Experimental Studies of Virtual Reality-Delivered Compared to Conventional Exercise Programs for Rehabilitation

HEIDI SVEISTRUP, Ph.D.,1 JOAN MCCOMAS, Ph.D., P.T.,1 MARIANNE THORNTON, B.Sc. (PT),1 SHAWN MARSHALL, M.D., M.Sc., FRCPC,2 HILLEL FINESTONE, M.D., FRCPC,3 ANNA MCCORMICK, M.D., FRCPC,2 KEVIN BABULIC, B.Sc. (PT),4 and ALAIN MAYHEW, B.Sc. (PT)5

ABSTRACT

This paper presents preliminary data from two clinical trials currently underway using flat screen virtual reality (VR) technology for physical rehabilitation. In the first study, we are comparing a VR-delivered exercise program to a conventional exercise program for the rehabilitation of shoulder joint range-of-motion in patients with chronic frozen shoulder. In the second study, we are comparing two exercise programs, VR and conventional, for balance retraining in subjects post-traumatic brain injury. Effective VR-based rehabilitation that is easily adapted for individuals to use both in inpatient, outpatient and home-based care could be used as a supplement or alternative to conventional therapy. If this new treatment approach is found to be effective, it could provide a way to encourage exercise and treatment compliance, provide safe and motivating therapy and could lead to the ability to provide exercises to clients in distant locations through telehealth applications of VR treatment. VR is a new technology and the possibilities for rehabilitation are only just beginning to be assessed.

INTRODUCTION

Several preliminary reports have indicated that virtual reality (VR) may be a useful tool for physical rehabilitation.1–4 However, prior to incorporating VR approaches into mainstream practice, evidence of its effectiveness must be demonstrated. This paper presents preliminary data from two clinical trials currently underway using flat-screen VR technology for physical rehabilitation. In the first study, we are comparing a VR-delivered exercise program to a conventional exercise program for the rehabilitation of shoulder joint range-of-motion in patients with chronic frozen shoulder. In the second study, we are comparing two exercise programs—VR and conventional—for balance retraining in subjects post-traumatic brain injury.

In both trials we are using a commercially available system (IREX, Interactive Rehabilitation Exercise System, Jestertek, 240 Catherine St. West, Ste 403, Ottawa ON K2P 2G8, Canada) to provide the virtual environments. The system is an extension of the system seen every day on the weather channel where a forecaster is shown standing in front of a weather map. In our studies, subjects stand or sit in front of a green or blue screen (Fig. 1). A real-time camera is used to record the subject’s image. The system then eliminates the screen to isolate the person and super-

1Faculty of Health Sciences, University of Ottawa, Ottawa, Canada.
2Division of Physical Medicine and Rehabilitation, The Rehabilitation Centre, The Ottawa Hospital, Ottawa, Canada.
3Department of Physical Medicine and Rehabilitation, Elizabeth Bruyère Health Centre, University of Ottawa, Ottawa, Canada.
4Rehabilitation Services, The Ottawa Hospital, Ottawa, Canada.
5Prevention and Rehabilitation Centre, University of Ottawa Heart Institute, Ottawa, Canada.
imposes the subject’s image into a virtual environment. Multiple environments and interactions have been designed that permit the exercise specialist or physical therapist to grade the intensity and difficulty of the movements elicited from the subject. For example, a soccer application places the subject in front of a soccer net. The subject is required to stop virtual soccer balls from scoring. The therapist is able to regulate the vertical location of the balls in order to work within a pain free range of shoulder motion, such as in our study of frozen shoulder. In the balance retraining study, the exercise specialist is able to regulate the horizontal location of the balls in order to elicit sidestepping and/or side leaning, such as in our study of balance retraining.

Brief reviews of relevant literature as well as overviews of the methodology for each study are provided. Preliminary data from each study are also presented and consist of pre-post intervention scores on the primary outcome measures for a small sample of the two study populations.

