Muscle Volume Increases Following 16 Weeks of Resistive Exercise Training with the Advanced Resistive Exercise Device (ARED) and Free Weights

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Abstract

Free weight-loaded muscle atrophy, particularly in the posterior and cancellous muscles, may impact task performance during long-duration space missions and planetary exploration. High intensity free weight (FW) training has been shown to prevent atrophy during only a few space flights. NASA has employed the International SUpercomputer for Medical Research (ISMR) to examine the effects of whole-body free weight (FW) training. Free weight nominal training consists of multiple repetition maximum strength measurements (1RM) at the squat (SQ), heel raise (HR), and deadlift (DL). The recent deployment of the Advanced Resistive Exercise Device (ARED) presents an opportunity to study the effects of FW training. The purpose of this study was to compare the efficacy of ARED and FW training to induce hypertrophy in specific muscle groups in ambulatory subjects. The image above is the CSA of a thigh. The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green). The image above is the CSA of a calf. The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green). The image above is the CSA of a calf. The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green).

Introduction

• Muscle atrophy and reduced muscle strength have been observed following long-duration space missions (Fletcher, 2006, Trappe, 2009). Decreased muscle performance is considered a human health and performance risk by the Human Research Project at the Johnson Space Center, National Aeronautics and Space Administration (NASA). Decreased muscle function may impact career performance and mission success during long-duration missions and planetary exploration.

• The interim Resistive Exercise Device (iRED) has been utilized since the first International Space Station (ISS) mission as a cornerstone for strength losses and muscle atrophy, but did not prove to be completely effective (Lee, 2004). ARED was developed by NASA to address iRED's limitations in workload, 1.3 kg of resistive resistance, limited range of motion, and low eccentric forces that may have decreased in efficacy. ARED, recently deployed on ISS during Expedition 18, provides up to 272 kg of loading.

Purpose

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Methods

A RED was deployed on the ISS during Expedition 18, providing up to 272 kg of loading. ARED and FW training were conducted 3 d·wk-1 for 16 wks.  SQ, HR, and DL muscle strength (1RM) was measured before, after 8 wks, and developed the Advanced Resistive Exercise Device (ARED) to simulate the characteristics of FW exercise (i.e. eccentric loading, high intensity). The image at left is the CSA of a thigh.  The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green). The image above is the CSA of a calf. The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green). The image at left is the CSA of a thigh.  The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green).

Results

There were no between-group differences in strength gains in squat, heel raise, or deadlift. There were no differences between the training groups in any of the muscle groups.

Conclusions

ARED training elicited increases in muscle volume and strength that were not different than those elicited by FW training. Some subjects during bed rest utilized loads as high as 24 kg during their exercise training to prevent muscle atrophy and bone demineralization (Shackelford, 2004). By providing the capability to perform resistive exercise at similar levels of intensity, with eccentric loading, we suspect that muscle and bone will be better protected than previously observed (Lee, 2004; Trappe, 2009). The increases in the V/AUG, LG, and MG over the test of the muscle groups indicates a possible need to revisit either the primary exercises themselves (squat, bed rest, and deadlift) and the kinetics of potentially add other exercises focusing on the other muscle groups.

Acknowledgments

This work was supported by NASA Johnson Space Center’s Exercise Countermeasures Project. The authors gratefully acknowledge the authors who performed the experiments, Yerachmiel A. Loehr, David A. Lee, and Sherry Restall. This project is dedicated in the memory of former management, member, and friend, Dr. Don Hagan.

References


Protection of Human Subjects.

Overall Study Design

• Twenty volunteers (14 men, 6 women) consented to participate in this study and were assigned to either a FW or ARED training group. The study protocol was reviewed and approved by the Johnson Space Center’s Committee for the Protection of Human Subjects.

• Subjects performed squat, heel raise, and deadlift exercises 3 d·wk-1 for 16 weeks using a personalized resistive exercise training program.

• Each group performed 33% maximum strength measurements (1RM) on both the ARED and FW. Training loads were prescribed from the BMI acquired on the training specific hardware for each exercise before and after 8 weeks of training.

• FW & ARED 1RM were measured pre-, mid-, and post-training for all three exercises.

MRI Methods

• Magnetic Resonance images (MRI) were acquired pre- and post-training.

• Images were analyzed using the GNU Image Manipulation Program (GIMP 2.6.6, Berkley, California).

• Cross-sectional area (CSA) was calculated within each slice of the Rectus Femoris (RF), the Vasti group (V), the Hamstring group (H), and the Adductor group (Add) in the thigh and the Anatomical Compartment (AC), Lateral Gastrocnemius (LG), Medial Gastrocnemius (MG), and the Deep Posterior Group (DP) in the calf.

• CSA (% of peak) = PDV

• Muscle Volume = sum of CSA of each slice (sum of slice thickness and intensity (ppi))

Figure Legend

The image at left is the CSA of a thigh. The four muscle groups in this image are the RF (red), the V (blue), the H (yellow), and the Add (green). The image above is the CSA of a calf. The four muscle groups are the AC (blue), the LG (yellow), the MG (purple), and the DP (green).

* = Main effect of time (p < 0.05)

** = There were no differences between the training groups in any of the muscle groups.

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