ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

FALL-PREVENTION TRAINING PROGRAM FOR PERSONS WITH LOWER EXTREMITY AMPUTATIONS: EARLY RESULTS

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SUMMARY
A novel rehabilitation program has been developed for individuals with lower extremity amputations. The program consists of postural disturbances of increasing difficulty delivered by a custom treadmill. The instruction consists of six 30-minute training sessions. Trained subjects have reduced falls and retained the improved recovery skills for six months after receiving the training.

INTRODUCTION
Lower extremity limb loss results in restricted mobility, which can dramatically affect an individual's quality of life. The key factors that limit the ability of patients with amputations to achieve maximum functional capabilities are falls and fear of falling. Among individuals with a lower extremity amputation, 52% reported having fallen in the previous 12 months, 49% reported being fearful of falling, and 65% had low balance confidence scores [1]. This research program was designed to rehabilitate lower extremity amputees to increase trust in their prosthesis and reduce falls by using a novel training method.

METHODS
Eight service members (age: 25 ± 3 years, BMI: 23 ± 2 kg/m^2) with unilateral transtibial amputations were recruited at the Naval Medical Center San Diego (NMCSD). Prior to participation, each subject signed an informed consent approved by the Institutional Review Board at the NMCSD. The subjects had been walking without an assistive device for 8 ± 3 months.

The fall prevention training program utilized an Active-Step treadmill (Simbex, Lebanon, NH). This microprocessor-controlled treadmill was designed to deliver task specific training perturbations. Three types of perturbations were used during six, 30 minute training sessions during which the task difficulty increased as the patient's ability progressed. The three types of perturbations were 1) static: during which the belt moved while the patient was standing still and to which the patient responded with one forward step; 2) static walk: during which the belt moved while the patient was standing still and to which the patient responded with multiple forward steps: and 3) the eTRIP: where the patient was walking on the treadmill and the perturbation was delivered at a random time during the walk and which required the patient to recover with multiple forward steps.

Assessment of the training program effectiveness was done using a perturbation testing protocol in a Computer Assisted Rehabilitation Environment (CAREN). This fully immersive virtual environment contains a 6 degree-of-freedom, hydraulically activated motion platform containing an instrumented dual belt treadmill with integrated force plates. The platform was surrounded by a 120^0 screen. The testing protocol delivered a perturbation simulating a trip in the natural environment. Six perturbations (3 left/3 right) were delivered in a randomized manner while the subject walked for five to six minutes at a velocity standardized to leg length. A pre-test and post-test assessment of the rehabilitative program was performed. Select biomechanical data using motion analysis methods were collected to determine effectiveness of the subjects' ability to recover from these disturbances.

In addition, subjects completed the Prosthesis Evaluation Questionnaire (PEQ-A) [2] and Activities-Specific Balance Confidence (ABC) Scale [3] prior to and at the conclusion of the training. For the questionnaire, an uncontrolled fall was defined as a sudden loss of balance without any time to protect against a fall. A semi-controlled fall was defined as a loss of balance with awareness that a fall is occurring resulting in the opportunity to brace for the fall or catch something in order to not get hurt and land in a protected fashion. The assessment on the CAREN and the questionnaires were also completed at 3 and 6 months post-training.

Data analysis was performed using a two-factor (limb and time) repeated measure ANOVA. The key outcome variables were peak trunk flexion and velocity at recovery step, since these variables have been shown to determine likelihood of a fall [4,5]. Statistical significance was set at p=0.05.

RESULTS AND DISCUSSION

All subjects enrolled in the study could be considered high functioning based on their ABC scores of 90 $\pm$ 8 at baseline testing. There was a significant decrease pre to post training for mean peak trunk flexion angle ($p<0.001$) and velocity ($p<0.001$) at the time of the recovery step (Figure 1). Perturbations of the non-prosthetic limb exhibited significantly greater mean peak trunk flexion velocity ($p=0.01$) at recovery step when compared to perturbations the prosthetic limb. There was no significant side-to-side difference in mean peak trunk flexion angle ($p=0.10$).

