Proposed Design Approach for Interactive Feedback Technology Supports in Rehabilitation

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ABSTRACT

Despite the anticipated benefits associated with the use interactive feedback technology, the adoption of these technologies into clinical practice has not yet been widespread. Initial usability studies and anecdotal evidence suggests that interactive feedback technology supports are effective in rehabilitation, yet they don't seem to satisfy the needs or the expectations of clinicians and patients. This paper outlines a proposed approach to the design, development and selection of interactive feedback supports for use in rehabilitation. The proposed process comprises seven stages; 1) Understand the problem, 2) Identify the benefits that a technology support may offer, 3) Devise a modified care pathway, 4) Outline the design specification for an interactive technology support, 5) Ascertain whether other solutions exist, 6) Develop interactive feedback technology platform, 7) And finally evaluate. In this paper we outline this approach using orthopaedic rehabilitation as a specific example, however the same basic principles can be applied to many different rehabilitation groups.

Categories and Subject Descriptors

J.3 [**Computer Applications**]: Life and Medical Sciences – *Biology and genetics, Health, Medical information systems*.

General Terms

Management, Performance, Human Factors.

Keywords

Rehabilitation Exercise, Interactive Rehabilitation, Technology Supports, Adherence, Exercise Accuracy.

1. INTRODUCTION

Recent years have witnessed the development of a wide range of interactive feedback technologies that are designed to support and enhance rehabilitation. These technologies may result in improved rehabilitation exercise technique, increased patient motivation to perform rehabilitation exercises, improved adherence to exercise programmes, and improved patient satisfaction with rehabilitation. Preliminary research has outlined the efficacy of a number of technology platforms in rehabilitation [1-3].

However despite the suggested benefits, these technologies have not been widely implemented in practice, and are generally only in use in specialized rehabilitation clinics. The reason why they have not been utilised needs to be examined, however it appears that many platforms are not meeting the needs of both clinicians and patients, and therefore they cannot be integrated into treatment pathways. In this paper we are proposing a design process that seeks to deliver greater success in this field, by allowing interactive feedback technologies to be woven into rehabilitation care pathways. In this paper we will describe this process using orthopaedic rehabilitation as a specific example.

The proposed approach to the design, development and selection of interactive feedback technology supports for use in rehabilitation consists of seven stages;

- Understanding the specific clinical challenges to be addressed,
- Identify the potential benefits that a technology support may offer,
- Outline and devise a modified care pathway incorporating the interactive technology support,
- Outline a design specification for an interactive technology support,
- Review the existing state of the art solutions and determine whether an appropriate support already exists,
- If no appropriate support exists, develop an interactive technology support and evaluate its usability,
- Evaluate new care pathways incorporating the developed interactive technology support.

The remainder of this paper outlines this process in detail, using the challenges associated with orthopaedic rehabilitation as an example.

2. THE CHALLENGE OF ORTHOPAEDIC REHABILITATION

Chronic health conditions, such as osteoarthritis (OA) are placing a huge burden on global healthcare. Current worldwide estimates are that 10% of men and 18% of women over the age of 60 have symptomatic OA [4], and these figures can be anticipated to escalate in line with the world's increasing ageing population and the increasing obesity epidemic. Typical management of OA incudes a combination of lifestyle modifications, pain-reliving medications, as well as a tailored programme of rehabilitation exercises. High quality evidence from a number of reviews has demonstrated the benefits of exercise in OA [5-8]. However for patients with severe, end-stage joint degeneration, a total joint arthroplasty (TJA) is the only successful intervention.

Rehabilitation following TJA generally begins in the hospital and continues following hospital discharge in an outpatient clinic. A rapid increase in the number of TJAs being performed, limited staffing and resources, as well as the requirements for shorter hospital stays are greatly increasing the demand for outpatient rehabilitation. Meeting the demand for outpatient rehabilitation is difficult, with many patients thus performing a significant portion of their rehabilitation in their own home. Patients are often given a programme of rehabilitation exercises to do at home. However without the therapist present, patients often have difficulty interpreting the instructions for the exercises or can forget their therapist's specific instructions on how to perform the exercises accurately. As a result, many perform the exercises incorrectly and are unaware they are doing so until their next scheduled physiotherapy appointment. With incorrect biomechanical alignment during exercise, patients may not gain the full benefit of the exercise. Incorrect speed of movement and poor quality of movement can also have an impact on the efficacy of an exercise [9]. Although it has yet to be clearly demonstrated by a controlled experimental study, it is generally accepted that poor exercise technique can result in a poor outcome from therapy and can limit patient recovery [10], and with certain complex exercises, inaccuracy in exercise technique could potentially cause further injury. This can result in a delay in a patient's return to full physical function.

