

# Isokinetic muscle strength and fatigue evaluation following a combined aerobic and resistance training program on a gravity independent flywheel device

Joshua A. Cotter<sup>1</sup>, Tomasz Owerkowicz<sup>2,3</sup>, Alvin M. Yu<sup>2</sup>, Marinelle L. Camilon<sup>2</sup>, Theresa Hoang<sup>2</sup>, Per A. Tesch<sup>4</sup>, Vince J. Caiozzo<sup>1</sup>, Greg R. Adams<sup>2</sup>

<sup>1</sup>Orthopaedic Surgery, <sup>2</sup>Physiology and Biophysics, <sup>3</sup>Ecology and Evolutionary Biology, Medical Sciences I, University of California, Irvine, CA 92697-4560; <sup>4</sup>Health Science, Mid Sweden University, Östersund, SE-83125.

**Introduction.** Exposure to microgravity imposes changes on the musculoskeletal and cardiovascular systems leading to decreases in aerobic capacity, muscular strength, and muscular fatigue (1). Anti-gravity muscles, those that play a postural role in a standard gravity environment such as the soleus and quadriceps, are most affected by microgravity (2) with nearly all musculature affected with extended spaceflight (3). The multi-mode exercise device (M-MED) is a gravity independent device that provides both high force resistance type and low force aerobic type modes of exercise. Consequently, the M-MED has the ability to enhance both skeletal muscle function through resistance training exercises as well as cardiovascular function with aerobic training.

**Materials and Methods.** The efficacy of the M-MED to provide increases in both aerobic and skeletal muscle function was tested on a group of young sedentary subjects (6 males, 169.1 cm, 69.0 kg; 6 females, 163.7 cm, 68.8 kg). All subjects performed 15 aerobic sessions of high-intensity interval rowing, 9 resistance training sessions of horizontal squats, heel raises, and hamstring curls, and 5 sessions of heel raises only throughout a 5 week period. Rowing consisted of a 5 minute warm-up followed by 4 intervals of 4 minutes of high-intensity (90% heart rate max) and 4 minutes of low-intensity (50% HR max) rowing. Resistance training included 4 sets of 7 repetitions for horizontal squats and hamstring curls and 4 sets of 15

repetitions for heel raises. Differences between pre and post values were determined by using the paired t-test.

**Results.** Aerobic capacity, determined by graded cycle ergometry, increased by 10.1%. Maximal knee extensor torque obtained from isokinetic dynamometry was increased at angular velocities between 90-300°/s but not at 30 and 60°/s or with isometric contractions and eccentric velocities of 30 and 120°/s (Figure 1).

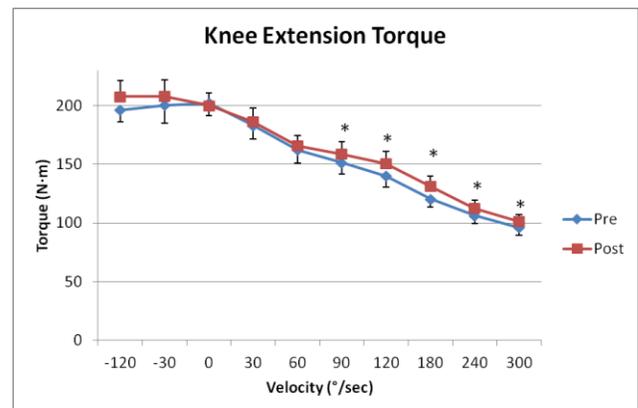


Figure 1. Knee extension torque. \* denotes significant difference at  $p < 0.05$ .

Maximal knee flexor torque was increased at all velocities (30-300°/s) and isometric contractions but not with eccentric velocities (Figure 2). Maximal ankle plantar flexor torque was unchanged across all velocities except for 180°/s where torque decreased. Plantar flexor torque was increased for isometric contractions (Figure 3). Fatigue testing consisted of 3 sets of 30 maximal knee extensions at 180°/s with 60

seconds of rest between sets. Data was broken down into groups of five repetitions. Muscular endurance was increased at each time point throughout the test (Figure 4).

