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Comparing Outcomes of Kinect Videogame-Based Occupational/Physical Therapy Versus Usual Care

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Abstract

Objective: The purpose of this study was to assess the effectiveness of a game-like exercise tool as a component of occupational and physical therapy treatment for patients with shoulder pain and impairment in an outpatient physical therapy clinic.
Materials and Methods: The product evaluated is a hands-free therapy (HFT) prototype, using Microsoft® (Redmond, WA) Kinect™ technology. HFT was designed as a home exercise program (HEP), or adjunct to a clinic-based exercise program, with the goal to improve patient compliance and outcomes by providing patients with continuous immediate feedback and engaging them in a game-like experience. Eight patients with shoulder injuries were randomly assigned to study groups. Outcomes in pain, range of motion, and function were assessed. The experimental group received six sessions using HFT; the control group received six sessions of treatment as usual.
Results: The research demonstrated that patient outcomes were as good in the group using HFT as outcomes achieved with usual care. HFT was found to be a useful adjunct in an outpatient therapy clinic, allowing patients to complete exercises with real-time feedback and minimal therapist oversight.
Conclusions: These preliminary findings support the potential use of technology to provide an effective therapy and HEP system. Additional research utilizing a larger sample size is warranted to determine if this product can be an effective tool to improve HEP compliance and to determine the effectiveness of HFT as an adjunctive treatment in the clinic.

Introduction

To function within the limitations of insurance reimbursement, it is common practice for therapists to divide their time among several patients. As a result, therapists regularly discuss their quest for new ways to maximize treatment effectiveness. New technologies offer a potential means of enhancing patient engagement in usual care or traditional therapy, as the use of computers and gaming equipment in occupational therapy (OT) and physical therapy (PT) is progressively more relevant in the medical community.[1–5] Virtual exercise programs are becoming increasingly popular, as occupational and physical therapists are beginning to use these interactive games with patients in the clinic setting.[1–5] One study examining the use of the Nintendo® (Redmond, WA) Wii™ for rehabilitation suggested that the interactive component of this technology is useful; however, patients who suffer upper extremity impairment may have difficulty managing the hand-held control.[4] Studies and potential projects using the Microsoft® (Redmond, WA) Kinect™ in rehabilitation are beginning to appear as well.[1,3,4] Overall, study outcomes support the use of hands-free technology in the effective provision of rehabilitation treatments; however, research has suggested that videogames created to address specific injuries will be more effective treatment tools than those created for the general public.[1,3,4]

Motivation is an important factor in patient compliance with therapy programs, and technology is being used to increase patient motivation, compliance, and accuracy of movement.[1] The game-like fashion of videogame-based therapy exercise programs is one way to enhance patient motivation. Considering the interactive nature of the practice of OT and PT and the popularity of videogames among patients, applying this technology to patient care is logical. Hands-free therapy (HFT) software additionally has the potential to help address the strain that changes in healthcare are

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placing on patients. Historically, patients have identified several barriers to engaging in therapy services, including the limited number of clinic visits that patients are allowed by their insurance companies, rising gas prices, and limited time off work. HFT technology may be instrumental in addressing these issues by allowing patients to successfully engage in their treatment plan from the confines of their homes. HFT also has the potential to improve therapist productivity by allowing patients to work independently in the clinic, as HFT software provides the feedback that is currently provided by the therapist. Similarly, a HFT program may be used to provide a more effective home exercise program (HEP) for patients through increased feedback and more effective tracking of patient performance.

Musculoskeletal complaints are among the most common reasons for patients to see their primary care physician, with shoulder pain being second only to knee pain.[6] Approximately 20 percent of the population experiences shoulder pain leading to disability, and over 50 percent of these patients with shoulder pain are referred for OT or PT.[7,8] Shoulder pain is known to significantly and negatively affect the lives of those suffering with this pain. Function is affected as pain and resulting impairment limit the ability to perform essential activities of daily living.[9] Although the type of therapy to which the patients are referred is consistent (e.g., PT), there is not necessarily consistency in the manner in which these treatments are conducted.[7,10] Despite this lack of uniformity in specific treatment protocols, the importance of exercise in the treatment of shoulder injuries is well documented.[10,11]

Although the concept of merging OT and PT with technology is gaining popularity, there is a paucity of research on the use of Kinect as a therapeutic tool. As a result, it is reasonable to assess the plausibility of this videogame technology as a therapy tool. The purpose of this study was to assess the effectiveness of a HFT prototype, using Microsoft Kinect, as a component of OT and PT treatment for patients with shoulder pain and impairment. Outcomes in pain, range of motion (ROM), and function were compared between a control group receiving usual care and an experimental group using HFT. The researchers hypothesized that outcomes in functional improvement, pain, and ROM would be at least as good in patients using HFT as those obtained by patients receiving usual-care OT and PT. The researchers also hypothesized that patients would report satisfaction with the HFT prototype and a desire to use it as an HEP if it were to become available.

