Project Title:	Patient Self Monitoring to Transfer Physical Therapy Exercise from Clinic to Home
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Project Period:	September 30, 2012 – March 31, 2014
Federal Project Officer:	Dr. Steve Bernstein
Supported by:	Agency for Healthcare Research and Quality PAR: HS08-269: Exploratory and Developmental Grant to Improve Health Care Quality through Health Information Technology (IT) (R21)
Grant Number:	R21 HS 021733

1. Abstract

Purpose: We developed an image-based electronic health record (IBEHR) to help patients adhere to prescribed physical therapy exercise, because adherence enhances functional recovery and relief from pain.

Scope: The IBEHR shows patients their exercise performance by recording an avatar when they exercise at home and comparing it with an avatar recorded of themselves exercising correctly in the clinic under their physical therapist (PT)'s supervision. The IBEHR reveals deviations from correct exercise form to guide patients in performing their exercise more correctly.

Methods: We aimed to develop the hardware and software for the IBEHR, perform alpha testing to measure the limits of accuracy of body tracking by the IBEHR, and then perform beta testing to verify that the user interface is easy to use by both PTs and patients. We then aimed to assess whether the IBEHR improves adherence in a randomized controlled study of 60 patients with anterior knee pain or anterior cruciate ligament (ACL) injury.

Results: The hardware and software for the IBEHR was developed. Alpha testing revealed gross inaccuracy in tracking lower extremity exercise. The clinical target was changed to shoulder injury because initial testing indicated that upper extremity exercise could be more accurately tracked. Alpha testing showed that the IBEHR measured change in shoulder angle between two arm positions with a bias of -1± 5° and with a 95% confidence interval between -2.2 and +0.3°; the error in measuring shoulder angle was -0.1 ± 3.2°; the precision in repeatedly measuring shoulder angle was 1°. On the beta test, one PT and three patients found the IBEHR to be easy to use.

Key Words: adherence, physical therapy, exercise, shoulder

Purpose: This project is for developing an image-based electronic health record (IBEHR) to give patients visual feedback on their adherence while performing exercise prescribed by their physical therapist (PT). The IBEHR generates an avatar of the patient performing an exercise at home so that the performance of each repetition of that exercise can be compared in real time with an avatar created in clinic of the patient him/herself performing the exercise correctly under the PT's supervision. The feedback shows the patient whether there is a significant deviation in his/her form and how to correct the deviation. The IBEHR records all of the patient's exercises performed at home for review by the PT at the next clinic visit. The recording informs the PT whether the patient adhered poorly to the prescribed exercise frequency or duration, performed the exercise incorrectly, or if a different exercise would be more beneficial.

Our Specific Aims are to:

- Develop the software for synchronizing the clinic and home avatars, aligning them, and measuring deviations.
- Perform alpha and beta testing. The alpha test measures the limits of accuracy of body tracking by the IBEHR. The beta test verifies that the user interface is easy to use by both PTs and patients.
- Assess the efficacy of the IBEHR to improve adherence in 60 patients with anterior knee pain or anterior cruciate ligament (ACL) injury.

Scope: The problem we address is that of poor patient adherence when patients are asked to exercise at home, transitioning away from the direct supervision of their physical therapist (PT). The rationale for this research is that adherence to home exercise is the most important factor in functional recovery. Studies have identified many factors that affect adherence, including personal factors such as barriers both perceived and encountered and feeling of helplessness, method of instruction, and follow through by the PT to provide feedback and encouragement. Adherence to exercise can refer to session frequency, e.g., per week; number of repetitions per session; correctness or accuracy with which the exercise is performed; and/or terminating the exercise prematurely. Most studies have focused on adherence to session frequency and duration, e.g. by motivating patients through computer games, but correctness of exercise has also been shown to impact patient outcome: that is, patients who reproduce exercises by themselves in the same manner as they performed them in front of the PT have better recovery of function and greater relief from pain. Conversely non-adherence not only leads to suboptimal clinical efficacy for the patient, but also increases healthcare costs both directly (due to additional PT visits) and indirectly (longer time away from work).

