Designing Physical Telerehabilitation System for Patients with Multiple Sclerosis

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Abstract—**Physical rehabilitation positively affects clinical outcomes in multiple sclerosis (MS) however it is limited by delivery modes, cost and distance. Telemedicine approaches can potentially facilitate home-based rehabilitation however they were not systematically implemented for patients with MS. We developed a Home Automated Telemanagement (HAT) system for computer-guided management of patients with MS providing individualized instruction and monitoring of physical therapy exercise at patient homes. The HAT home unit runs on a netbook in the patient's home connected to a remote server via internet. The system questions the patient on their condition, gives detailed step by step exercise instructions, records their daily exercise log, and informs and quizzes the patient on their knowledge of multiple sclerosis. The exercise log is transmitted to the remote HAT server where it is analyzed using decision support algorithms to facilitate MS management. The exercise logs are available on-line for review by patient providers. Patient exercise regimen is determined by their physical therapist and can be updated on-line, keeping a personalized approach to disease management while taking advantage of the convenience the technology supplies. This telemanagement system has been successfully designed and implemented to optimize the care of patients with multiple sclerosis.**

Keywords-telerehabilitation; eHealth; multiple sclerosis

I. INTRODUCTION

Multiple sclerosis (MS) is a chronic debilitating disease of the central nervous system that may result in significant damage of the neuromuscular system, vision, and affective and cognitive functions [1]. Approximately 400,000 persons in the United States have MS [2]. Lifelong rehabilitation measures, along with medication treatment, are the major components of patient management [3–4]. Physical exercises positively affect patients' quality of life and their functional capacities [5–6]. Poor adherence to rehabilitation, limited patient education, and access to specialized care can be barriers to treatment [7–8]. Removing those barriers is an important step towards improving patient care for multiple sclerosis.

Current technology allows for remote information transfer in a variety of circumstances. Information can be easily transferred to and from a person's home through the existing telephone and internet infrastructures. Our goal was to design a telemanagement system for patient use in MS. This paper reports the success of design and implementation of the Home Automated Telemanagement (HAT) software in patients with MS. We describe the software and hardware used, website design, and overall interactions of the HAT system design.

II. SYSTEM DESIGN

The HAT system is based on Wagner's model of chronic disease care [9]. The HAT system supports the major components of this model including patient self-care, tailored education and counseling, individualized treatment plan, guideline-concordant decision support, comprehensive patient provider communication, and multidisciplinary care coordination [10-12]. Using this model, the HAT system has been successfully implemented and tested in various health conditions [13-17].

The HAT system consists of home unit, HAT server and clinician unit [18]. The previous applications utilized laptops, PDA, IVR, and cell phones for patient home units [19-22]. The HAT system for MS takes advantage of the current technology to provide patients with a convenient treatment plan and exercise regimen as well as enforcing adherence to rehabilitation through more frequent monitoring.

The home unit was developed using Visual Basic and runs on netbooks with Windows operating systems. Visual Basic is a programming language and development environment from Microsoft derived from the BASIC programming language. The language allows for quick development and has extended Microsoft Windows functionality for more complex projects. Visual Basic is also well supported by older operating systems, making it ideal for projects utilizing less expensive computers with limited system resources.

The patient home unit sends patient self-report information via internet to a HAT server running Windows 2008. A server running Internet Information Services (IIS) collects the patient's data and integrates it into a website to be accessed by the patient's physician and physical therapist. IIS is one of the most widely used web servers and provides a stable and widely compatible system for receiving and editing patient information.

The webpage was developed using Microsoft's .NET framework. This is a framework for developing dynamic websites which offers extensive built-in functionality and is supported by most browsers.

The patient home unit allows a patient to run a self-test and exercise program which asks the patient a series of symptom questions, instructs them on exercise routines,

records exercise completion and attempts, then questions and educates the patient on multiple sclerosis. The system then sends the symptom and exercise information to the server. Once a report has been sent to the server it can be viewed by the patient's physician through the MS HAT website.