Subjects and Methods

Adult ambulatory patients with nonsurgical orthopedic shoulder injuries participated in the study. These patients were referred for OT or PT by a physician and were recruited at the outpatient therapy clinic in which the study was performed. All evaluations and treatments were provided by a licensed occupational or physical therapist. For the purposes of this article, the terms exercise, therapy, and PT refer to the treatment provided by these licensed therapists. Patient diagnoses included humerus fracture, adhesive capsulitis, rotator cuff syndrome, shoulder impingement, shoulder dislocation, and unspecified shoulder injury. All participants gave their informed consent, and the study was approved by the Arizona State University Institutional Review Board.

Patients were randomly assigned to a control or experimental group. The experimental group performed a protocol of active, active assistive, and passive ROM exercises using HFT. Patients in the experimental group attempted to match their movements to the movements and pace of an on-screen template with an avatar overlay of the patient (Fig. 1). Patients received visual feedback by monitoring their movements compared with that of the template. The HFT gave verbal instructions and counted the number of repetitions completed, giving the exercise program a game-like quality. After the initial instruction session, patients completed their exercises independently, with the therapist providing as few cues as

FIG. 1. Demonstration of the prototype in use. Color images available online at www.liebertonline.com/g4h

possible. After the initial instruction period, the patients worked independently with the HFT for the next six visits. In comparison, the control group performed similar exercises with minimal, intermittent therapist feedback for six visits.

Measures of ROM, pain, and function were obtained at the first and sixth sessions. Shoulder total active ROM (TAM) measurements included flexion, abduction, extension, internal rotation, and external rotation. TAM was measured using goniometric measures, an industry standard tool with well-documented validity and reliability. According to Kolber and Hanney,[12] concurrent validity between digital inclinometry and goniometry is ≥ 0.85, and intrarater reliability is strong (≥ 0.94). Pain was self-reported using a 0–10 visual analog scale (VAS).[12] When the VAS was compared with a numerical pain rating scale, convergent validity was 0.85.[13] Finally, functional status was assessed with the Focus on Therapeutic Outcomes (FOTO) measurement tool; FOTO has been found to be a valid and reliable assessment of functional status, with a Cronbach's alpha of 0.97.[14] A patient satisfaction survey was developed to determine if patients enjoyed using HFT and if they would likely use it as a HEP if it became available. The four patients in the experimental group completed the survey at their sixth session.

A descriptive analysis of the patient satisfaction survey was performed. All other data were expressed as mean ± standard deviation (SD) values. Outcome differences between the experimental and control groups in ROM, VAS, and FOTO were compared using a multivariate analysis of variance completed with Statistical Package for the Social Sciences for Windows version 21 software (SPSS Inc., Chicago, IL).

Results

Eight adult ambulatory patients (18–75 years old; five women, three men) were randomly selected and assigned to one of two groups. The experimental group comprised three women and one man. Ages ranged from 18 to 60 years, and the mean age was 44 years (SD = 19.53 years). The diagnoses in this group included two unspecified shoulder injuries, one adhesive capsulitis, and one shoulder dislocation. In the control group, there were two men and two women. Ages ranged from 43 to 71 years, and the mean age was 58 years (SD = 11.52 years). The diagnoses in this group included shoulder impingement, humerus fracture, adhesive capsulitis, and rotator cuff syndrome. Compliance with instructions provided in the clinic was 100 percent with both groups.

Improvements were noted in all measures for both groups. Functional improvement, as measured by FOTO, occurred in the control group with an increased score of 3.25 (SD = 3.30). In the experimental group, the total mean FOTO improvement score was 10 (SD = 5.35), with a range of 4–17.

Measurement of pain using the VAS improved for both groups. Pain improvement is measured inversely with the VAS, such that a decrease in score indicates pain improvement. The total mean improvement in pain in the control group was 2.25 (SD = 2.62), with a range of 0–5. In the experimental group, the total mean improvement in pain was 2.5 (SD = 1.73), with a range of 1–5.