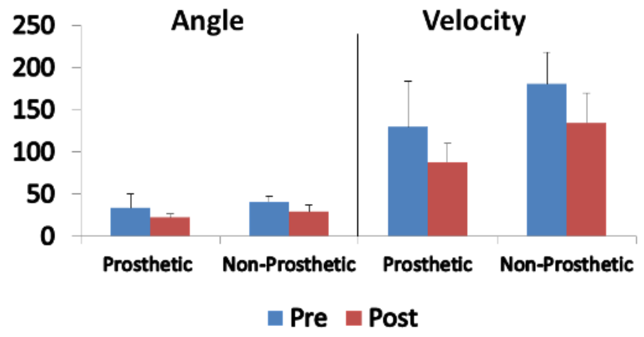

Figure 1: Trunk flexion angle (degrees) and velocity (deg/sec) before and after training when the subject was tripped on the prosthetic and non-prosthetic limb.

Further, the skills acquired were retained at 3 and 6 months after training (Figure 2). There were no significant changes in the mean peak trunk flexion angle ($p=0.12$) or mean peak trunk flexion velocity ($p=0.22$) over time. Perturbations of the non-prosthetic side resulted in higher trunk flexion velocities than when the prosthetic side was tripped ($p=0.05$). The PEQ questionnaire responses indicate an increased confidence in the ability to recover from a trip in the community. All subjects reported that the number of uncontrolled falls were zero after training. Further, most (5/8) of the subjects indicated that the number of semi-controlled falls had been reduced to zero following training, one subject reported that the number had been reduced, and two subjects did not demonstrate any trend.

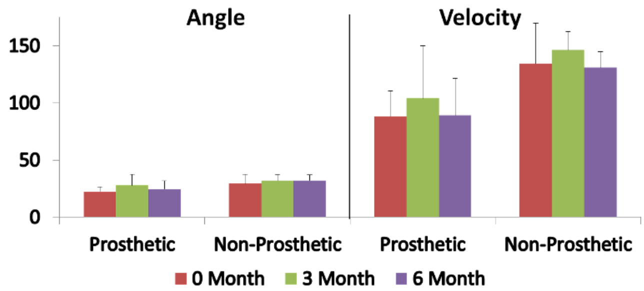

Figure 2: Changes in trunk flexion angle (degrees) and velocity (deg/sec) over time following training. The subject was tripped on the prosthetic and non-prosthetic limb.

This novel rehabilitation method uses an innovative treadmill training method in an attempt to reduce falls in the natural environment. The training is aimed at increasing the ability of the patients with amputations to rely on their prostheses during challenging perturbations and thus improving their functional capabilities. This type of training has been shown to reduce falls in older adults [6,7]. The preliminary results indicate that this rehabilitation method will also be effective for amputees by increasing their ability to recover from a challenging perturbation and demonstrate increased functional performance.

CONCLUSIONS

These initial results indicate that task-specific training can be an effective rehabilitation method to reduce falls by persons with lower limb amputations.

ACKNOWLEDGEMENTS

Department of Defense Grant No. DM090896; The Navy Bureau of Medicine and Surgery (BUMED), Wounded Ill and Injured.

The views expressed in the article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or the United States Government.

REFERENCES

1. Miller WC et al. The prevalence of risk factors of falling and fear of falling among lower extremity amputees. *Archives of Physical Medicine and Rehabilitation*. **82**: 1031-1037, 2001.
2. Prosthesis Evaluation Questionnaire, Prosthetics Research Study 1998, Seattle, WA
3. Powell, LE & Myers, AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol Med Sci* 1995; **50**(1): M28-34
4. Owings TM et al. Mechanisms of failed recovery following postural perturbations on a motorized treadmill mimic those associated with an actual forward trip. *Clinical Biomechanics*, **16**:813-819, 2001.
5. Crenshaw JR et al. Trip recoveries of people with unilateral transfemoral or knee disarticulation amputations: Initial Findings. *Gait and Posture*, in press, 2013.
6. Grabiner MD, et al. Task-specific training reduces trip-related fall risk in women. *Medicine and Science in Sports and Exercise*, In Revision.
7. Rosenblatt N, Marone J, Grabiner MD: A Novel step-training paradigm to reduce prospective community-based falls. *Journal of the American Medical Association*, In Review.