MATERIALS AND METHODS

Musculoskeletal rehabilitation: joint range of motion limitations in patients with frozen shoulder

Shoulder pain is a common problem, with up to 34% of the general population affected. It is the third most common reason for primary care visits. The term “frozen shoulder” is now interpreted as a general term used to describe shoulders stiff and painful because of capsular restriction including adhesive capsulitis. Traditional methods of treatment include physiotherapy, NSAIDS, corticosteroid injection, surgery and manipulation. The average patient does not obtain functional ROM for 12–14 months, and over 10% of patients have functional impairment up 7 years later. This loss of range of motion, and the pain and loss of strength that accompanies it, results in a marked disability in many sufferers of frozen shoulder. Chipchase et al. suggested that patients with chronic shoulder impingement whose condition was resistant to conservative treatment were very functionally limited particularly in being able to return to their regular job. Even 3 months after manipulation under anesthesia, over 40% of patients had a moderate to severe level of disability. It is believed that 12–45% of clients with shoulder problems do not fully recover after physiotherapy treatment methods. Different treatments may help the progress and possibly avoid surgery and/or manipulation under anesthesia.

Overview of the clinical trial. Individuals who present with frozen shoulder due to musculoskeletal pathology, who are able to actively contract muscles and move the affected arm either with or without assistance, and who have no contraindications to active
range of motion are included in the study. Exclusion criteria include insulin-dependent Type 1 diabetes or corticosteroid shoulder injection. As subjects are identified, they are quasi-randomly assigned to either a conventional stretching/exercise group or to a virtual reality exercise group. The two groups are matched as closely as possible for participant age and sex.

**Protocol.** All study participants receive three sessions of exercise per week over a 6-week period. For both groups, the therapy sessions consist of a 15-min warm-up followed by 30 min of active exercise and terminated with 15 min of ice application. The two exercise programs have been designed to elicit three specific movements: shoulder forward flexion, shoulder abduction in the scapular plane and internal/external shoulder rotation. Exercises are discontinued if the shoulder pain is severe or prolonged. All clients participating in the study are encouraged to do the same home exercise program.

**Outcome measures.** Multiple clinical outcome measures including pain, range of motion and strength are assessed for all clients at three time points: (1) prior to beginning therapy; (2) immediately at the end of therapy; and (3) at a 3-month follow-up visit. The primary outcome measure we are using to determine treatment efficacy is the Disabilities of the arm, shoulder and hand (DASH), a 30-item self-report condition-specific disability measure. The questionnaire is intended to measure physical function at the level of disability and evaluates a client’s ability to perform an activity, regardless of how it is done. Lower scores on the DASH reflect less disability and higher scores reflect more disability. A change in a DASH score of 15 points has been reported to be the most accurate change score in terms of distinguishing individuals who become able to cope with their problem over time from those who do not.

**Results.** Two participants in the virtual reality exercise group and one in the conventional exercise group have completed their exercise sessions. All three participants improved on the DASH with greater than a 15-point change after the 6-week intervention period. The changes in DASH for the individuals in the VR group were 17 and 20 points. The change in DASH for the individual in the conventional group was 16 points. The study is in its infancy and final study results from 40 individuals will provide us with information specifically addressing the feasibility and effectiveness of this approach to exercise delivery for a chronic musculoskeletal population.

Neurological rehabilitation: balance retraining in individuals’ post-traumatic brain injury

Balance dysfunction is one of the most difficult deficits to treat in brain-injured patients due in part to multiple structures involved in maintaining balance and in part to inadequacy of current treatment techniques. Residual balance deficits post-rehabilitation therapy often lead to loss of independence, as well as the inability to participate in work and leisure activities. Most relevant to the clinical trial we are running is the large percentage of individuals reporting residual balance deficits more than 6 months post-trauma. A recent assessment of recovery and outcome in 67 people 5 years post-traumatic brain injury (TBI) reported balance deficits as the most frequent area of residual impairment next to headaches. Moreover, residual balance impairments were reported in 34% of these individuals post-TBI with gait also altered in 24%. The strikingly limited amount of evidence available regarding the effect of physiotherapy on quality of movement, balance, ability to perform functional tasks and outcome of TBI patients suggests the need for research into these aspects of physiotherapy management of this population.

