with audio cues, for example simply the words “right” and “left”. If the device were to be adapted in this way, the FyisoMeter would be a great piece of technology for physiotherapists to treat their blind patients.

ICURA

As it is now, ICURA is dependent on visual cues as exercises are shown through videos and pictures, and results represented in graphs. In addition, this application currently only works on Samsung Galaxy phones, which do not provide the same level of accessibility features as iOS phones for someone who is visually impaired. If the application was translated to iOS software, or Android phones became more accessible, it would allow for individuals who are visually impaired to more easily operate the application through voice feedback and control. The sensors allow for immediate audio feedback on the quality of exercises, which is beneficial for any patient, including the visually impaired, to be corrected immediately ensuring quality training at home. The application also includes a messaging feature to allow patients to contact their physiotherapists through written communication if further instruction is needed. Thus transferring the ICURA application to a more accessible mobile platform or including voice control within the application itself would make it a promising technology to be used by an individual who is visually impaired.

MITII

Progressing with MITII for the eventual use with visually impaired patients would be very difficult due to the dependency on visual aids. The tasks designed for this technology are displayed on a screen and are dependent upon visual cues that cannot easily be replaced by other sensory stimuli. The programs are also not helpful for regaining strength after getting an injury or surgery. The Kinect movement tracking is precise but does not accurately track movement of the entire body. It is not reliable enough to accurately determine if stretches or exercises are being done with the correct form (Christensen, Personal Communication, March 29, 2106). These features make this technology unusable for a visually impaired patient in need of the type of at-home rehabilitation described by this project.

Virtual Training

Virtual Training has been a successful tool for self-rehabilitation for many patients, but it is expensive to implement, often lacks reliability, and receives resistance from physiotherapists. Due to the additional staffing and transportation costs, Virtual Training also does not provide a cost-saving solution to at-home rehabilitation. The device is often not supported by physiotherapists due to the lack of precision with the Microsoft Kinect camera and the complicated web interface (Rask, Personal Communication, April 18, 2016).

This device primarily uses videos from physiotherapists and other visual cues to help patients complete their rehabilitation exercises, making it difficult for a blind or visually impaired patient to use. If Virtual Training developers implemented features such as voice control and additional audio features, the device may be useful to a visually impaired patient.

Despite the potential modifications to this device, our team is recommending that the Danish Association of the Blind does not pursue Virtual Training as a self-rehabilitation technology for visually impaired patients.

Bandcizer

There was limited research completed on Bandcizer as a result of time constraints and an inability to make contact with product developers. More information will be available on the technology once the results from an ongoing study are released. Bandcizer appears to be a promising technology for someone who is visually impaired. The sensor technology can connect to iOS devices, which would make it accessible through audio feedback and voice control. The biggest drawback with the device for a visually impaired individual is that the exercises are shown through videos. If the exercises were demonstrated to the patient beforehand or were simple enough to be described solely through text, this technology would be a good candidate to be used by a rehabilitation patient who is visually impaired.

TREX Rehab Systems

The TREX Shoulder and Knee Rehab Systems provide simple solutions to at-home rehabilitation. These devices minimize the use of visual cues, and only require the patient to operate a handheld remote control, indicating that the device is accessible for someone who is visually impaired. The ability for healthcare professionals to remotely pre-set the device end range limits allows for custom rehabilitation exercises and minimizes the responsibility of the patient (TREX REHAB, 2014).

However, a patient would still have to seat themselves and strap their leg or arm into the equipment, which may be difficult depending on the complexity of the devices. The device does not provide instant feedback to the user, however TREX's SMART-REHAB technology allows the physiotherapist to track a patient's progress and compliance and the patient could be contacted separately, as needed.

Unfortunately, knowledge about these products is limited due to time constraints and the inability to contact the developers of this product. With the proper training, this device may be an accessible rehabilitation solution for someone who is visually impaired.