There were improvements in ROM for each group. TAM mean improvement of the four patients in the control group at Visit 6 was 70.75° (SD = 43.15), with a range of improvement of 28°–130°. TAM mean improvement of the four patients in the experimental group was 93.75° (SD = 28.39°), with a range of 70°–135° of improvement.

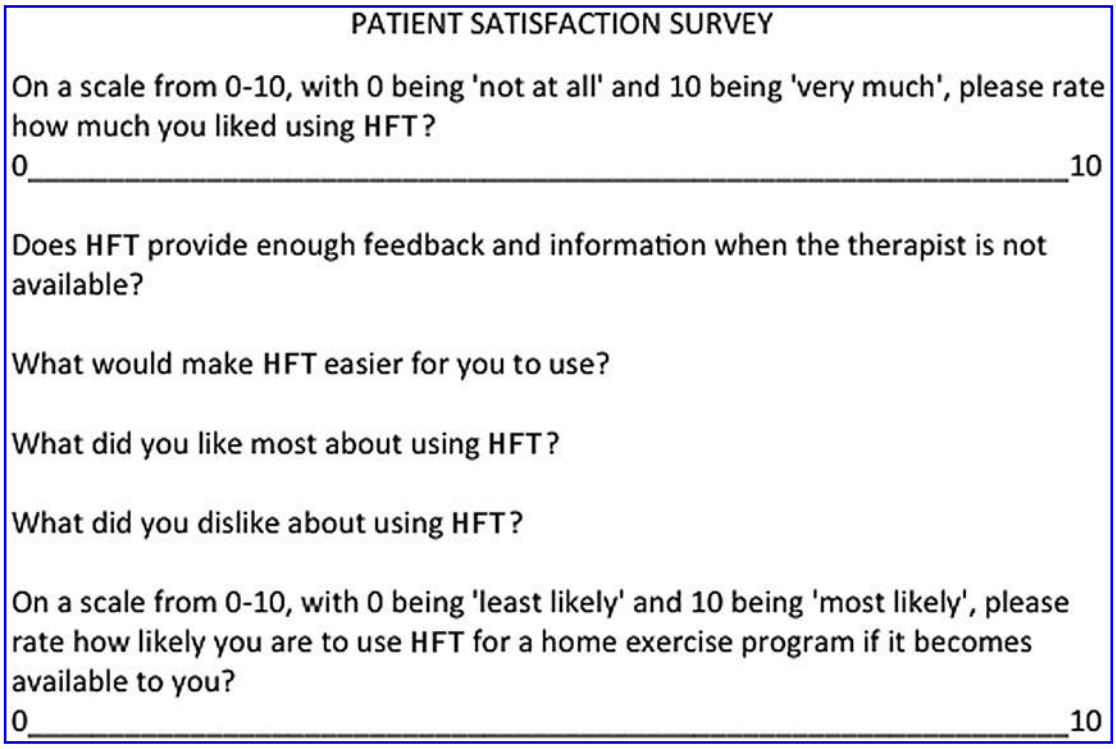
A multivariate analysis of variance was conducted to determine whether the independent variable (HFT) had a significant effect on the outcomes of the three dependent variables (pain, ROM, and function) compared with the outcomes of the patients in the control group receiving usual care. As the sample size was small, multivariate analysis of variance results failed to support a significant difference in treatment outcomes between the two groups ($F_{1,\ 7} = 1.15$), as $P = 0.433$. These results were expected, as the researchers hypothesized that the experimental group would have at least the same level of improvement as the control group. Therefore, the nonsignificant results in this study are consistent with the researchers' prediction.

The four patients in the experimental group were provided a patient satisfaction survey regarding HFT as shown in Figure 2. On a Likert-type scale ranging from 0 to 10, patients reported high levels of enjoyment using the HFT (mean = 9.5, SD = 1.0), and a willingness to use the HFT as a HEP if it becomes available (mean = 9.0, SD = 1.15). When asked if HFT provided sufficient feedback when the therapist was unavailable, all patients stated that it did. Improvement in accuracy of verbal feedback, a pause option, increased number of exercise options, and repetition of verbal instructions were all suggested improvements to the prototype. Patients reported that the prototype was fun and easy to use. Finally, the ability to work independently, visual guidance regarding form and pacing, and the ability to focus on exercises were aspects of the prototype with which the patients reported satisfaction.

