

KINEMATIC AND EMG COMPARISON OF GAIT IN NORMAL G AND MICROGRAVITY

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INTRODUCTION

Astronauts regularly perform treadmill locomotion as part of their exercise prescription while they are on board the International Space Station. Although locomotive exercise has been shown to be beneficial for bone, muscle, and cardiovascular health, astronauts return to Earth after long-duration missions with net losses in all three areas [1]. These losses might be partially explained by fundamental differences in locomotive performance between normal gravity (NG) and microgravity (MG).

During locomotive exercise in MG, the subject must wear a waist and shoulder harness that is attached to elastomer bungees. The bungees are attached to the treadmill, and provide forces that are intended to replace gravity. However, unlike gravity, which provides a constant force on all body parts, the bungees provide a spring force only to the harness. Therefore, exercise in MG has two fundamental differences from exercise in NG: 1) forces returning the subject to the treadmill are not constant, and 2) forces are applied to the axial skeleton only at the waist and shoulders. The effectiveness of the exercise may also be affected by the magnitude of the gravity replacement load. Historically, astronauts have difficulty performing treadmill exercise with loads that approach body weight (BW) because of discomfort and inherent stiffness in the bungee system.

The unique requirements for locomotion in MG could cause differences in performance between gravitational locations. These differences may help to explain why long-term effects of treadmill exercise training in MG may differ from those found in NG. The purpose of this investigation was to compare locomotion in NG and MG to determine if differences in kinematic or muscular activation pattern occur between gravitational environments.

METHODS

Five subjects (2M, 3F) completed treadmill walking at $1.34 \text{ m}\cdot\text{s}^{-1}$ and running at $3.13 \text{ m}\cdot\text{s}^{-1}$ in NG and MG. NG trials were collected on a laboratory treadmill at NASA Glenn Research Center. MG trials were collected during parabolic flight on a C-9 aircraft at NASA Johnson Space Center. The external load (EL) was provided by bungees during MG trials. Trials were completed under low EL ($56.2 \pm 6.3\% \text{ BW}$) and high EL ($87.3 \pm 6.6\% \text{ BW}$) conditions.

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

Telemetered electromyography (EMG) (Myomonitor III Wireless EMG System, Delsys Inc., Boston, MA) was used to obtain data on activation of the tibialis anterior, gastrocnemius, rectus femoris, semimembranosus, and gluteus maximus. Before any motion trials were conducted, subjects performed maximal voluntary isometric contractions of each muscle to standardize electrode placement. All motion capture and EMG data were synchronized via a global analog pulse that was recorded simultaneously by each hardware device.

Hip, knee, and ankle joint range of motion (ROM) and flexion and extension extremes were computed using the angles between adjacent segments, with markers defining their long axes. EMG data were rectified and filtered and then examined to quantify the time of initial activation and the total activation duration of each stride using the methods of Browning et al. [2]. Multiple strides were analyzed

for each gravitational environment, and trial means were computed. Effect sizes (ESs) and their 95% confidence intervals (CIs) were computed for joint kinematic and EMG scores.

RESULTS and DISCUSSION

When all factors tested were combined (EL, locomotive mode), 96 comparisons were made. Because our intent was to identify differences between gravitational environments, we have limited our presentation to variables in which the 95% confidence interval for the effect size did not include 0 (see Table 1, Figure 1).

Hip ROM during walking was larger in MG with low EL, and the hip achieved greater flexion during MG than NG. Maximum dorsiflexion was larger in NG than MG during walking with high EL. The gastrocnemius was activated earlier in the stride in MG during high EL.

Hip ROM was the only kinematic measure that was different for the two gravitational environments during running. Subjects achieved greater hip flexion in MG. In each running condition, the gluteus maximus and semimembranosus were activated later in the stride in MG.

Although we tested only a small sample, we have detected some differences between locomotion in MG and NG that centralize about the hip, with the exception of ankle kinematic and musculature effects found during walking with high EL. Returning astronauts have been found to have a net decrease in bone mineral density at the hip after long-term spaceflight [1]. Interestingly, hip ROM seems to be greater in MG than in NG. This increase in ROM may be an adaptation to accommodate the EL, but also acts to reduce the countermeasure efficacy.

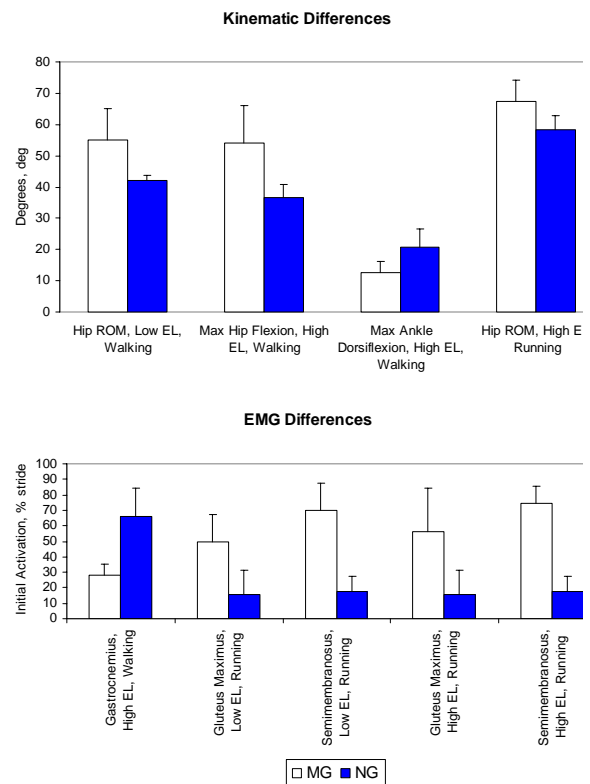


Figure 1: Differences between MG and NG for kinematic (upper) and EMG (lower) dependent variables.

Our data suggest that kinematics and muscle activation may be different in MG and NG during running, and this could influence responses to training. It may also help us better understand why musculoskeletal deconditioning occurs during space flight. Future research with larger numbers of subjects is necessary to better quantify kinematic and EMG differences between MG and NG.

REFERENCES

1. LeBlanc AD, et al. *J Musculoskelet Neuronal Interact* **7**, 33-47, 2007.
2. Browning RC, et al. *Med Sci Sports Exerc* **39**, 515-525, 2007.

Table 1: Effect sizes (ESs, MG vs NG) and their 95% CIs for kinematic and EMG dependent variables.

Walking	ES	95% CI	Running	ES	95% CI
Low EL					
Hip ROM	1.62	[0.19,3.05]	Gluteus Maximus Initial Activation	1.80	[0.33,3.26]
			Semimembranosus Initial Activation	3.35	[1.43,5.28]
High EL					
Gastrocnemius Initial Activation	-2.48	[-4.13,-0.83]	Hip ROM	1.41	[0.03,2.80]
Maximal Hip Flexion	1.73	[0.28,3.18]	Gluteus Maximus Initial Activation	1.64	[0.21,3.07]
Maximal Ankle Dorsiflexion	-1.48	[-2.88,-0.08]	Semimembranosus Initial Activation	5.04	[2.51,7.57]