The system is designed so that each patient has an individual exercise plan decided by their physical therapist. The exercise plan specifies a set of exercises chosen by their physical therapist to optimize treatment and can be reviewed on the laptop system and the website. Prior to beginning home unit use, a physical therapist creates the patient's exercise plan. The physical therapist chooses from a library of 47 predefined stretching and strengthening exercises, each with their own step by step instructions, illustration, safety tips, and instructional video. During the self-test the patient records how many times they completed each exercise, along with the number of attempts made. This allows the physician to determine which exercises are more challenging to the patient. The exercise plan can be updated through the website by the physical therapist and will update on the home system the next time it connects to the server or when the patient chooses the "Update Exercise Plan" from the main menu on the home unit. There are also general exercise safety tips as well as specific tips for each exercise designed to minimize the risk of injury during exercise. Information flow for the exercise plan can be seen in Fig. 1.
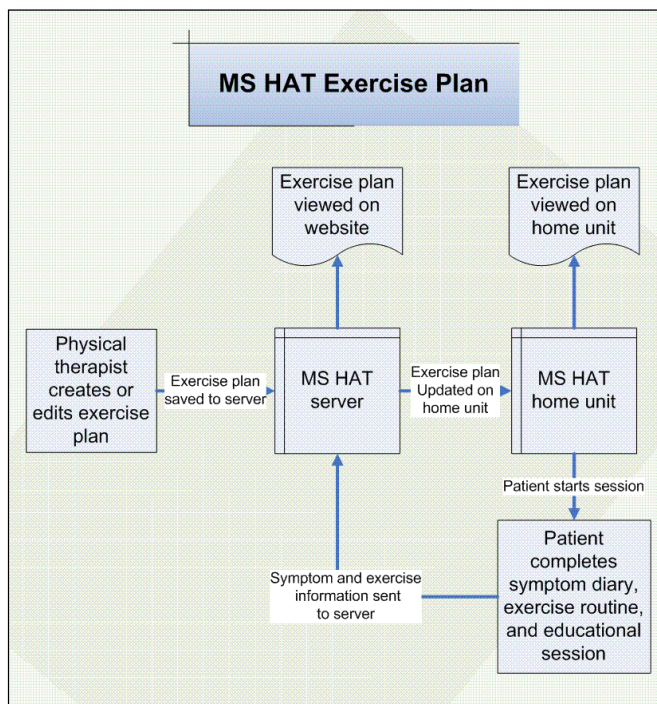

Fig. 1. Exercise plan information flow

III. RESULTS

The MS HAT system was successfully designed and implemented on low-cost touch-screen netbooks running Windows operating system. Information was successfully sent and received from a remote location to the server using

wireless internet. The website was successfully launched and provides full system functionality.

The patient home unit runs the MS HAT program when it starts up and the user can navigate through the menu using the enter, space, and backspace keys along with the arrow keys. These keys are marked clearly with their function to avoid any confusion. There is also the option of using a wireless keypad to navigate the program. The wireless keypad is clearly marked like the keyboard and allows the patient to navigate the different exercises without having to go back the unit and make selections between exercises or exercise steps. This functionality is especially important in MS where the patient's mobility may be limited.

The text is large and easy to read while all the instructions are kept simple. The program is designed to be simple enough for someone with no previous computer experience to use.

The home unit main menu options five different options. The first section is "Start Exercises". This portion of the program is broken into 3 parts, the symptom diary, the exercise plan, and the educational portion. This section begins with a self-testing portion where the patient answers a series of 16 questions pertaining to their multiple sclerosis. One of these questions is shown in Fig. 2.
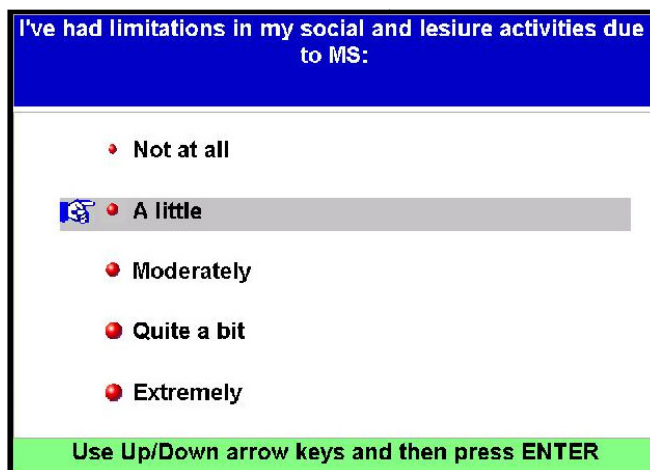