Attention to the transition of PT prescribed exercise from clinic to home is important for the following reasons:

1) Achieving adherence depends on feedback from the exercise prescriber, which patients typically only receive at clinic visits that may be weeks apart. Infrequent contact and minimal monitoring of patients' home exercises also makes it difficult for the physical therapist (PT) to determine why patients fail to recover as expected.

2) Current methods only assess correctness in the clinic, not in the home because they require observation by the health care provider or body sensors and monitoring and analysis equipment.

3) The IBEHR will enable home exercise feedback for all patient populations, not just for the wealthy who can afford a private trainer and for professional athletes and dancers and.

4) The proposed IBEHR leverages on the recent availability of inexpensive imaging technology to enable affordable electronic health records to be generated both in the clinic and at home to aid in monitoring the correctness of exercise at home and thereby facilitating the transition of care from the clinic.

The patient population who could benefit from the IBEHR is very large. Each year, more than 17 million patients are diagnosed with conditions that might benefit from physical therapy. According to the Centers for Disease Control, 3.5 million youth under age 14 and 5,250,000 adults suffer sports-related injuries each year. Physical therapy is used not only to facilitate recovery but also to prevent injury through focused training. For example, PTs work with K-12 students to avoid brachial plexus injury from heavy backpacks. Physical therapy is vital for the elderly to facilitate recovery from illness or injury. In 2008, 4,000,000 senior citizens received physical therapy, an increase of 44% from 2003. Medicare paid $4.76 billion for these services. As for children and younger adults, senior citizens could utilize the IBEHR to learn exercises for injury prevention, e.g. from falling. The tool can also be applied to help seniors maintain the activities of daily living, such as exercises for getting up from a chair. A third patient population comprises work-related injuries: 3 million occurred in 2010 resulting in 933,000 missed work days. Most, 69%, were injuries that might be prevented through better safety training -- ergonomic injuries and muscle sprains, strains, and tears – e.g, by PTs working with private companies and state and local governments to teach workers better safety practices. These patient populations are all stable except for rapidly growing Medicare population, which will rise from 40 million in 2010 or 13% to 55 million (16%) by 2020. Other patients who benefit from physical therapy are those who have lost function due to surgery, cancer treatment, accidents, or battlefield injury. In summary, the IBEHR enables more effective preventive care as well as rehabilitation to a wide spectrum of the population from children to seniors.

The IBEHR has the potential to reduce health care costs because improved compliance with PT may enhance functional recovery, reduce pain, and enable independence in senior citizens. The enhancement of functional recovery will also hasten return to work and improve worker productivity. If just 1% of the 3 million workers injured each year on the job, and 1% of the 5.25 million adults with sports related injuries return to work one day earlier, then already $24.25 million would be saved (assuming $300/day in wages and productivity).

Methods:

AIM #1. DEVELOP THE SOFTWARE FOR SYNCHRONIZING THE CLINIC AND HOME AVATARS, ALIGNING THEM, AND MEASURING DEVIATIONS.

We developed the software to record a person performing a motion, and then overlay the recorded motion onto a live performance of the same motion (Figure 1) which would be visualized on a computer screen. The IBEHR (Figure 1) creates a personal avatar of the patient as s/he performs an exercise correctly under

