2.17 Biomechanical Evaluation of Russian BD-1 Treadmill during Non-Motorized Treadmill Locomotion in a Weightless Environment (KC-135)

FLIGHT DATES:
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GOAL:

The goal of this experiment was to evaluate the ability of subjects to walk and run under bungee loading on the Russian BD-1 treadmill during weightlessness provided by parabolic flight.

OBJECTIVES:

1) To measure the average speeds maintained by subjects and compare this with the corresponding target speeds.
2) To measure the external load (EL) provided by the bungee loading system and determine the load dependence on body size.
3) To measure subject ground reaction force (GRF) in weightlessness and compare this with ground reaction force in normal gravity.

METHODS AND MATERIALS:

Eight subjects (33.3 ± 6.0 years, 174.3 ± 8.6 cm; 75.1 ± 11.7 kg) ran at 5, 8, and 14 km/h (3.1, 5.0, and 8.7 mph) on the non-motorized Russian BD-1 treadmill during weightlessness (0g) onboard the KC-135 aircraft and on the ground (1g). Subjects were held down to the treadmill by means of an applied external load provided by the treadmill's bungee loading system connected to an upper body harness. Treadmill belt speed was measured and recorded by means of the speed sensor built into the treadmill interfaced with a LabView (National Instruments, Austin, TX) data acquisition system. Bungee loading was measured and recorded by means of load cells (Entran, Inc., Fairfield, NJ) placed between the bungee and harness attachment points and connected to a second LabView data acquisition system. Ground reaction force was measured and recorded by a Tekscan pressure insole system (Tekscan, Inc., South Boston, MA). Subjects performed two trials for each set of conditions.

RESULTS:

Speed Maintenance

A chart showing the average and standard deviation of speed for each subject at each of the three target speeds is provided in Figure 1. The average speed for all subjects was within one standard deviation of the target speed for 5 km/h (walking) and 8 km/h (slow running). For the 14 km/h (fast running) condition, however, two subjects had average speeds that were more than one standard deviation below the target speed. Also, the plot trend suggests that small and large body size subjects had the most difficulty reaching and maintaining the 14 km/h target speed based on the deviation of their average speed from the target speed.