Fig. 2. Patient symptom diary question

The responses are used to gauge the overall health of the patient, as well as to raise flags when the patient may be experiencing multiple sclerosis symptoms that require attention and treatment.

After the self-test portion of the session, the patient enters the exercise portion of the session. First the patient is asked whether they would like to view general exercise safety tips, then the patient is presented with their specialized list of exercises. The patient can then navigate to any exercise on the list and select it. This brings the patient to a screen with a diagram of the exercise and step by step instructions. The screen also lists the amount of times the exercise is supposed to be completed as specified by a physician. This screen can be seen in Fig. 3.
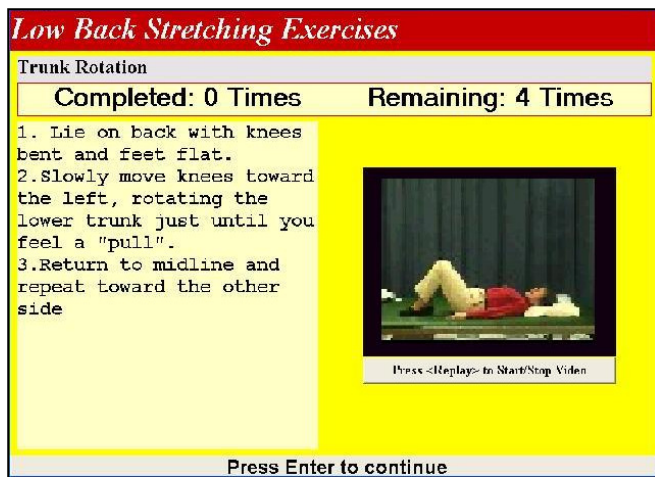
Fig. 3. Trunk rotation exercise instruction screen

If the patient still needs more instruction about the exercise, they can choose to view a video of an instructor giving detailed directions and performing the exercise.

Once the patient has completed the exercise to their satisfaction, they are questioned about the number of times they performed the exercise. If this number is equal to or more than the amount specified by the physician then the exercise is highlighted red in the exercise menu, otherwise it remains green, indicating it is not completed as seen in Fig. 4.
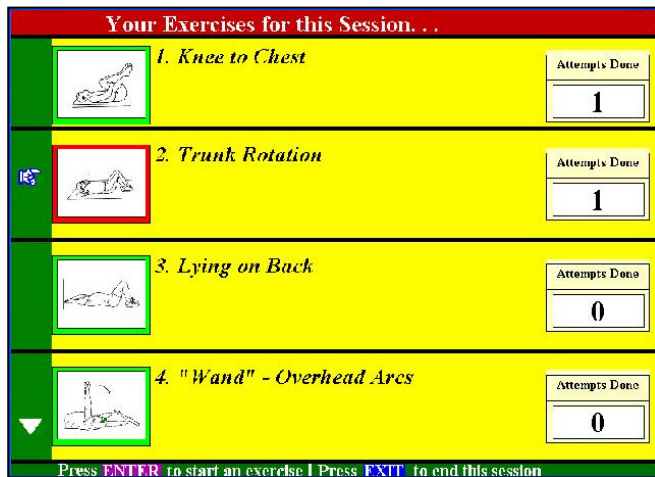

Fig. 4. Patient exercise list screen

The patient may leave the exercise screen at any time by hitting the key marked "Exit". If all exercises are not completed when the patient tries to exit they will be presented a dialog box telling them the exercises are not completed, asking for confirmation that they wish to exit to the main menu.