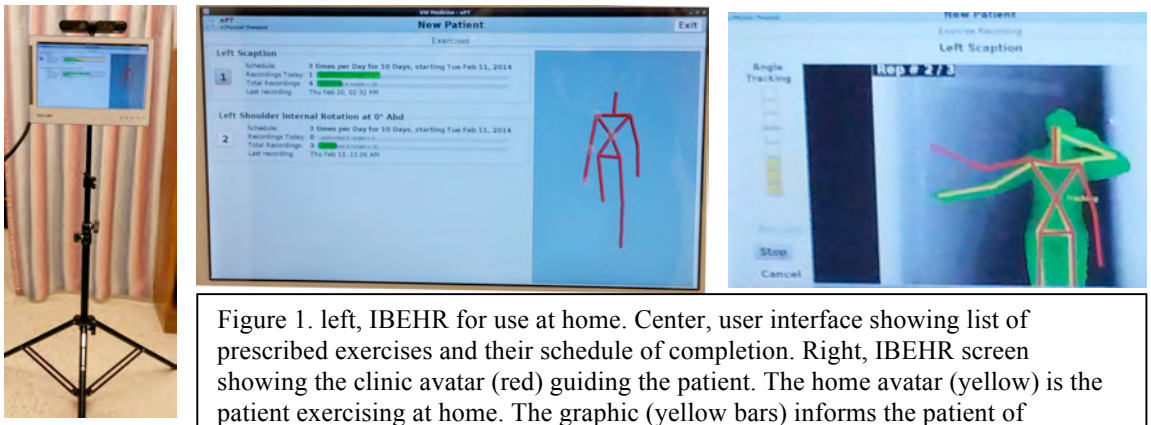
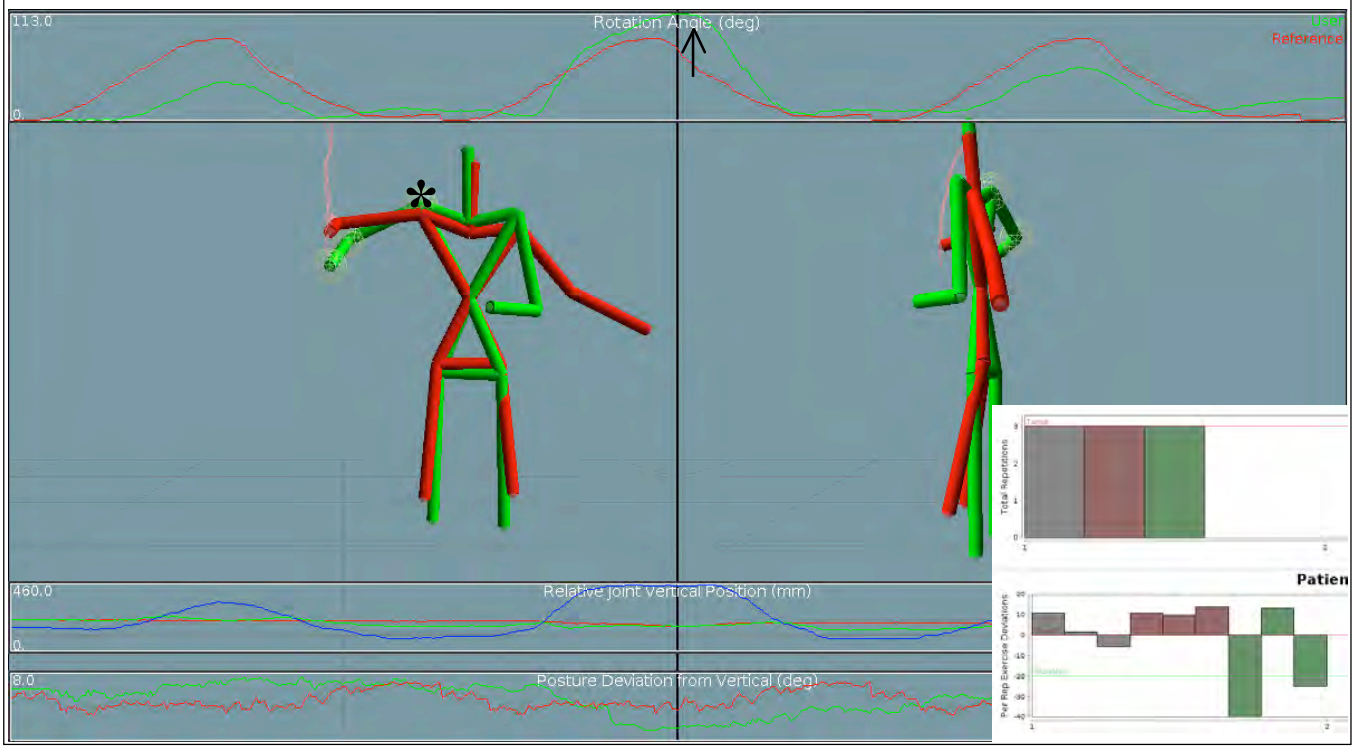


