Exercise Endurance and Functional Mobility Improve for Individuals with Physical Disabilities After Training on a Motorized Elliptical

Marie C. Yeseta[1,2], Adam P. Taylor[1], Thad W. Buster[1], Yu Shu[1], Judith M. Burnfield[1,2]
[1] *Madonna Rehabilitation Hospital, Lincoln, NE*
[2] *University of Southern California, Los Angeles, CA*

ABSTRACT

Improving fitness and walking are critical goals for many individuals participating in physical rehabilitation; however, accessibility and usability of equipment often limit available treatment options. We discuss utilization of the ICARE, an **I**ntelligently **C**ontrolled **A**ssistive **R**ehabilitation **E**lliptical, as an adjunct to outpatient physical therapy. The effect of ICARE training on balance, walking speed, and endurance was assessed in individuals with diverse medical conditions. Improved exercise tolerance, balance and walking endurance were documented following twelve training sessions on the ICARE. Further work should explore the independent effects of ICARE training.

BACKGROUND

Individuals with chronic conditions and physical disabilities seek physical therapy treatment to address movement dysfunctions that limit their participation in daily activities. Cardiovascular endurance and walking ability are often significant factors that are targeted to enhance patients' functional mobility. Current evidence-driven locomotor training techniques, including use of robotic devices and body weight supported treadmill systems, are based on providing individuals with a high volume of task-specific practice (Dean, 2010; Field-Fote, 2011; Lo, 2010; Wier, 2011). Unfortunately, these treatment interventions are frequently unavailable within the rehabilitation setting because financial restrictions and staffing limitations result in poor access to the necessary technologies (Burnfield, Shu, 2011; Buster, 2009).

The ICARE, an **I**ntelligently **C**ontrolled **A**ssistive **R**ehabilitation **E**lliptical, was designed to provide an affordable tool that could be used across healthcare settings to improve the cardiovascular fitness and walking function of individuals with physical disabilities. The SportsArt Fitness E870 elliptical trainer was selected for inclusion of an affordable set of modifications because of the similarities to normal walking in both muscle demands and joint movements (Burnfield, Shu, 2010). The system integrates an intelligently controlled motor providing assistance for continuous pedal motion at speeds up to 65+ revolutions per minute (rpm), enabling individuals with weakness and/or decreased endurance to utilize the device. The stride length of the elliptical adjusts between 17in (43cm) to 29in (74cm) to accommodate various step lengths during training. Additional adaptations include safety rails, steps, a ramp, an adjustable height seat, a body weight support (BWS) system, and footplate straps for improved accessibility and usability. Through manipulation of the ICARE speed and BWS level, a person's training program can be customized and progressed as needed (Burnfield, Buster, 2010; Burnfield, Hildner, 2011). Overall, the modifications incorporated into the ICARE minimize the need for assistance and improve feelings of safety and comfort for an enhanced exercise experience by individuals with various medical conditions (Burnfield, Shu, 2011).

PURPOSE

The primary objective of this study was to assess use of the ICARE as an adjunct to physical therapy in a population of individuals with physical disabilities and chronic conditions. We hypothesized that, within this population, the ICARE device could serve as a feasible therapeutic treatment option to improve cardiovascular fitness and functional mobility.

METHODS

Six females and four males (ages 29-88 years) receiving outpatient physical therapy at Madonna Rehabilitation Hospital were recruited for the study. These individuals were referred for physical therapy treatment to address trunk or lower extremity movement deficits related to their primary diagnoses which included multiple sclerosis, Parkinson's disease, stroke, spinal cord injury, Guillain-Barré syndrome, stiff person's syndrome, encephalitis, and a blood infection. Among the sample, secondary medical conditions of arthritis, osteoporosis, thyroid dysfunction, total joint replacement, cancer, diabetes, and cardiovascular disease also were reported by individuals. Each participant signed an informed consent form approved by the Institutional Review Board at Madonna Rehabilitation Hospital.