MOVER

What sets this device apart from other digital exercise technology is that the MOVER system already includes voice command functionality, and there are future plans to give the MOVER the ability to provide instructions and encouragement verbally. This type of functionality suggests that the device has the potential to be accessible for visually impaired patients.

The device has been “successfully tested by researchers” and is currently being used in clinical trials at the Spaulding Rehabilitation Hospital (phys.org, 2015). Unfortunately, due to time constraints, discussion beyond initial contact with the developers was not possible.

MOVER and all the other technologies found are summarized in Table 3.

Table 3: Comparison of Devices

Product	Technology	Injuries	Benefits	Drawbacks
Fysiometer	Wii Balance Board, computer monitor	Not specified	Self-monitoring	Relies on visual cues
ICURA	Sensors, Smartphone	Hip and knee replacement	Self-monitoring, live feedback, high accuracy	Relies on visual cues
MITII	Microsoft Kinect camera, computer monitor	Cerebral Palsy	Self-monitoring	Lacks precision, relies on visual cues
Virtual Training	Microsoft Kinect camera, computer webcam, computer screen, mobile network	Balance, stability, cardio, other	Self-monitoring, live feedback	High installation costs, equipment is large, poor network reliability, lacks precision, relies on visual cues
Bandcizer	Sensors, Bluetooth, smartphone	Knee, hip, and shoulder	Self-monitoring, live feedback, easy setup	Relies on visual cues, still in development
TREX Rehab Systems	Robotic equipment, remote controller, Bluetooth, smartphone	Shoulder, knee	Safety, precision, easy to use	Still in development, lacks motivational features
MOVER	Home computer and webcam	Not specified	Self-monitoring, live-feedback verbal control	Partially relies on visual cues, still in development

Evaluation of Implementation Process

Some of the biggest reasons physiotherapists are resistant to adopting these self-rehabilitation technologies is they are unaware of the benefits of such technologies and are apprehensive about technology overtaking their role. Self-rehabilitation technologies are not designed to replace physiotherapists but rather aid in a more effective recovery process. Successful technologies provide a monitoring system that allow physiotherapists to constantly review their patients' exercises and adjust them as needed. This allows the physiotherapists to maintain control over their patients' programs. In order for self-rehabilitation to be more prevalent, physiotherapists must be convinced of the benefits and accuracies of such products. Extensive evaluation studies such as in the case of ICURA will be beneficial in providing concrete evidence of the dependability of such devices. Physiotherapists must not only be educated on the benefits of the technologies but also the capabilities of the visually impaired. If a physiotherapist does not have experience rehabilitating someone who is visually impaired, they can be ignorant in assigning programs that are either too simple or too complex to properly help the patient. Therefore, a major obstacle in implementing at-home rehabilitation technologies is gaining the support of physiotherapists, as they are the ones in charge of prescribing such technologies.

The resistance from municipalities comes from both costs and lack of knowledge. Wealthier municipalities are more likely to be able and willing to adopt new technologies than municipalities with less resources. Loaning technologies between municipalities would help make self-rehabilitation devices more accessible throughout Denmark, even in municipalities with minimal resources. This would also expose more municipalities to at-home rehabilitation technologies and the benefits they provide, making it more likely for these municipalities to adopt technologies of their own. As of now, municipalities are usually made aware of devices when a technology developer chooses to approach them about their product. This limits the municipality's knowledge of technologies to the devices they are presented with and any they are able to find on their own. This method does not always result in the best results, and a more centralized information center of existing technologies could help identify the best technologies for different needs.

Recommendations

Collaborate with ICURA to develop adaptations to the device to accommodate blind and visually-impaired patients

Our team recommends that the Danish Association of the Blind advocates for further development of ICURA rehabilitation technology. This device is currently only used for rehabilitation after hip and knee replacement surgeries and among that specific population, 70% of patients qualify to use the product. If the adaptations discussed in our conclusions were implemented, this technology could be made available to a more diverse population, including the blind and visually impaired.