Additionally patient motivation to perform the exercises at home can be remarkably low, and thus adherence to a home exercise programme may also be a major limitation to home-based rehabilitation. The degree to which patients adhere to their home exercise therapy programme may influence the success of rehabilitation. Up to 65% of patients report being non adherent or partially adherent to their exercise programmes, with over 10% failing to complete their physiotherapy programmes [11]. In recognition of these limitations to home rehabilitation, clinicians are pursuing ways of motivating and supporting their patients to undertake their prescribed exercise routines in the correct manner.

3. THE POTENTIAL BENEFITS OF USING TECHNOLGY SUPPORTS IN REHABILITATION

Advances in technology have resulted in the development of a number of interactive technology platforms which are designed to support patients to overcome the challenges associated with home rehabilitation. These solutions seek to enhance home rehabilitation by guiding the patient through their rehabilitation programme, assisting the user to execute the exercises with accurate and precise technique. They also seek to increase the patient's motivation to perform their exercises and adhere to the exercise programme. Improving the accuracy of the exercise and adherence to an exercise programme may result in improved outcomes from rehabilitation programmes, and thus greater patient satisfaction. Using these platforms fosters a more patient-centered approach to rehabilitation, which may result in greater patient self-efficacy. Using technology supports in rehabilitation also provides clinicians with the opportunity to reinforce their clinical message when the patient has gone home, and allows the clinician to send motivational messages to their patients, encouraging them to engage with their rehabilitation programme. This may help strengthen the relationship between the therapist and the patient, and thus result in higher patient engagement with their rehabilitation programme. Ultimately these technology supports seek to enhance home rehabilitation and reduce the burden on the healthcare system.

4. A NEW MODEL OF CARE

Using an interactive feedback technology solution in home rehabilitation encourages the development of new pathways of care in rehabilitation. Interactive technology solutions are not designed to take the place of the clinician in rehabilitation, but instead they are designed to enhance home rehabilitation, and act as a supplement and to reinforce in-clinic rehabilitation. In orthopaedic rehabilitation for example, technology platforms can be implemented in both the pre- and post-operative rehabilitation stage. The patient may use the technology support in the pre-operative phase to educate themselves about their scheduled procedure, and to support them as they perform their recommended pre-operative exercise programme. In the post-operative period, the technology support can be implemented immediately following surgery in the early rehabilitation phase to support the patient during their rehabilitation in the hospital. Following discharge from hospital the patient can continue to use the platform in the home. This new model of care incorporating a technology support in rehabilitation is anticipated to empower patients to take a more active and engaged role in management of their own health.

5. DESIGN SPECIFICATION FOR AN INTERACTIVE TECHNOLOGY SUPPORT

The infrastructure of an interactive support for rehabilitation will vary depending on the technology that is used, ranging from telephones and mobile phones, through to internet-based solutions, to the more expensive virtual reality and robotic systems. However, the same principles should be considered when designing/selecting an interactive platform for home rehabilitation. The platform should be an affordable solution, which is accessible to all potential users. The platform should be clinically valid, with the measurements performed by the system comparable to the gold standard measurement. The classification of performance and the feedback delivered should be accurate and appropriate. The platform should require minimal interactions to operate, it should be easy to calibrate and set-up, easily interacted with, and if worn, should not impede movement nor cause any irritation to the user. Other desirable features would include a means by which the user can track and monitor their progress, a communication portal through which communication between the therapist and the patient can occur, and a social interaction portal, through which users can interact with their peers. An educational component would also be advantageous, through which the user can attain disease specific information and general information on healthy eating, recommended physical activity levels, etc.

