KINEMATIC AND EMG COMPARISON OF GAIT IN NORMAL AND MICROGRAVITY

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INTRODUCTION

Astronauts regularly perform treadmill locomotion as a part of their exercise prescription while onboard 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) environments.

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 upon all body parts, the bungees provide a spring force only to the harness. Therefore, subjects are subjected to two fundamental differences in MG: 1) forces returning the subject to the treadmill are not constant, and 2) forces are only applied to the axial skeleton 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) due to comfort and inherent stiffness in the bungee system.

Although locomotion can be executed in MG, the unique requirements could result in performance differences as compared to NG. These differences may help to explain why long term training effects of treadmill exercise may differ from those found in NG. The purpose of this investigation was to compare locomotion in NG and MG to determine if kinematic or muscular activation pattern differences occur between gravitational environments.

METHODS

Five subjects (2M/3F) completed treadmill walking at 1.34 $m \cdot s^{-1}$ and running at 3.13 $m \cdot s^{-1}$ in NG, and MG. NG trials were collected on a laboratory treadmill at NASA Glenn Research Center. AM trials were collected during parabolic flight onboard a DC9 aircraft at NASA Johnson Space Center. The external load provided by bungees (EL) during AM was 87.3 ± 6.6 %BW. Data were collected in each location on different days; the schedule was not under the control of the investigators.

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.

Telemetered EMG (Myomonitor III Wireless EMG System, Delsys Inc., Boston, MA) was used to obtain muscle activation data of the tibialis anterior, gastrocnemius, rectus femoris, semimembranosus, and gluteus maximus. Before any motion trials, 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 total activation duration during each stride using the methods of Browning et al. [2]. Multiple strides were analyzed for each gravitational location and trial means were computed. Effect sizes and their 95% confidence intervals were computed joint kinematic and EMG scores between each condition.

RESULTS AND DISCUSSION

When combining all factors tests (EL, locomotive mode), ninety-six comparisons were made. Because our intent was to identify differences between gravitational locations, we will limit our presentation to those 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 during the Low EL condition, and the hip achieved greater flexion during MG than NG. Maximum dorsiflexion was larger in NG than MG during walking with the high EL. The gastrocnemius was activated earlier in the stride in MG during the high EL condition.

Hip ROM was the only kinematic measure during running that was differentiated between gravitational locations. Subjects achieved greater amounts of hip flexion in MG. During 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 longterm spaceflight [1]. Interestingly, hip ROM appears to increase in MG compared to NG. This increase may be an adaptation to accommodating the gravity replacement load.

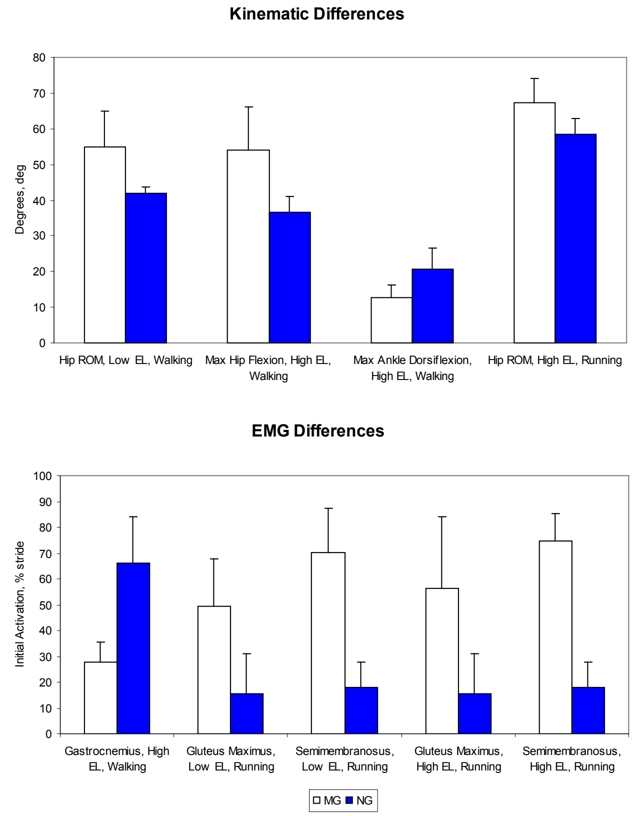

Figure 1: Kinematic (upper) and EMG (lower) dependent variables with effect size differences between MG & NG.

Our data suggest that there may be kinematic and muscle activation differences during running between MG and NG that could influence training responses, and may help to better understand why these deficits occur. Future research is necessary with larger subject sizes to better quantify kinematic and EMG differences between locations.

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 size and 95% confidence intervals 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]
Max Hip Flexion	**1.73**	[0.28,3.18]	Gluteus Maximus Initial Activation	**1.64**	[0.21,3.07]
Max Ankle Dorsiflexion	**–1.48**	[–2.88,–0.08]	Semimembranosus Initial Activation	**5.04**	[2.51,7.57]