Collaborate with FysioMeter to develop adaptations to the device to accommodate blind and visually-impaired patients

Our team recommends that the Danish Association of the Blind advocates for further development of FysioMeter technology. Based on our discussion with the developers, there is a high potential to modify the device to accommodate the blind and visually impaired. A customized version of FysioMeter would be available with a minimum purchase of ten devices. The DAB may be able to ask surrounding municipalities to purchase these devices if the cost is too great.

Establish contact with Bandcizer and discuss how the device can be made accessible to visually-impaired patients

Our team recommends the Danish Association of the Blind research further into Bandcizer. Based on our research, Bandcizer would be adaptable to visually impaired patients if exercises were taught in methods other than the videos currently used. Therefore, our team recommends the DAB pursues establishing contact with the

Bandcizer developers to investigate this technology further and initiate a discussion on potential adaptations to make it accessible to visually-impaired individuals.

Establish contact with TREX and discuss how the device can be made accessible to visually-impaired patients

Our team recommends that the DAB further research TREX Shoulder and Knee Rehab Systems. Unfortunately, the information on these rehabilitation solutions is very limited. The TREX technology provides a promising rehabilitation solution that could potentially be used by visually-impaired individuals. Therefore, our team recommends the DAB pursue further communication with TREX developers to discuss current developments and possible adaptations to make this technology accessible for the visually impaired.

Establish contact with MOVER and discuss how the device can be made accessible to visually-impaired patients

We recommend that the DAB investigate the MOVER. This device has already proven itself in various tests. It already has voice control functionality and actively verbally encourages the patient and tells him or her how to improve. The next step would be to discuss specific adaptations for the visually impaired and pricing with Charles River Analytics. If they are open to catering to the needs of the DAB, this would be a great technology for municipalities in Denmark to acquire.

Continue to research new technologies that have the potential to be made accessible to visually-impaired patients

In the continuing pursuit of new technologies, there are important characteristics of successful rehabilitation devices that must be taken into account. Our team recommends only pursuing technologies that have self-monitoring capabilities, as technologies that require constant attention from a physiotherapist such as video calls do not save time. In order for a technology to be beneficial it should have the capability to precisely monitor movements and provide feedback independently. Our team also recommends the Danish Association of the Blind looks outside of Denmark for rehabilitation technologies, as the small size of Denmark creates a very small market for specialized devices. Collaboration with other advocacy groups outside the country may be beneficial in advocating for more accessible technologies.

Unfortunately, since home-based rehabilitation technology is a fairly new field, there are virtually no devices currently available which are specifically designed to cater to the needs of the visually impaired. However, certain patient demographics face similar difficulties with rehabilitation as visually impaired patients. For example, patients with dementia may also struggle to regularly travel to a physiotherapist, or may struggle to remember what exercises they need to do or how to perform them properly. Instead of searching for devices that are specifically designed for the visually impaired, our team found it more effective to look for devices that were designed to accommodate the needs of different patient demographics that face similar challenges, and then consider potential adaptations to these devices that could make them blind accessible.

Improve patient and physiotherapist awareness about modern self-rehabilitation technologies

To ensure technologies are adopted and implemented, our team recommends advocating and sponsoring scientific studies to validate self-rehabilitation technologies, such as the study on ICURA completed by Berit Rask. Educating physiotherapists on self-rehabilitation technologies will help aid in the adoption of these technologies into practice. Using these studies will help convince physiotherapists to adopt such technologies. We also recommend an online database of available technology in each municipality so patients and healthcare professionals can easily see what their options are.

Conclusion

Our research has presented several outstanding self-rehabilitation technologies that can be adapted to accommodate the blind and visually impaired. All these technologies would need to be modified with voice feedback controls, audio cues, and other features to be successfully used by a visually impaired patient.