When the exercise portion is completed, the patient begins the education portion of the program. The patient is asked a question about MS and then shown an educational tip about the disease. Each question is based upon the tip given during the previous exercise session and if a question is answered wrong the tip for the question is repeated and the question is repeated the next time the session is completed.

Once the patient completes the educational portion, the program attempts to send the collected data to the server through the phone connection. If there is no connection or the data can not be sent to the server, the data is stored on the home unit and sent to the server the next time a successful connection is made.

From the main menu the patient may also review general exercise safety tips and view their prescribed exercises without having to start a self testing session. There are also options to check for an updated exercise plan and to shut down the system. The main menu is shown in Fig. 5.
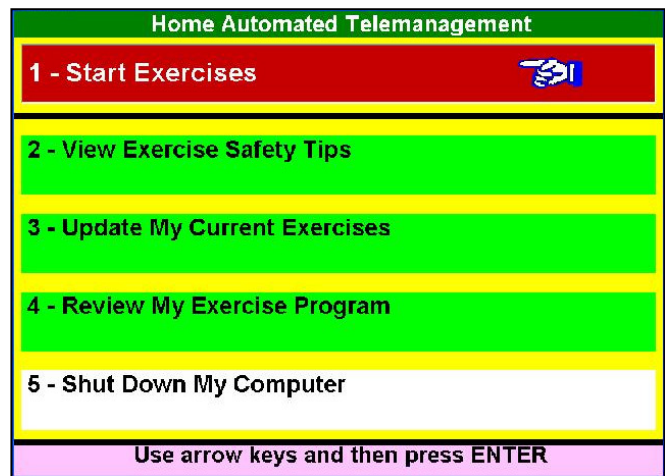

Fig. 5. MS HAT main menu

The MS HAT website is hosted on our servers and can be accessed by a patient's physical therapist using any computer with a web browser and an internet connection. The physical therapist can view and edit the patient's current exercise plan as seen in Fig. 6.

Fig. 6. Exercise editing on the website

The physical therapist can also change their exercise plan for the patient, send a message to the patient, record clinical notes, and view completed exercise data as shown in Fig. 7.

IV. DISCUSSION

The MS HAT system was pilot tested in patient's homes. The patient's response was positive and the system design shows great potential for providing multiple sclerosis patients better care. The system's ease of use and convenience can provide reluctant patients with an

alternative to frequent doctor visits as well as provide them with a strict and easy to follow exercise regimen for disease intervention. While face to face visits would still be important to the patient's care, allowing the patient to monitor their health frequently, educating them on their condition, and walking them through a tailored exercise routine will hopefully increase their awareness, quality of life, and rehabilitation adherence.

Patient Summary			Patient Name: Phone:	
Home Monitoring				
Exercise	**Attempts**	**Times**		
11/6/2006				
Knee to Chest	1	0		Details
Trunk Rotation	1	0		Details
Face-Lying over Pillow	1	0		Details
Seated	1	0		Details
One Joint (Iliopsoas)	1	0		Details
Passive - Seated with Towel Assist	1	0		Details
Calf Muscles: Gastroc Stretching-Standing	1	0		Details
"Wand" - Overhead Arcs	1	0		Details
"Wand" - Circles	1	0		Details
Wall-Sitting	1	0		Details

Figure 7. Exercise home monitoring on the website

The proposed system can be adapted for other chronic diseases such as chronic obstructive pulmonary disease [23] where the same principles have been applied to facilitate patient-centered care [24].

We are also looking toward expanding the HAT system to other electronic platforms [25-26]. Mobile computing is becoming smaller, faster, and cheaper, creating more potential environments for the HAT disease management system. Systems such as the Apple iPhone and mobile phones are rapidly becoming viable options for implementing HAT systems.

V. CONCLUSION

The HAT system is a viable platform to facilitate management of multiple sclerosis. This system can be expanded to support rehabilitation in other chronic cardiovascular, respiratory, and neurodegenerative conditions. Including means to monitor blood pressure, oxygen saturation and heart rate can improve safety of home exercise. Adding Kinect-like sensors may enhance user interface, exercise assessment, and data collection.

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