Discussion

Outcomes in ROM, function, and pain were anticipated to be at least as good with the HFT program as with traditional or usual-care therapy. These anticipated results were realized, as patients in the experimental group (patients using HFT) experienced increased ROM, decreased pain, and functional improvement outcomes as good or better than outcomes achieved with usual-care therapy exercises. Findings support the potential usefulness of a HFT program in obtaining outcomes similar to those obtained by usual-care therapy. Future research with a larger sample size and a more homogeneous population with the same diagnosis is needed to substantiate these findings. The positive findings of this study support further research of HFT programs in the clinic and home setting to determine their effectiveness as a clinical tool and a HEP product. The HFT prototype used in this study was basic and still in the early development stage. Inaccuracy of verbal feedback was the primary patient complaint; however, the patients were able to simply turn the sound off and to depend on the visual feedback. This did not deter patients from using the prototype.

It stands to reason, based on the findings here and elsewhere in the literature, that good patient outcomes can be obtained with appropriate patient education and less direct therapist interaction.[15,16] Medina-Mirapeix et al.[16] identified therapist instruction as a key to success of a HEP. Malagoni et al.[15] reported long-term compliance with a HEP when the patient was initially educated by a healthcare provider and tracking strategies were used at home. These authors suggested there is the potential for improved cost-effectiveness


PATIENT SATISFACTION SURVEY

On a scale from 0-10, with 0 being 'not at all' and 10 being 'very much', please rate how much you liked using HFT?

0_____10

Does HFT provide enough feedback and information when the therapist is not available?

What would make HFT easier for you to use?

What did you like most about using HFT?

What did you dislike about using HFT?

On a scale from 0-10, with 0 being 'least likely' and 10 being 'most likely', please rate how likely you are to use HFT for a home exercise program if it becomes available to you?

0_____10

FIG. 2. Patient satisfaction questionnnaire.

of therapy when using a HEP with tracking strategies and intermittent follow-up versus solely clinic-based treatment. The use of a HFT program may result in increased therapist productivity as their patients can work with less supervision after initial instruction. Cost savings to the clinic using this program and to third-party payers is another potential benefit, and future research regarding the cost-effectiveness of a product such as HFT is indicated.

The timing of the template improved pace and form of the patients while they completed the exercises and helped patients keep track of the number of repetitions they were performing. It is anticipated that the behavioral issue of ineffective compliance that plagues therapy outcomes will likely improve with a HFT product, as patients reported they would be ''most likely'' to use HFT for a HEP if the product became available to them. The performance tracking provided by the software was one reason given by patients for their likeliness to use this product as a HEP. Patient motivation to follow through with therapist instructions varies and is often limited. Tracking in this situation may serve as an effective, additional factor motivating the patients to complete exercises with the frequency recommended by the therapist. As the current standard for a HEP is a paper with drawings of exercises, the feedback offered by HFT is a promising component that has the potential to improve both compliance and outcomes.

Limitations of the study were identified as well as successes. It is assumed that the patient's ability to use HFT in a supervised setting effectively, without cuing or assistance, implies that he or she will use it safely, independently, and consistently at home; however, this is yet to be demonstrated. The presence of the therapist and the freedom from home distractions afforded by the clinic setting may result in different results when this treatment modality is tested in the home setting.

Motivation was identified in the literature review as a factor in patient treatment adherence.[1] With the use of new technology, distinguishing between motivation that is associated with the novelty of the product versus the purpose of the program is difficult. This is an issue that should be addressed as novelty cannot be depended upon to maintain motivation, as novelty is inherently brief. To make this determination, future studies would require more visits over a longer period of time.

Another identified limitation was the small sample size. Most patients presenting to the clinic where the research was conducted had recently undergone surgical intervention. These patients initially are only allowed to complete passive ROM exercises and exercises completed with gravity eliminated. Few of these types of exercises were available through the HFT program at the time of the study; thus these patients were excluded from the study. As the study progressed, it was determined that these patients could benefit from the use of HFT with a limited exercise plan, and their inclusion in future studies is warranted.

Also contributing to the small sample size was the age range of recruited patients. Initially, it was thought that older adults, those over 60 years of age, would not be interested in using a computerized exercise program, and they were omitted from the initial recruitment plan. The opposite was found to be true, as patients in this age range who were not in the study were consistently excited about using the program. Of those who participated in the study, there was one 60-year-old (female) patient, but there were no patients older than 60 years of age in the experimental group. In the control group, there was one 60-year-old patient (female) and one 71-year-old (male) patient.

This segment of the population was also more likely to have a nonoperative shoulder injury, so including them in the study would have increased the sample size significantly. Including this population should be a consideration for future studies.

