THE EFFECT OF SPEED ON GROUND REACTION FORCES DURING LOCOMOTION IN WEIGHTLESSNESS

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INTRODUCTION

During long-term space missions, astronauts perform treadmill locomotion as an exercise countermeasure. One of the goals of the exercise is to apply force to the musculoskeletal system via the ground reaction force (GRF). Keller et al. [1] have shown that vertical GRF increases with increasing speed during locomotion at various speeds in normal gravity (1G). The purpose of this investigation was to determine how gait speed affects GRF during locomotion in weightlessness (0G). It was hypothesized that the interaction of speed and peak GRF will be affected by gravitational condition.

METHODS

Four subjects (2M/2F; 172.75 ± 11.14 cm; 73.18 ± 14.03 kg) performed locomotion at 1.34 (walk), 2.23 (jog) and 3.13 (run) m/s on the ground (1G) and during 0G onboard NASA's KC-135 airplane. Vertical GRF data were collected at 250 Hz for 25 sec during multiple trials with a GRF-measuring treadmill (Kistler Gaitway, Amherst, NY).

During 0G trials, the subjects wore a harness that attached at the hip to an external load (EL) set at 1.0 bodyweight (BW) during quiet standing. Bilateral dynamic loading forces were measured at 120 Hz with load cells (ELPS-T3E-500L, Entran Devices, Inc, Fairfield, NJ) placed inline with the EL configuration. The mean dynamic EL for each trial was calculated throughout the entire trial. During 1G trials, subjects ran without the harness.

Peak impact force (PIF) and peak propulsive force (PPF) were determined for eight consecutive footfalls (4 left and 4 right) from each trial. Trial means for all eight footfalls were computed for each GRF variable. All variables were normalized to subject body weight (BW).

A 2-way (gravitational condition × speed) ANOVA was performed on each outcome variable to identify any significant interactions. Bonferroni (all-pairwise) multiple comparison tests were used to determine differences at each speed. Results were considered significant at $p<.05$.

RESULTS AND DISCUSSION

Dynamic mean EL was determined to be 0.91 BW during the 0G trials. Mean PIF and PPF were between 1.0 and 2.4 BW depending on the speed and gravitational condition (see Table 1). The ANOVA analysis revealed significant effects for speed, and a significant interaction between speed and gravitational condition for both PIF and PPF. This suggests that each of these variables is affected by speed and that the speed effect is different between 0G and 1G (see Figures 1-2). The PIF were similar during 0G and 1G locomotion at each speed, but the PPF were different.

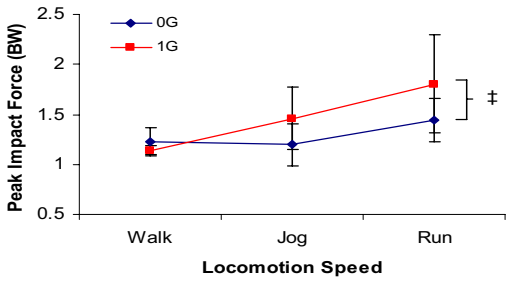

Figure 1: Mean peak impact force at varying speeds during locomotion in 0G and 1G. ‡ Significant speed × gravitational condition interaction, $p<.05$.

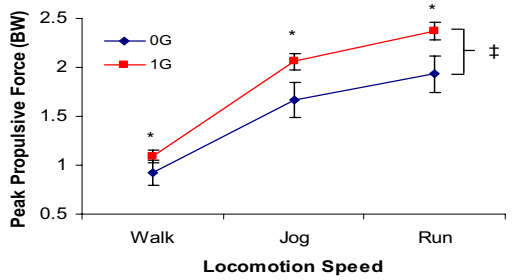

Figure 2: Mean peak propulsive force at varying speeds during locomotion in 0G and 1G. ‡ Significant speed × gravitational condition interaction, $p<.05$.*Significant speed effect, $p<.05$.

CONCLUSIONS

In both 0G and 1G, increases in locomotion speed affect the GRF. However, the affect is different between gravitational conditions. While locomotion in 0G may create similar PIF at varying speeds, PPF are less than those occurring at similar speeds in 1G. It is possible that the decreased PPF in 0G may be related to the harness-EL system that is necessary to allow locomotion during 0G exercise. The decreased PPF may result in different training effects during 0G locomotive exercise than that occurring during 1G exercise.

REFERENCES

1. Keller TS, et al. *Clinical Biomech* **11(5)**, 253-259, 1996.

Table 1: Mean ± SD of Peak Impact Force and Peak Propulsive Force during locomotion in 0G and 1G; *p<.05.

Gravitation Condition	Peak Impact Force (BW)			Peak Propulsive Force (BW)		
	Walk	Jog	Run	Walk	Jog	Run
0G	1.23 ± .13	1.20 ± .21	1.44 ± .22	0.92 ± .13*	1.67 ± .18*	1.93 ± .18*
1G	1.14 ± .05	1.46 ± .31	1.80 ± .49	1.09 ± .07	2.06 ± .08	2.37 ± .09