6. EXISTING STATE OF THE ART

A substantial body of work has been conducted in recent years, resulting in the development of a range of different technology platforms designed to enhance rehabilitation. While research and the clinical application of virtual reality and robotic systems are predominately focused on post-stroke rehabilitation [12-14], a number of researchers have examined phone- and internet-based approaches in orthopaedic rehabilitation. Telerehabilitation is a means by which rehabilitation is delivered remotely to a patient with the support of information and communication technology. A randomized controlled trial (RCT) by Russell and colleagues [15] demonstrated the efficacy of a telerehabilitation programme in terms of improving both physical and functional outcome measures in total knee replacement (TKA) rehabilitation, with the improvements following the telerehabilitation programme being similar to that attained in the control group who received conventional face-to-face physiotherapy. In this study the telerehabilitation system consisted of an internet-based videoconferencing system through which the therapist and the patient interacted. A more recent study demonstrated that home telerehabilitation, consisting of a videoconferencing system through which the therapist interacted with the patient, is as effective as usual care in reducing disability and improving function after two months of rehabilitation following joint replacement [16]. While this type of videoconferencing system is more labour intensive for the therapist, it was shown, when all direct and indirect costs were accounted for that this approach is 18% less expensive than providing the same service in home visits [17].

Commercial gaming systems, such as the Wii from Nintendo are been examined as a means of supporting TJA rehabilitation. The Wii Fit platform has been shown to be an acceptable adjunct to physiotherapy treatment in clinic-based rehabilitation following TKA [18] and a clinical trial is currently underway investigating the effectiveness of this tool in home rehabilitation after TKA [19].

Wearable sensors, such as inertial measurement units (IMUs) are cost-effective means of quantifying exercise performance, and form the basis of many platforms designed to support rehabilitation in the home. Many researchers have developed IMU-based systems to support patients with orthopaedic or musculoskeletal conditions as they perform their rehabilitation exercises at home, providing them with real-time feedback [20-24]. However these platforms have only been evaluated in laboratory based studies. Piqueras and colleagues [25] conducted a clinical trial to compare the effectiveness of their interactive IMU-based rehabilitation system to a conventional rehabilitation programme following TKA. The system consisted of a touch screen computer and a wireless system to capture patient movements, the core of which is two sensors, and a low-bandwidth mobile-internet device. The results of this investigation showed that the 2-week interactive rehabilitation programme was as effective as the conventional rehabilitation programme, thus highlighting the promise for a sensor-based rehabilitation support. However it is worth noting that this system, as well as those referenced in [20-24], used multiple sensors to quantify exercise performance. Using multiple sensors is not convenient for patients to set-up and use in the home. Minimising the number of sensors that are required would not only reduce the cost of the system but would also make a sensor-based system more usable. Recent work conducted by our group has demonstrated that it is possible to accurately quantify exercise performance using data from a single IMU sensor placed on the lower limb [26]. This work provides evidence to suggest that a single sensor can be used as an input to an interactive rehabilitation system. A single sensor approach is appealing as not only does it reduce the cost of the system, but also indicates that a smartphone with inertial sensing capabilities can be used to track exercise performance.

7. EVALUATION PROCEDURES

There is a need to evaluate the usability, validity and efficacy of these interactive technology supports before they can be widely implemented in home rehabilitation. Previous work that has been conducted has been mainly in a laboratory setting, or with small sample sizes, and therefore the next stage is to examine these platforms in larger clinical trials. The usability of the solutions should be established with both clinicians and patients providing input. The validity of the measurements performed by the system should be examined by comparison with the relevant gold standard measurements. The efficacy of the platform should be established through a RCT, comparing the modified care pathway incorporating the technology platform to the traditional care pathway. A pragmatic approach to participant recruitment and sampling should be adopted to increase the external validity of the results. Considering the example of orthopaedic rehabilitation, participants should be randomly allocated one of two groups; the intervention group undergo 6-weeks of technology supported rehabilitation in addition to usual care, while the control group receive standard care only. Primary outcomes measured at baseline, six weeks and six months include pain (visual analogue scale), self-reported physical function (Western Ontario and McMaster Universities Osteoarthritis Index and Oxford Hip/knee score), and exercise capacity (6 minute walk distance). Secondary outcomes include measures of health-related quality-of-life and perceived global change in symptoms. Other measures of adherence, adverse events, use of health services/co-interventions, and user satisfaction with the intervention could also be assessed.

8. CONCLUSIONS

As home exercise is a fundamental part of many rehabilitation protocols, a need exists to develop novel strategies to instruct, monitor and encourage patients while they perform their home exercise routines. This paper outlines an approach that should be considered when developing or selecting an interactive technology support for home rehabilitation. As the range of interactive feedback technologies in rehabilitation are increasing, it is important to establish the usability, validity and efficacy of these approaches before they can be widely implemented in rehabilitation.

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