In addition to attending scheduled physical therapy appointments, each participant was asked to train on the ICARE two to three times per week for a total of twelve, 1-hour sessions. Training duration (DUR), rest periods,

velocity (VEL), stride length (SL), total strides, and amount BWS provided were recorded for each session. Heart rate (HR) and blood pressure (BP) also were measured, and participants reported their Borg rate of perceived exertion (RPE) following each training bout. Combined, this information was utilized to customize and progress the training program for each individual.

Prior to initiating the structured ICARE program, participants engaged in a brief clinical assessment to evaluate functional abilities. Clients completed tests for balance including the Dynamic Gait Index (DGI), Timed Up and Go test (TUG), and the Berg Balance Scale (BBS). Walking ability was assessed through a 5 Minute Walk Test (5MWT) to measure endurance and a 6 meter walk test to calculate self selected walking speeds at comfortable and fast paces. Following completion of the ICARE training program, these clinical tests were repeated to reassess participants' functional capabilities.

Individual responses and ICARE parameters from early training (second session) and late training (last session) were averaged using Excel for each participant. Data from the second session were utilized for the assessment of early training demands because the first session was abbreviated to allow for baseline clinical measures. A heuristic process determined training parameters that guided individualized exercise progression in successive sessions. Descriptive statistics across all 10 participants for ICARE training variables and clinical test scores were then calculated using SigmaPlot 11.0. Paired t-tests identified significant differences in exercise parameters as well as pre and post clinical data with statistical significance defined as $p<0.05$.

RESULTS

ICARE training parameters increased in intensity from early to late training phases with corresponding improvements in the group's clinical measures of endurance and balance. Table 1 summarizes the changes in ICARE training parameters over time, while Table 2 highlights physiologic responses. Significant increases in DUR, VEL, SL, and total strides/session occurred without notable changes in the participants' RPEs, HR, and BP, indicating that participants tolerated more demanding levels of exercise at the end of the training program. Performance on clinical measures of walking endurance and balance significantly improved following training (Table 3). The participants covered greater distances during the 5MWT and scored higher on the BBS. TUG time and walking speed showed a trend toward improvement, but these measures did not achieve statistical significance.

Table 1: Differences in ICARE Training Parameters Between Second and Last Session (mean, SD)

Parameter	Second Session	Last Session	Significance
Session Duration (s)	586 (265)	899 (272)	$p = 0.001$
Total Strides per Session	330 (214)	621 (319)	$p < 0.001$
Velocity (rpm)	33.8 (6.9)	40.7 (8.8)	$p = 0.003$
Stride Length (m)	0.56 (0.097)	0.65 (0.086)	$p = 0.030$
Body Weight Support (% body weight)	13.6 (10.4)	10.0 (11.0)	NS

NS= not significant

Table 2: Comparison of Physiological Measures Between Second and Last Session (mean, SD)

Measure	Second Session	Last Session	Significance
Borg Perceived Exertion	12.2 (1.9)	12.8 (1.6)	NS
Heart Rate	94.6 (17.5)	98.3 (19.0)	NS
Systolic BP	133.2 (23.8)	129.5 (22.0)	NS
Diastolic BP	79.3 (11.7)	76.3 (10.5)	NS

NS= not significant

Table 3: Changes in Functional Clinical Assessments Before (Pre) and After (Post) Training (mean, SD)

Measure	Pre-Training	Post-Training	Significance
Comfortable Walking Speed (m/s)	0.50 (0.35)	0.61 (0.43)	NS
Fast Walking Speed (m/s)	0.67 (0.44)	0.73 (0.46)	NS
5MWT (m)	106.4 (67.1)	137.0 (87.6)	$p = 0.002$
TUG (s)	33.2 (23.9)	31.2 (26.6)	NS
Berg Balance Score	37.0 (14.5)	39.6 (14.5)	$p = 0.004$