At-home rehabilitation technology is a very new area of research. There are few technologies available that are reliable, precise, and cost-effective, as well as accommodating to the visually impaired. As self-rehabilitation technology continues to advance in the coming years, the variety and accessibility of products will continue to improve and enhance patients’ rehabilitation experiences.

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Appendix A: Interview Questions for Government Officials/Consultants

Thank you for taking the time to see us today. Our names are John, Taryn, Michael, and Tori. We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews for a study to help make rehabilitation and treatment of physical injuries more accessible for patients with visual impairments.

Your participation in this interview is completely voluntary and you may withdraw at any time. Please remember that your answers will remain confidential. No names or identifying information will appear in our project reports or publications.

This is a collaborative project between the Danish Association of the Blind and WPI, and your participation is greatly appreciated.

We would like to ask you some questions about your experiences with physical rehabilitation. Would you be comfortable with us recording our conversation today?

Are you aware of any self-rehabilitation devices?
What are problems with integrating self-rehabilitation into current healthcare policies?
Would/Are self-rehabilitation devices subsidized by the government?

  - Is there any cost difference between these devices and standard physiotherapy devices?

Is there push within the government to move towards more self-reliant healthcare?

  - Are government officials aware of any special requirements of individuals with disabilities such as the visually impaired to use such programs?

How is payment for rehabilitation programs distributed between the municipalities, regions, and the state?
How variable are the rehabilitation devices between every municipality?

  - How do you ensure people are getting adequate care?

What is the process for acquiring a specific technology for individual use?

Appendix B: Developer Interview Questions

Thank you for taking the time to see us today. Our names are John, Taryn, Michael, and Tori. We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews for a study to help make rehabilitation and treatment of physical injuries more accessible for patients with visual impairments.

Your participation in this interview is completely voluntary and you may withdraw at any time. Please remember that your answers will remain confidential. No names or identifying information will appear in our project reports or publications.

This is a collaborative project between the Danish Association of the Blind and WPI, and your participation is greatly appreciated.

We would like to ask you some questions about your experiences with physical rehabilitation. Would you be comfortable with us recording our conversation today?

Could you describe what technologies you have or are working on regarding rehabilitation?
What technologies are currently in use?
    How widespread is the use of these technologies? How many municipalities are using them?
What are the challenges of creating a new medical device such as one for rehabilitation?
    What are the challenges in implementing such devices?
Do your devices provide feedback to the user?

Appendix C: Interview Questions for Physiotherapist

Thank you for taking the time to see us today. Our names are John, Taryn, Michael, and Tori. We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews for a study to help make rehabilitation and treatment of physical injuries more accessible for patients with visual impairments.

Your participation in this interview is completely voluntary and you may withdraw at any time. Please remember that your answers will remain confidential. No names or identifying information will appear in our project reports or publications.

This is a collaborative project between the Danish Association of the Blind and WPI, and your participation is greatly appreciated.

We would like to ask you some questions about your experiences with physical rehabilitation. Would you be comfortable with us recording our conversation today?

Are you aware of any self-rehabilitation devices or programs?

- How are these programs implemented in an individual's home?

How much freedom do you have when prescribing rehabilitation programs/devices?

- How many options are there?

What are the standard procedures? How strict are they?

How do you decide how to treat a patient with a disability that does not allow them to perform the recommended rehabilitation program/use the device?

How does the recovery time of a facilitated rehabilitation program compare to the recovery time of self-rehabilitation?

What shortcomings do you see in the system? What would you like to see changed?

How accessible is the established rehabilitation procedure for the blind/elderly?

- Have you worked with a patient who had a visual impairment?

What special accommodations have you made?

Do these sessions require additional time? (Why/ Why not?)

Have you ever utilized assistive robotic technology?

If so, how did it compare to other sessions where the technology was not used?

Have you ever conducted group therapy sessions?

- Was this easier or more difficult to manage than singular patients?
- How do you think this affected each individual’s rehabilitation success?