The variability in diagnoses among participants may be considered an additional study limitation. Any nonoperative shoulder injury was included in the study, resulting in a highly heterogeneous sample. Assessing several patients with the same diagnosis, for the same number of visits, may potentially allow for a more statistically significant outcome. The success of the HFT prototype across diagnoses, however, implies utility with a diverse population.

Finally, inconsistency of attendance of some of the patients may have influenced study outcomes. Each patient recruited stated that he or she could come to therapy two to three times per week, but this rarely happened. This could have been due to the fact that these were all nonoperative patients, and their injuries were less severe than the postoperative patients who attend therapy with more regularity. Multiple reasons for this limited attendance were given, including travel, work schedules, family conflicts, etc. Failure to regularly engage in treatment may have limited adherence to protocol, thereby potentially impacting patient outcomes.

In summary, the findings of this study support the need for, and use of, technology to provide a more efficient and effective therapy and HEP system. Outcomes support the benefit of a HFT program in the provision of OT and PT to patients with shoulder injuries in the clinic setting. There is clearly potential to use such a system to address injuries affecting additional joints, and perhaps for the entire human body. The positive patient response regarding the use of a hands-free game-like therapy program also supports the potential such a program can offer to the healthcare community. Therapists, patients, and third-party payers can potentially benefit from effective use of the technology outlined here. The findings of this and other studies[1,4,5] support the need for more research to accurately assess the effectiveness and cost-effectiveness of such a system.

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Author Disclosure Statement

J.L. is an employee of APEX Physical Therapy, LLC. S.D.-P. and C.C.C. declare no competing financial interests exist.

References

1. Chang YJ, Chen SF, Huang JD. A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities. Res Dev Disabil 2011; 32:2566–2570.
2. Ilg W, Schatton C, Schicks J, et al. Video game-based coordinative training improves ataxia in children with degenerative ataxia. Neurology 2012; 79:2056–2060.
3. Lange B, Chang CY, Suma E, et al. Development and evaluation of low cost game-based balance rehabilitation tool using the Microsoft Kinect sensor. Conf Proc IEEE Eng Med Biol Soc 2011; 2011:183–184.
4. Taylor MJ, McCormick D, Shawis T, et al. Activity-promoting gaming systems in exercise and rehabilitation. J Rehabil Res Dev 2011; 48:1171–1186.
5. Sveistrup H, McComas J, Thornton M, et al. Experimental studies of virtual reality-delivered compared to conventional exercise programs for rehabilitation. Cyberpsychol Behav 2003; 6:245–249.
6. Arcuni SE. Rotator cuff pathology and subacromial impingement. Nurse Pract 2000; 25:58, 61, 65–66 passim.
7. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for shoulder pain. Phys Ther 2001; 81:1719–1730.
8. Kromer TO, De Bie RA, Bastiaenen CH. Effectiveness of individualized physiotherapy on pain and functioning compared to a standard exercise protocol in patients presenting with clinical signs of subacromial impingement syndrome. A randomized controlled trial. BMC Musculoskelet Disord 2010; 11:114.
9. Green S, Buchbinder R, Hetrick S. Physiotherapy interventions for shoulder pain. Cochrane Database Syst Rev 2003; (2):CD004258.
10. Kuhn JE. Exercise in the treatment of rotator cuff impingement: A systematic review and a synthesized evidence-based rehabilitation protocol. J Shoulder Elbow Surg 2009; 18:138–160.
11. Gleyze P, Flurin PH, Laprelle E, et al. Pain management in the rehabilitation of stiff shoulder: prospective multicenter comparative study of 193 cases. Orthop Traumatol Surg Res 2011; 97(8 Suppl):S195–S203.
12. Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: A technical report. Int J Sports Phys Ther 2012; 7:306–313.
13. McDowell I. *Measuring Health: A Guide to Rating Scales and Questionnaires*, 3rd ed. Oxford, United Kingdom: Oxford University Press; 2006.
14. Wang YC, Hart DL, Cook KF, Mioduski JE. Translating shoulder computerized adaptive testing generated outcome measures into clinical practice. J Hand Ther 2010; 23:372–382.
15. Malagoni AM, Vagnoni E, Felisatti M, et al. Evaluation of patient compliance, quality of life impact and cost-effectiveness of a ''test in-train out'' exercise-based rehabilitation program for patients with intermittent claudication. Circ J 2011; 75:2128–2134.
16. Medina-Mirapeix F, Escolar-Reina P, Gascón-Cánovas JJ, et al. Predictive factors of adherence to frequency and duration components in home exercise programs for neck and low back pain: An observational study. BMC Musculoskelet Disord 2009; 10:155.

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