NS= not significant

DISCUSSION

In the current study we evaluated application of ICARE training as an adjunct to physical therapy treatment to determine if the device can be utilized to improve cardiovascular fitness and functional mobility. Collectively, the changes in ICARE training parameters over the course of the program suggest that exercise tolerance improved, with individuals enduring longer exercise bouts at higher speeds without an increase in perceived exertion, HR or BP. Also consistent with our hypothesis, improvements in functional mobility were observed in the group for balance and walking endurance. No adverse events were reported during this pilot program, suggesting that ICARE training is a feasible treatment option for individuals with a wide variety of diagnoses receiving outpatient therapy. Overall, the results indicate that the ICARE is a practical training device likely to benefit individuals with limited functional abilities receiving physical therapy. Given that ICARE training was provided as an adjunct to therapy, the independent effects of the intervention cannot yet be determined. Further work is currently underway to assess ICARE utilization for individuals with chronic conditions not concurrently enrolled in physical therapy. Future investigations of ICARE use will need to consider the most effective combination of training parameters (e.g., training speed, level of body weight support, stride length, duration of exercise sessions) and evaluate in what phases of the disease process or stages of injury recovery individuals are most responsive.

ACKNOWLEDGEMENTS

This work was supported in part by a grant from the Department of Education, NIDRR grant number H133G070209.

REFERENCES

Burnfield, J.M., Buster, T.W., Taylor, A., Keenan, S., Shu, Y., Nelson, C.A. (2010). Intelligently controlled assistive rehabilitation elliptical (ICARE) training: An analysis of lower extremity electromyographic (EMG) demands with varying levels of motor assistance. *Online Proceedings, Rehabilitation Engineering and Assistive Technology Society of North America's 2010 Annual Conference.*

Burnfield, J.M., Hildner, G.A., Buster, T.W., Taylor, A.P., Shu, Y. (2011). Impact of speed on muscle demands during partial body weight supported training on a motorized elliptical. *Archives of Physical Medicine, 92*(10): 1700.

Burnfield, J.M., Shu, Y., Buster, T.W., Taylor, A.P. (2010). Similarity of joint kinematics and muscle demands between elliptical training and walking: Implications for practice. *Physical Therapy, 90*(2), 289-305.

Burnfield, J.M., Shu, Y., Buster, T.W., Taylor, A.P., Nelson, C.A. (2011). Impact of elliptical trainer ergomomic modifications on perceptions of safety, comfort, workout, and usability for people with physical disabilities and chronic conditions. *Physical Therapy, 91*(11),1604-1617.

Buster, T.W., Goldman, A.J., Corbridge, L.M., Shu, Y., Burnfield, J.M. (2009). Partial body weight support treadmill training: Clinician's upper extremity muscle activation during facilitation of hemiparetic limb movement. *Proceeding of the Gait and Clinical Movement Analysis Society 14th Annual Meeting,* 258-259.

Dean, C.M., Ada, L., Bampton, J., Morris, M.E., Katrak, P.H., Potts, S. (2010). Treadmill walking with body weight support in subacute non-ambulatory stroke improves walking capacity more than overground walking: A randomized trial. *Journal of Physiotherapy, 56*, 97-103.

Field-Fote, E.C., Roach, K.E. (2011). Influence of a locomotor training approach on walking speed and distance in people with chronic spinal cord injury: A randomized clinical trial. *Physical Therapy, 91*(1), 48-60.

Lo, A.C., Chang, V.C., Gianfrancesco, M.A., Friedman, J.H., Patterson, T.S., Benedicto, D.F. (2010). Reduction of freezing of gait in Parkinson's disease by repetitive robot assisted treadmill training: A pilot study. *Journal of NeuroEngineering and Rehabilitation, 7*, 51-58.

Wier, L.M., Hatcher, M.S., Triche, E.W., Lo, A.C. (2011). Effect of robot assisted versus conventional body weight supported treadmill training on quality of life for people with multiple sclerosis. *Journal of Rehabilitation Research and Development, 48*(4), 483-492.