BIOMECHANICS OF TREADMILL LOCOMOTION ON THE INTERNATIONAL SPACE STATION

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INTRODUCTION

Exercise prescriptions completed by International Space Station (ISS) crewmembers are typically based upon evidence obtained during ground-based investigations, with the assumption that the results of long-term training in weightlessness will be similar to that attained in normal gravity. Coupled with this supposition are the assumptions that exercise motions and external loading are also similar between gravitational environments. Normal control of locomotion is dependent upon learning patterns of muscular activation and requires continual monitoring of internal and external sensory input [1]. Internal sensory input includes signals that may be dependent on or independent of gravity. Bernstein hypothesized that movement strategy planning and execution must include the consideration of segmental weights and inertia [2]. Studies of arm movements in microgravity showed that individuals tend to make errors but that compensation strategies result in adaptations, suggesting that control mechanisms must include peripheral information [3-5]. To date, however, there have been no studies examining a gross-motor activity such as running in weightlessness other than using microgravity analogs [6-8]. The objective of this evaluation was to collect biomechanical data from crewmembers during treadmill exercise before and during flight. The goal was to determine locomotive biomechanics similarities and differences between normal and weightless environments. The data will be used to optimize future exercise prescriptions. This project addresses the Critical Path Roadmap risks 1 (Accelerated Bone Loss and Fracture Risk) and 11 (Reduced Muscle Mass, Strength, and Endurance).

METHODS

Data were collected from 7 crewmembers before flight and during their ISS missions. Before launch, crewmembers performed a single data collection session at the NASA Johnson Space Center. Three-dimensional motion capture data were collected for 30 s at speeds ranging from 1.5 to 9.5 mph in 0.5 mph increments with a 12-camera system. During flight, each crewmember completed up to 6 data collection sessions spread across their missions, performing their normal exercise prescription for the test day, resulting in varying data collection protocols between sessions. Motion data were collected by a single HD video camera positioned to view the crewmembers' left side, and tape markers were placed on their feet, legs, and neck on specific landmarks. Before data collection, the crewmembers calibrated the video camera. Video data were collected during the entire exercise session at 30 Hz. Kinematic data were used to determine left leg hip, knee, and ankle range of motion and contact time, flight time, and stride time for each stride – 129 trials in weightlessness were analyzed. Mean time-normalized strides were found for each trial, and cross-correlation procedures were used to examine the strength and direction of relationships between segment movement pattern timing in each gravitational condition.

RESULTS

Cross-correlation analyses between gravitational conditions revealed highly consistent movement patterns at each joint. Peak correlation coefficients occurred at 0% phase, indicating there were no lags in movement timing. Joint ranges of motion were similar between gravitational conditions, with some slight differences between subjects.

DISCUSSION

Motion patterns in weightlessness were highly consistent at a given speed with those occurring in 1 G, indicating that despite differing sensory input, subjects maintained running kinematics. The data suggest that individuals are capable of compensating for loss of limb weight when creating movement strategies. These results have important implications for creating training programs for use in weightlessness as practitioners can have greater confidence in running motions transferring across gravitational environments. Furthermore, these results have implications for use by researchers investigating motor control mechanisms and investigating hypotheses related to movement strategies when using sensory input that is dependent upon gravity.

REFERENCES

[1] Clement G, Reschke MF. (2008) *Neuroscience in Space* (Springer, New York), 152-161. [2] Bongaardt R, et al. (2000) *J Motor Behav* 32, 57-71. [3] Papaxanthis C, et al. (2005) *Neuroscience* 135, 371-383. [4] Bringoux L, et al. (2012) *J Neurophysiol* 107, 2541-2548. [5] Gaveau J, et al. (2011) *J Neurophysiol* 106, 620-629. [6] Massion J, et al. (1998) *Brain Res Rev* 28, 83-91. [7] De Witt JK, et al. (2010) *Aviat Space Environ Med*, 81, 1092-1099. [8] Everett ME, et al. (2009) *Aviat Space Environ Med*, 80, 882-886.