EFFECTS OF LONG-TERM SPACE FLIGHT ON MUSCLE VOLUME

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INTRODUCTION

In a microgravity environment, the disuse of the lower extremities is known to cause physiological deconditioning of muscle. Previous studies have reported that considerable lower extremity muscle volume loss occurs during both short (Shuttle) and long-duration space flights (MIR), 3-10% and 5-17% loss respectively, even with exercise countermeasures [1]. It has been speculated that disuse of the lower extremity may be the principal mechanism of atrophy. The purpose of this study is to quantify the atrophy that occurs in the individual muscle groups of the lower and upper extremities of crewmembers on the International Space Station (ISS). This information will later be coupled with activity and strength data obtained from the same subjects.

METHODS

Muscle volume changes were calculated using Magnetic Resonance (MR) images taken from two male ISS crewmembers before and after space flights of 161 and 194 days. Images of the thigh, calf, and arm were acquired pre- and post-flight (within 5 days of re-entry). Images of standard cylindrical calibration phantoms were also obtained to allow quantification of distortion in the images. The muscle groups of interest were the quadriceps, hamstrings, medial gastrocnemius, soleus, anterior calf, and anterior and posterior arm. The non-anatomical groupings (e.g. anterior calf) were used because of the difficulty in identifying individual muscles on MRI.

Each muscle group was traced manually from individual slices using custom MATLAB (MathWorks Inc.) software and then corrected for MRI distortion. The offset between pre- and post-flight images was accounted for by aligning each scan according to the endosteal area of the femur, tibia, or humerus. This alignment ensured that comparable regions were evaluated pre- and post-flight. The traced muscle contours were reconstructed using Rhinoceros 3D Modeling software (Robert McNeel & Associates) to visualize the muscle mass and volume measured.

In order to estimate the user-reliability of the manual tracings, statistical analyses were performed in terms of intra-class correlation coefficient (ICC) based on two-way ANOVA. Three users traced three groups of muscles three times each in order to calculate the ICCs.

RESULTS AND DISCUSSION

The mean intra-observer ICCs of all the muscle groups, calculated based on muscle cross-sectional area (CSA), for all observers were $\geq$ 0.99, the mean inter-observer ICC for all muscle groups based on muscle CSA were $\geq$ 0.98. These high values indicate good agreement between and within observers.

The mean percentage volume changes, over the duration of the missions, of the quadriceps, hamstrings, medial gastrocnemius soleus, and the anterior calf, were found to be -6.4%, -4.4%, -7.7%, -16.4% and -11.9% respectively. In the anterior and posterior arm groups of muscles, the volume changes were 1.7% and no change respectively.

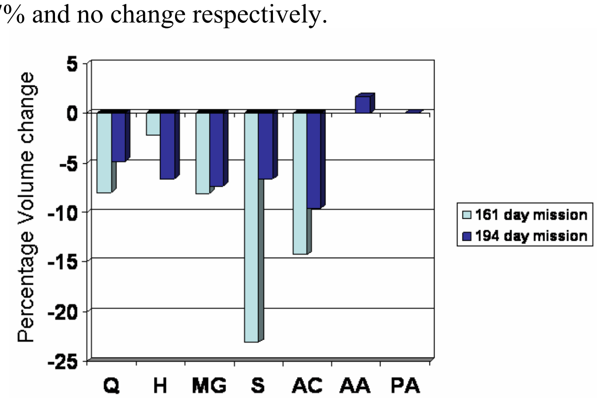

Figure 1: Percentage muscle volume changes for two subjects during 161- and 194-day missions on the ISS. Quadriceps (Q), hamstrings (H), medial gastrocnemius (MG), soleus (S), anterior calf (AC), anterior arm (AA), and posterior arm (PA)

CONCLUSIONS

Although exercise countermeasures were performed on-orbit, significant muscle loss was observed in the lower extremities while no loss occurred in the arms (Figure 1). This atrophy is likely due to disuse of the lower extremity which was not adequately protected by the exercise regimens performed on-orbit [2]. The absence of substantial change in muscle volume in the arms is possibly due to the continued daily use of the upper extremities on-board the ISS. More research is needed to design and implement effective countermeasures to the changes observed and data from additional subjects will be available on future ISS missions. Current experiments using bedrest to evaluate proposed countermeasures and exercise prescriptions will provide valuable insights into muscle loss and its prevention during long-duration space flight.

REFERENCES

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