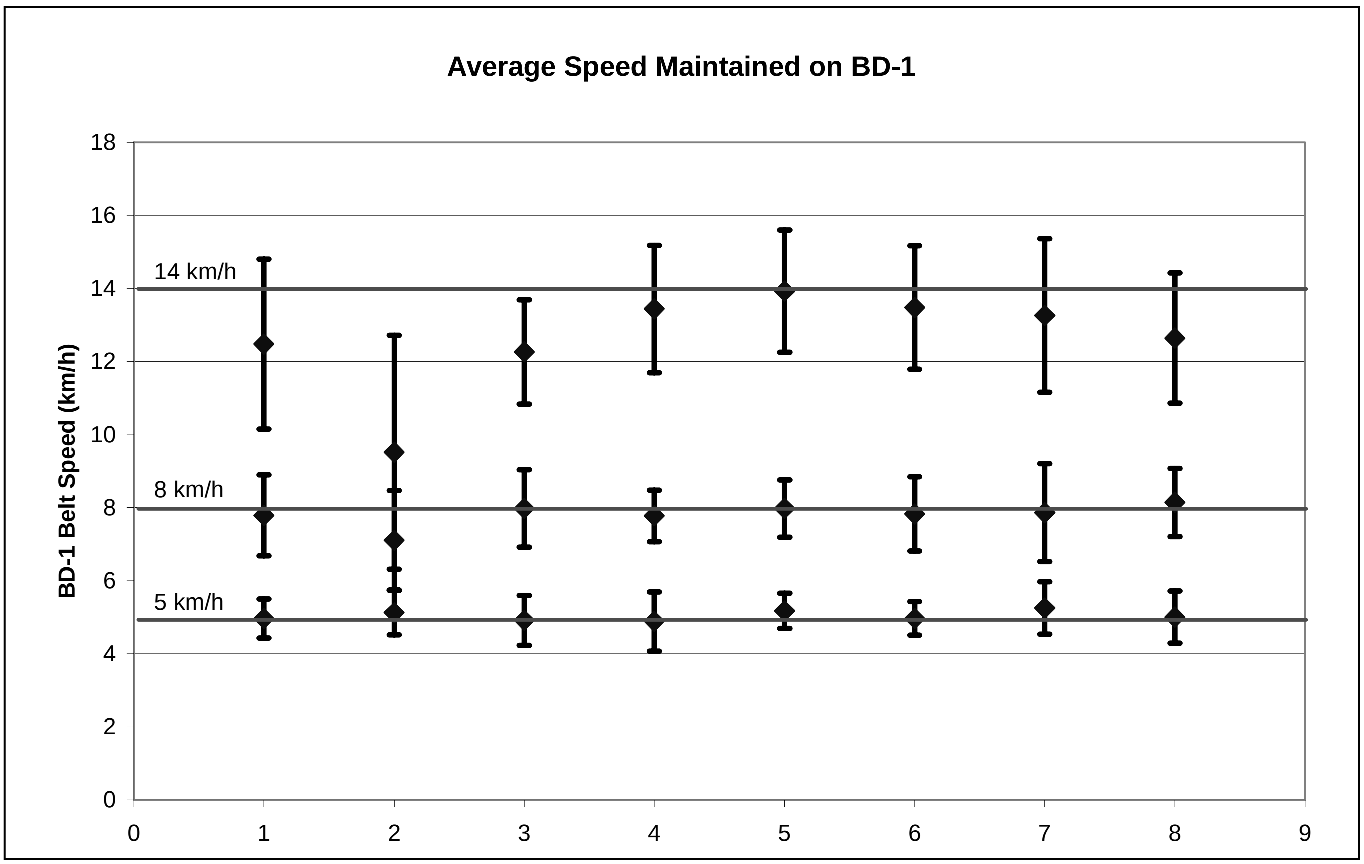

Figure 1. Ability of subjects to reach and maintain the three speed levels for walking and running in weightlessness.

External Load

The average external load provided during walking and running (all speeds) is presented according to body size in Figure 2. The average external load ranged from approximately 80 percent of body weight for the smallest subjects to approximately 60 percent of body weight for the largest subjects. External load, as a percentage of body weight, showed a consistent decrease as body weight increased.

