GRAVITAIONAL EFFECTS UPON LOCOMOTION POSTURE

John K. DeWitt[1], Jason R. Bentley[1], W. Brent Edwards[2], Gail P. Perusek[3] and Sergey Samorezov[4]

[1]Wyle's Life Sciences Group, Houston, TX, USA; [2]The Iowa State University, Ames, IA, USA; [3]NASA Glenn Research Center, Cleveland, OH, USA; [4]ZIN Technologies, Cleveland, OH, USA. email: john.k.dewitt@nasa.gov

INTRODUCTION

Researchers use actual microgravity (AM) during parabolic flight and simulated microgravity (SM) obtained with horizontal suspension analogs to better understand the effect of gravity upon gait. In both environments, the gravitational force is replaced by an external load (EL) that returns the subject to the treadmill. However, when compared to normal gravity (N), researchers consistently find reduced ground reaction forces (GRF) and subtle kinematic differences (Schaffner et al., 2005).

On the International Space Station, the EL is applied by elastic bungees attached to a waist and shoulder harness. While bungees can provide EL approaching body weight (BW), their force-length characteristics coupled with vertical oscillations of the body during gait result in a variable load. However, during locomotion in N, the EL is consistently equal to 100% body weight.

Comparisons between AM and N have shown that during running, GRF are decreased in AM (Schaffner et al, 2005). Kinematic evaluations in the past have focussed on joint range of motion rather than joint posture at specific instances of the gait cycle. The reduced GRF in microgravity may be a result of differing hip, knee, and ankle positions during contact. The purpose of this investigation was to compare joint angles of the lower extremities during walking and running in AM, SM, and N. We hypothesized that in AM and SM, joints would be more flexed at heel strike (HS), mid-stance (MS) and toe-off (TO) than in N.

METHODS AND PROCEDURES

Five subjects (2M/3F) completed treadmill walking at 1.34 $m\cdot s^{-1}$ (3 mph) and running at 3.13 $m\cdot s^{-1}$ (7 mph) in SM, N, and AM. SM trials were collected on the enhanced Zero Gravity Locomotion Simulator (eZLS) at NASA Glenn Research Center. N trials were collected on a laboratory treadmill immediately following the SM trials. AM trials were collected during parabolic flight onboard a DC9 aircraft at NASA Johnson Space Center. The EL during AM and SM with EL were approximately 88% BW (SM = 89.0 ± 4.2 % BW; AM = 87.3 ± 6.6 %BW).

Kinematic data were collected with a video motion capture system (SMART Elite, BTS Bioengineering SPA, Milanese, IT) at 60 Hz. The 3-D positions of lower extremity and trunk markers were recorded, rotated into a treadmill reference frame, and projected on to the sagittal plane. All subsequent kinematic calculations were completed in 2-D.

Hip, knee, and ankle joint angles were computed as the angles between markers defining the long axes of adjacent segments. The HS and TO events were found using toe and heel markers. MS was defined as the event 20% between HS and TO. Contact time (CT) was the time between TO and HS, and stride time (ST) was the time between successive HS. Multiple strides were analyzed for each condition. Joint angle means were tested for differences using repeated measure

ANOVAs with location as the main effect. Tukey-Kramer multiple comparison post hoc tests were used to determine pairwise differences ($p<0.05$).

RESULTS (Figure 1)

During walking, the hip flexion angle at HS was greater in AM than in SM or N. Knee flexion angle at HS was greater in AM than N. At MS, the ankle dorsiflexion angle was greater in N than AM, and at TO, SM ankle dorsiflexion angle was greater than AM.

During running, ST was greater in SM than AM. The hip flexion angle at HS and MS was greater in AM than SM and N. The ankle dorsiflexion angle at TO in AM was less than in SM or N.

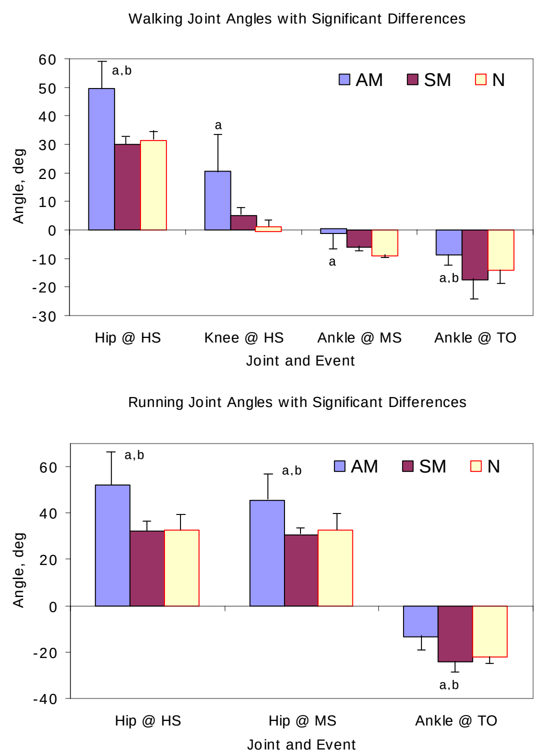

Figure 1. Walking (upper) and running (lower) joint angular displacements. [a]different than N, [b]different than SM

DISCUSSION

While temporal kinematics were similar between conditions during walking, and there were no differences in temporal kinematics between AM and N during running, differences were detected in joint angular displacements during specific instances of the gait cycle. Therefore, reporting only the range of motion of the lower extremity joints may not completely describe the effects of reduced gravity upon locomotion. Surprisingly, there were differences in joint angles between SM and AM, but no differences between SM and N, suggesting that locomotion in SM and N are more similar to one another than locomotion in AM.

McMahon et al. (1987) showed that when running with increased flexion at the knees, GRF were attenuated. The dampened GRF reported during locomotion in AM may result from the increased hip and knee flexion that occurs as a response to the EL being applied to the waist and shoulders via the harness.

SUMMARY

Locomotion in AM results in postural differences when compared to SM and N. The postural differences may explain attenuations in GRF. Increasing the EL to obtain greater GRF in AM may not be the best solution due to kinematic adaptations in response to the increased loads.

REFERENCES

McMahon et al. (1987). *J Appl Physiol*, 62: 2326-2337.

Schaffner, G. et al. (2005). *NASA/TP-2005-213169*.

ACKNOWLEDGEMENTS

We thank the Exercise Countermeasures Project at NASA JSC for their support.