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Virtual reality enhanced balance training for Service Members with amputations

A case series

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***Abstract* - Virtual applications developed for balance training in the Computer Assisted Rehabilitation Environment (CAREN) require subjects to perform dynamic weight shifts. This retrospective case study examines the use of the CAREN as an adjunct to conventional therapy for three service members with upper and/or lower extremity amputations. All three patients showed improved performance over several weeks of CAREN training, and the combined data can be characterized with a power curve fit ($y = 291.91x^{-0.165}$; $R^2 = 0.836$). These results support the need for more extensive studies on the effectiveness of CAREN balance training for those with amputations.**

Keywords - CAREN; virtual reality; balance; amputation

I. INTRODUCTION

Since the onset of Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF), over 1,400 active U.S. military personnel have incurred a traumatic amputation. Of those, more than 1,000 have suffered major limb loss with approximately 80% having lower extremity (LE) amputations and 20% having multiple limb involvement [1-3]. A majority of these service members are young, were pre-morbidly fit and have goals of attaining or surpassing prior levels of function. To date, approximately 17% have returned to active duty service [3,4].

At Walter Reed Army Medical Center (WRAMC), extensive rehabilitation is employed early on for those with amputations and balance skills are reinforced throughout all phases of treatment [5,6]. Since virtual reality has been shown to promote motivation and compliance [7], the Computer Assisted Rehabilitation Environment (CAREN) [Motek BV, Amsterdam, The Netherlands] has been incorporated into the rehabilitation of service members at WRAMC. This system has the ability to challenge patients through interactive virtual applications that focus on improving balance and core stability.

The purpose of this retrospective case series is to determine the feasibility of utilizing the CAREN as an adjunct to conventional therapies for balance training in service members with amputations.

II. REVIEW OF EQUIPMENT

The WRAMC CAREN Laboratory houses a six degree-of-freedom motion platform that is 3 m in diameter and can translate approximately 1 m with a maximum rotation of 18 degrees. It contains an embedded, instrumented treadmill with a maximum speed of 5 m/s. The platform operates in combination with a motion capture system (Vicon Inc., Oxford, United Kingdom) which allows patients to control and/or interact with virtual applications projected onto a large, 120 degree curved screen. Patient safety is ensured through the use of a full body harness system.

III. METHODS

A. *Patient History*

This retrospective case series includes three male service members, ranging in age from 22 to 32 years. Patient 01 had a transhumeral amputation of his right arm and a transfemoral amputation of his right leg. Patient 02 had a transhumeral amputation of his right arm, as well as ulnar nerve damage to his right arm and deep muscle tissue loss from his right leg. Patient 03 had a right knee disarticulation, as well as muscle tissue loss, lumbar plexus injury and sacral dissociation with lumbar fixation.

B. *CAREN Training*

All three patients were referred to the CAREN by their primary physical therapists. Each patient was scheduled for one or two sessions per week; sessions were 30 minutes in length. While attending CAREN sessions, all patients continued with conventional therapy.

For purposes of this study, progress is reported for a single balance application, Boat Buoy Count. The Boat application requires patients to weight and/or step shift on the platform to navigate a boat through a course of buoys displayed on the screen. Two reflective markers are placed on the back of the harness slightly above the pelvis. Forward movement of the markers advances the boat forward on the screen. The further forward a patient translates, the faster the boat moves. To turn the boat left or right, the patient must shift in those respective directions. To further simulate the movement of a boat, the platform rotates into each turn and is set to move continuously

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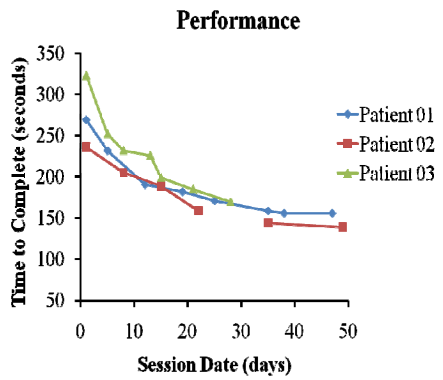

Figure 1. Performance over time. Data points represent each session and lines represent the amount of time between sessions. Gaps indicate that the Boat application was not carried out during sessions within the gap.

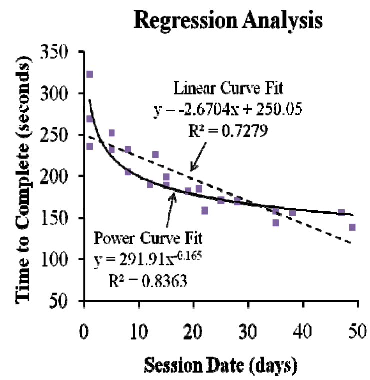

Figure 2. Linear and power curve fits. The power curve fit best represented the data ($y = 291.91x^{-0.165}$; $R^2 = 0.836$) and both curves showed statistical significance ($p = 0$).

with the motion of waves, the height and speed of which can be changed to increase the difficulty of the task.

C. Data Analysis

CAREN session notes were reviewed for all patients. The time required to complete the application was plotted against session date to determine each patient's progress. Time was displayed in seconds and session date was displayed as the number of days since the patient first began balance training with the Boat application. Additionally, SPSS statistical software (SPSS Inc., Chicago, IL) was used to model the combined data of all patients. R-squared values were used to determine a best fit line, and a regression analysis of variance (ANOVA) was used to determine if the relationship was due to chance.

IV. Results

Figure 1 displays the progress of each patient. Patient 03 showed the greatest improvement (153 seconds), followed by Patient 01 (113 seconds) and Patient 02 (97 seconds). However with only three patients, these improvements could not be statistically compared. Figure 2 shows the results of the regression analysis of the combined data. Both a linear ($y = 250.055 – 2.67x$) and a power ($y = 291.909x^{-0.165}$) curve fit are displayed. The power curve fit was the most successful ($R^2 = 0.836$), and was statistically significant ($p = 0$). The linear fit ($R^2 = 0.728$) was also significant ($p = 0$). The power curve may be more appropriate than the linear curve because it appears that as time progresses, smaller gains are made and performance begins to plateau.

V. Discussion

All three patients examined in this study demonstrated improved performance in the CAREN. The regression analysis provides some support for this result. However, more extensive analysis should be performed.

It was assumed that patients with different levels of amputation would progress similarly in the CAREN. This may not be the case. There are also several other patient populations that may benefit from CAREN training, and several different applications that could be used to do so. Examining data grouped by subject population, injury level, and application could determine which applications are most appropriate for which patient populations.

There were several other factors that could have influenced our results, including patient history and demographics, as well as the subjectivity of the applications and settings chosen for each patient. Factorial regression analysis should be employed to determine the effect of these factors. CAREN training must also be validated by comparing performance of subjects who receive standard of care with and without CAREN training.

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