**Overview of the clinical trial.** Individuals who have had a moderate or severe TBI at least 6 months earlier and who are no longer participating in acute inpatient rehabilitation are being recruited for study participation. The participants vary in the amount of residual balance deficits they have due to their TBI but must minimally be able to stand independently for 2 min without the need for a mobility aid. We have excluded individuals with vestibular deficits or benign postural vertigo for the purpose of this initial study. Random block assignment is being used to assign participants to three groups, one control and two experimental, that are matched as closely as possible for pretest Berg Balance Scale scores and for the number of years since the TBI.

**Protocol.** Participants in the two experimental groups receive three 1-h sessions of balance retraining exercise per week for a 6-week period. The balance exercises and skill progression are based on a program set by a physical therapist. Conventional Exercise Group: Exercise sessions consist of activities that work on stepping, picking up objects from the floor, single versus double limb stance, moving within the base of support, walking, sit-to-stand, reaching, hopping, jumping and jogging. VR-Exercise Group: Multiple scenarios are used that require participants to work on reaching, moving within
the base of support, stepping, sit-to-stand, hopping, jumping and jogging. **Control Group**: Participants in the control group complete the outcome measures protocol as per the two experimental groups but do not participate in any exercise sessions beyond their normal programs.

**Outcome measures.** Outcome measures including laboratory measures of quiet stance, gait speed and activity specific confidence are assessed for all clients at three time points: (1) prior to beginning the exercise program; (2) at the end of the exercise program; and (3) at a three-month follow-up visit. The repeated measures research design will determine effectiveness of the two exercise programs. The primary outcome measure, the Community Balance and Mobility Scale (CB&M), is a performance-based measure comprised of items such as single limb stance, lateral dodging and stair descent. Higher scores reflect better functional balance and mobility.

**Results.** Preliminary results from an initial group of 14 participants are presented in Figure 2. Note that two participants in the control group had large increases in CB&M which may reflect the process of natural recovery that occurs over the first two years post-injury. Both of these participants were within one year of their TBI. In general, clients in both the VR and the conventional exercise group improved on the CB&M after the 6-week intervention period. Additional benefits were reported during focus group sessions held with the two groups of exercise participants. Statements recorded from participants in the VR-exercise group and their family members included “I am not falling as much” and “He is not shuffling as much when walking. He is taking longer strides.” Although the conventional exercise group participants and family members did not suggest such strong changes in balance and mobility, other effects of study participation were noted in both groups. Specifically, both participants and family members reported increased confidence regardless of which exercise program they completed. The final study results will provide us with information specific to the effectiveness of this approach to exercise delivery in this neurologic population.

**CONCLUSION**

VR technology may provide a means to create rehabilitation and exercise environments that will allow health care professionals to precisely deliver and control complex, dynamic, interactive, three-dimensional stimulus presentations (Rizzo et al.20). For rehabilitation, the simulated experience may be designed to address certain aspects of sensory or motor loss experienced by an individual. For example, benefits to the use of virtual environments may include the ability to dramatically increase the amount of specific interaction a traumatic brain injury (TBI) survivor has with the environment.21 Moreover, some of the VR interfaces permit recording of targeted responses permitting assessment of functional performance.

Effective VR-based rehabilitation that is easily adapted for individuals to use both in inpatient, outpatient and home-based care could be used as a supplement or alternative to conventional therapy. If this new treatment approach is found to be effective, it could provide a way to encourage exercise and treatment compliance, provide safe and moti-
vating therapy and could lead to the ability to provide exercises to clients in distant locations through telehealth applications of VR treatment. VR is a new technology and the possibilities for rehabilitation are only just beginning to be assessed.

ACKNOWLEDGMENTS

“Special thanks to IREX Corp. (www.irexonline.com), a division of Jestertek, Inc., for supplying hardware, software and technical development expertise for this project. H. Sveistrup is a Career Scientist with the Ministry of Health and Longterm Care, Ontario. The studies are funded by the Ontario March of Dimes and the Ontario Neurotrauma Foundation.

REFERENCES


Address reprint requests to:
Heidi Sveistrup, Ph.D.
School of Rehabilitation Sciences
Faculty of Health Sciences
University of Ottawa
451 Smyth Rd.
Ottawa, ON K1H 8M5 Canada

E-mail: hsveist@uottawa.ca