Figure 1. left, IBEHR for use at home. Center, user interface showing list of prescribed exercises and their schedule of completion. Right, IBEHR screen showing the clinic avatar (red) guiding the patient. The home avatar (yellow) is the patient exercising at home. The graphic (yellow bars) informs the patient of deviation in range of motion so that s/he can improve his/her exercise performance.

the direction of the PT in the clinic, the "guiding avatar." In the home, the patient watches him/herself on the EPR display while exercising. The IBEHR creates a new avatar of the patient in real time as s/he performs the exercise, the "home avatar." The two avatars are overlaid so that the patient can visually compare whether and where his/her home avatar deviates from the guiding avatar. When the two avatars superimpose, the exercise is being performed correctly.

The patient's exercises at home are recorded. When the patient returns to clinic, these recordings provide the PT with a record of the patient's adherence and show any problems that the patient may have encountered (Figure 2).

Fig.2 Report for PT. Recording showing (top) that the first and third repetitions of a right shoulder (*) exercise by the patient at home (green) had less rotation than when performed in clinic (red); the second rep had excessive rotation (arrow). Position and posture can also be monitored (graphs below). The report (inset) shows that at this session the patient performed three sets of 3 repetitions (upper bar chart). Correctness for each rep of the third set (this recording) is displayed in terms of the angle of deviation from exercise performed in clinic (green bars in lower bar chart: one bar/ rep).



AIM #2. PERFORM ALPHA AND BETA TESTING.

Alpha Testing: The accuracy of the IBEHR for tracking knee flexion was inadequate when measured. Hip flexion could not be measured either. Attempts to modify the software to improve accuracy were unsuccessful. Therefore the target patient population was changed from knee pain to shoulder pain. Alpha testing showed that the IBEHR measured change in shoulder angle between two arm positions with a bias of -1± 5° and with a 95% confidence interval between -2.2 and +0.3°; the error in measuring shoulder angle was -0.1 ± 3.2°; the precision in repeatedly measuring shoulder angle was 1°. On the basis of these test results, we proceeded with implementation of the IBEHR for shoulder pain, and developed an Exercise Library for shoulder pain in various medical conditions.

Beta Testing: The IBEHR user interface was tested by the PT (Mr. Aaron Kingsland) and by our co-investigator, Dr. O'Kane. The user interface was modified to implement their recommendations, and

passed a second test by Mr. Kingsland. The IBEHR was then tested on three patients with shoulder pain in clinic. Two observers (the PI and Mr. Kingsland) evaluated patients' ability to operate the IBEHR using a checklist: all three patients successfully set up the IBEHR hardware, operated the software, and recorded their exercise (two patients succeeded on the first try; one patient succeeded on the 2nd try). When surveyed regarding their feelings about the IBEHR, the patients indicated a high level of comfort (Table).

Question	strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree
I was comfortable having the camera record my body						XXX
I was able to tell from the home exercise guide when my motions were correct or not						XXX
I think that the home exercise guide can help me perform my exercise better					X	XX
The quality of the images was acceptable					X	XX
Seeing myself on the screen made exercise more enjoyable, tolerable, or fun			X	X		X
I would like to use this exercise guide at home				X	X	X
I would recommend this guide to others					XX	X

AIM # 3. ASSESS THE EFFICACY OF THE IBEHR TO IMPROVE ADHERENCE

The proposed clinical testing of the IBEHR was not performed because the grant term ended before it could be initiated.

CONCLUSIONS:

The results of this research demonstrate that the IBEHR is accurate at tracking exercise involving the upper extremity, but not of the lower extremity, when employing currently available technology. However this field is moving rapidly and since the completion of the study newer products have been announced that may make lower extremity tracking possible. The results of this research furthermore demonstrate a high level of acceptance of the IBEHR by both PT and patient.

SIGNIFICANCE:

These results are significant because the IBEHR is conceptually novel. Therefore its ready acceptance by clinicians and patients demonstrate the potential value of the IBEHR for helping patients transition from clinic to home based physical therapy exercise.

PUBLICATIONS:

None.