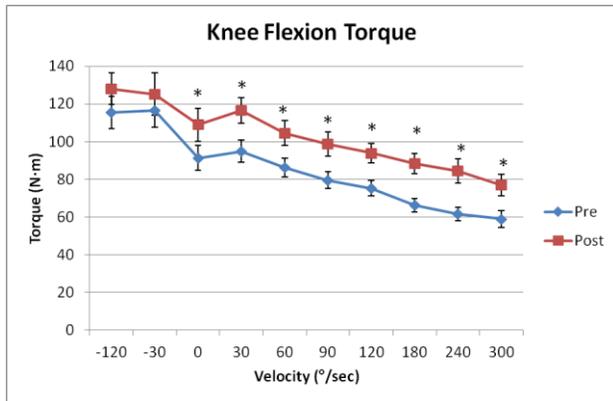


Figure 2. Knee flexion torque. \* denotes significant difference at  $p < 0.05$ .

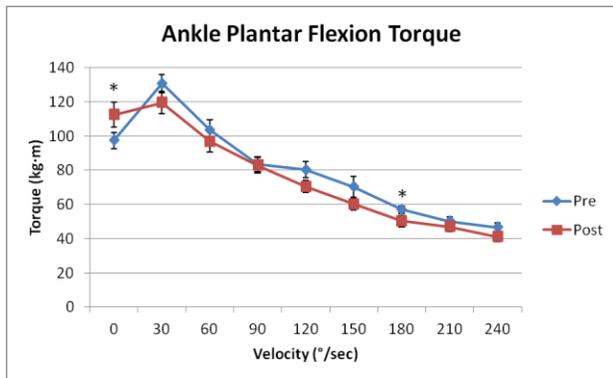


Figure 3. Ankle plantar flexion torque. \* denotes significant difference at  $p < 0.05$ .

*Discussion.* Five weeks of combined aerobic and resistance training on the M-MED showed improvements in aerobic capacity and isokinetic strength and endurance. Although either a decrease or no change was seen at all contraction velocities except for isometric, the authors hypothesize that this may be due to a learning effect. Due to a high level of encouragement, subjects may have engaged their quadriceps muscles to assist the plantar flexors thereby inflating the pre-training values for torque production. During post-testing, subjects may have learned improved control through both practice as well as training to better utilize the plantar flexor group while limiting quadriceps involvement producing more accurate, yet lower, torque values.

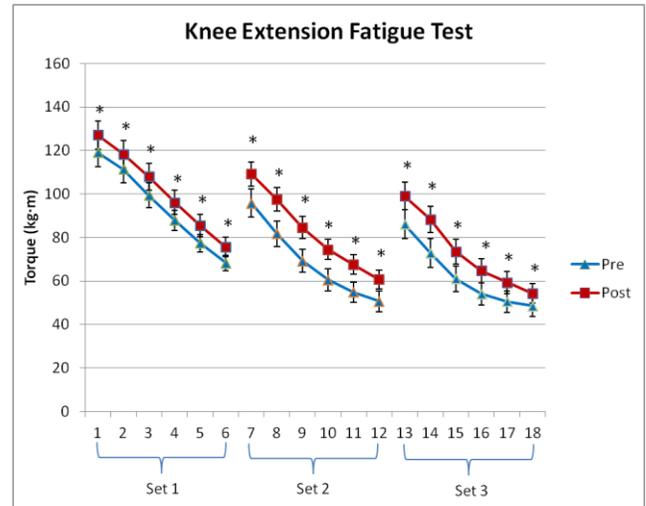


Figure 4. Knee extension fatigue test. \* denotes significant difference at  $p < 0.05$ .

Additional testing has shown that the 3-repetition max, another measure of strength, had a trend towards a 7% increase for the plantar flexors ( $p = 0.108$ , data not shown) utilizing the same training program described here. Future studies should evaluate the effectiveness of the M-MED in a simulated microgravity environment. In conclusion, the M-MED provides both resistance and endurance type training allowing for improvements in both aerobic and muscular performance supporting its efficacy as a potential countermeasure to microgravity.

## References

- Steinburg S. Bioastronautics Roadmap, Vol. 2010 Rev. B. <http://humanresearchroadmap.nasa.gov/>. National Aeronautics and Space Administration, Houston, TX.
- Fitts RH, Riley DR, and Widrick JJ. Physiology of a Microgravity Environment Invited Review: Microgravity and skeletal muscle. *Journal of Applied Physiology*. 2000;89(2):823-39.
- LeBlanc A, Lin C, Shackelford L, Sinitsyn V, Evans H, Belichenko O, Schenkman B, Kozlovskaya I, Oganov V, Bakulin A, Hedrick T, and Feedback D. Muscle volume, MRI relaxation times ( $T_2$ ), and body composition after spaceflight. *Journal of Applied Physiology*. 2000;89(6):2158-64.