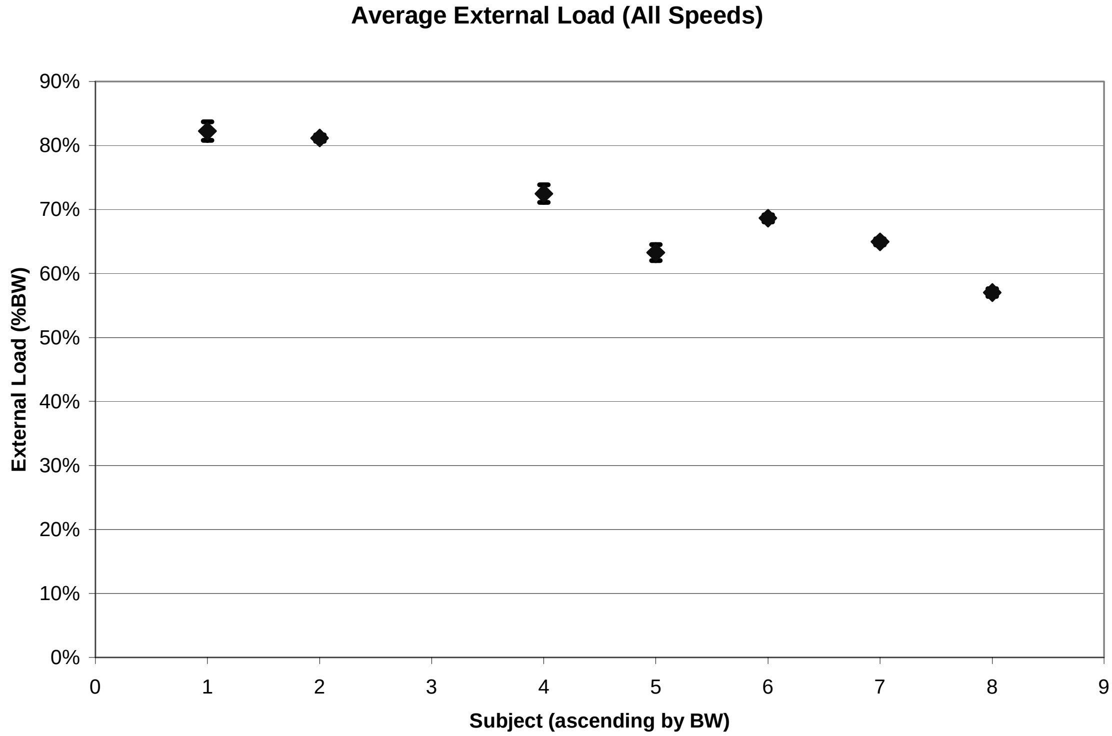

Figure 2. Average external load and standard deviation sorted according to subject size.

Ground Reaction Force

A typical ground reaction force plot for a single walking step at 5 km/h on the BD-1 treadmill in weightlessness is shown on the right side of Figure 3. For comparison, GRF plots obtained from a motorized treadmill in 1g and 0g at the same speed are shown on the left side of Figure 3. The shape of the motorized treadmill curves are similar in 1g and 0g. The BD-1 contact time tends to be less than with the motorized treadmill in 1g. The BD-1 impact GRF magnitude (first peak) is similar to the motorized treadmill, but the propulsive GRF magnitude (second peak) is greater for the BD-1.

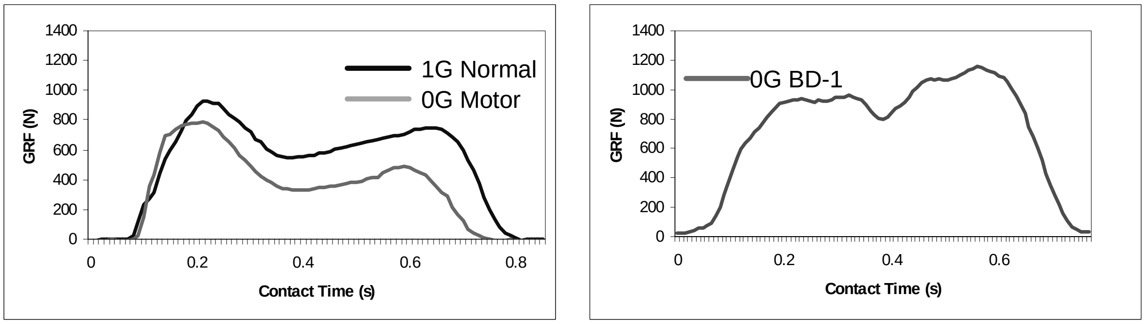

Figure 3. Typical GRF for walking at 5 km/h on a motorized treadmill in 1G and 0G (left) versus the BD-1 non-motorized treadmill in 0G (right).

A similar comparison of ground reaction force plots for a single running step at 8 km/h is shown in Figure 4. Again, the shape of the motorized treadmill curves are similar in 1g and 0g, but the impact peak is absent in the BD-1 GRF plot. The peak propulsive GRF on the BD-1 appears to be closer to the 1g peak for the motorized treadmill than the corresponding 0g peak for the motorized treadmill. The BD-1 contact time tends to be similar to that obtained on the motorized treadmill in 1g.

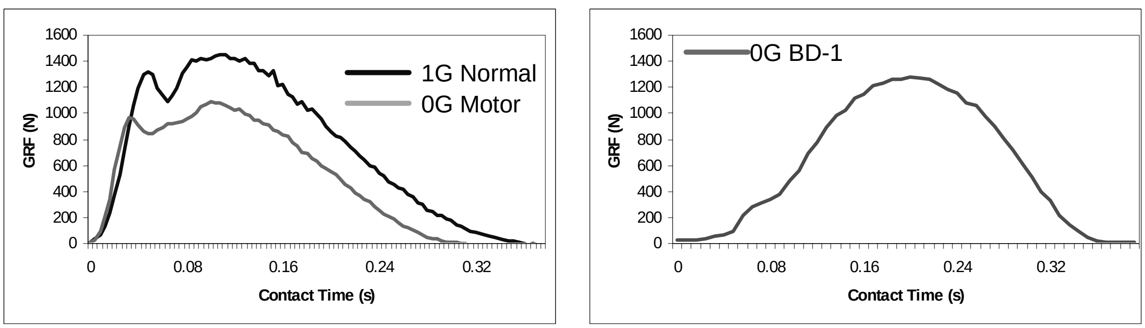

Figure 4. Typical GRF for running at 8 km/h on a motorized treadmill in 1G and 0G (left) versus the BD-1 non-motorized treadmill in 0G (right).

