Biomechanics of Treadmill Locomotion on the International Space Station: Does gravity influence running biomechanics?

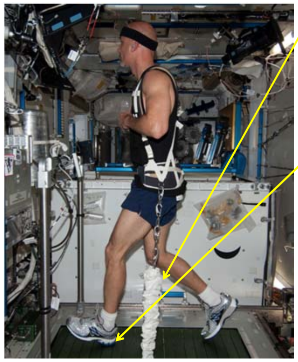
John K. De Witt[1,3], Ronita L. Cromwell[2], Lori L. Ploutz-Snyder[2,3]

1. Wyle Science, Technology and Engineering; 2. Universities Space Research Association;
3. NASA JSC Exercise Physiology and Countermeasures Laboratory

Key Findings:

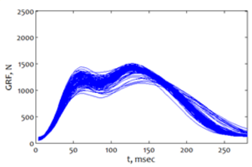
- Running motions maintained in the *absence* of gravity; Push-off forces may be *modulated* to maintain consistent running motions
- High speed exercise is important for maximizing mechanical loading
- Increasing bungee forces to 1 G body weight *does not* create 1 G mechanical loading at a given speed

Astronauts perform treadmill exercise on the ISS:



Bungee forces applied to a harness provide gravity replacement loading

Ground reaction forces (GRF) between the feet and treadmill provide mechanical loading (beneficial for health)



Typical GRFs in 0 G during running at 14.5 kph.

Questions:

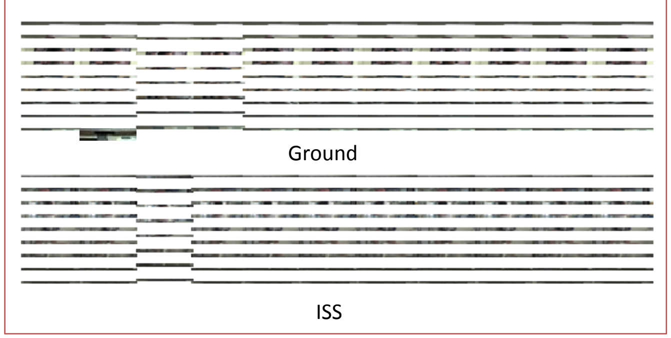
1. Do subjects run differently in 0 G?
2. How are ground reaction forces (GRF) affected by speed and bungee forces?
3. Is increasing bungee force important for increasing mechanical loading?

Basic Approach:

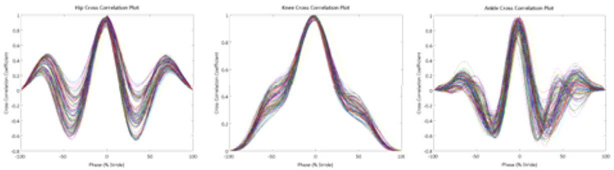
- Motion capture and foot-force data were collected before and during spaceflight (n=7) and during spaceflight only (n=1).
- Kinematic and GRF data analyzed

Question 1: Do subjects run differently in 0 G than in 1 G?

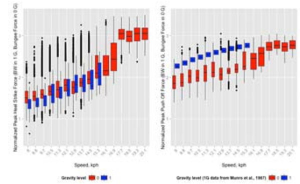
Basic kinematic pattern – 12.9 kph (8 mph)



Although slight differences are noticeable in specific joint range of motion, movement patterns are similar

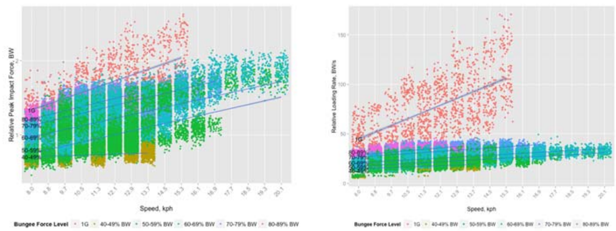


Cross correlation analyses reveal motion trajectories in 1 G similar to those in 0 G at a given speed (peak cross coefficients occur at 0 deg phase shift).



When expressed relative to the bungee force level in 0 G and body weight in 1 G, subjects tend to maintain consistent heel strike (impact) forces while modulating push off (propulsive) forces.

Question 2: How are GRF affected by speed and bungee force?



Peak impact forces at a given speed in 0 G are always less than in 1 G, but increase with speed and bungee force. Increasing speed can make up for loss in peak impact forces.

Loading rates at a given speed in 0 G are always less than in 1 G. Data suggest loading rates in 0 G are never similar to those in 1 G, perhaps due to the vibration isolation system.

Step by step (n=79,172) peak heel strike force (left) and loading rate (right) plotted vs. speed. Loading rate is the rate of force application at heel strike. Differing bungee force levels are depicted by color. 1 G values are in red.

Question 3: Is increasing bungee force important for increasing mechanical loading?

Mean peak GRF vs. speed (left), mean peak GRF vs. bungee force magnitude(center), and mean loading rate vs. speed (right). Plots vs. speed are categorized by bungee force level, and plot vs. bungee force is categorized by speed. Data are means for workout stages and encompass almost an entire mission. Light blue datapoints indicate sessions where bungee force levels were approximately 100% BW. Despite these high loading levels, peak GRF did not increase appreciably and are far below values typically found in 1 G at similar speeds.

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Contact: john.k.dewitt@nasa.gov, 281-483-8939