Ground reaction force plots for a single running step at 11 km/h on a motorized treadmill and at 14 km/h on the BD-1 are shown in Figure 5. The 11 km/h speed was the closest speed to 14 km/h available in the motorized treadmill data. As with the slower running step, the impact peak is absent in the BD-1 GRF plot. The peak propulsive GRF on the BD-1 appears to be lower than the 1g GRF peak for the motorized treadmill, but similar to the 0g peak for the motorized treadmill. The BD-1 contact time appears to be less than with the motorized treadmill in 1g.

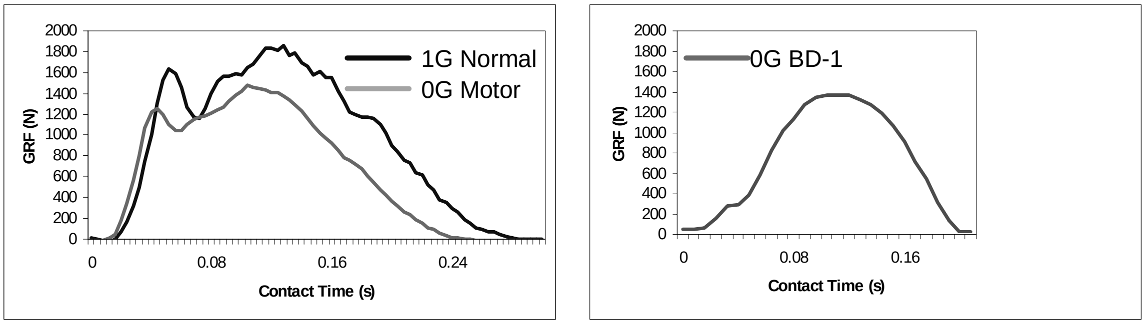

Figure 5. Typical GRF for running at 11 km/h on a motorized treadmill in 1G and 0G (left) versus 14 km/h on the BD-1 non-motorized treadmill in 0G (right).

DISCUSSION:

While subjects had no difficulty reaching and maintaining the walk (5 km/h) and slow run (8 km/h) speeds, it was clear that some subjects had difficulty reaching and maintaining the fast run (14 km/h) speed. This problem may be ameliorated with additional training and practice on the treadmill, but it is likely that some subjects may still have difficulty maintaining speeds in the range of 14 km/h for durations longer than about 20 seconds.
Due to the limited adjustability of the BD-1 bungee loading system, subject loading may be limited to a narrow range and depends on subject body size. Smaller subjects are limited to higher loadings closer to their full body weight while larger subjects are limited to load levels that may be as low as 60 percent of their body weight.

The ground reaction force obtained during BD-1 treadmill locomotion appears to have a heel strike peak during walking, but the heel strike peak appears to be absent during running. The absence of the heel strike peak may be due to the fact that the subjects held onto a handrail during locomotion on the BD-1 or it may be a natural occurrence in non-motorized treadmill running. Determining what factors contribute most to the absence of heel strike in the ground reaction force will require further study. The peak propulsive force appears to be similar to the 1g level, or at least equivalent to the 0g level, when using a motorized treadmill. The high rate of change of load associated with the heel strike peak along with the peak propulsive ground reaction force are both considered to be important factors in bone maintenance. Determining the extent to which these parameters are enhanced or diminished by non-motorized treadmill locomotion is an important topic for further investigation.

CONCLUSION:

Subjects are able to successfully perform locomotion exercise on the BD-1 treadmill in weightlessness. The BD-1 bungee system has limited adjustability and provides higher loading for small subjects and lower loading for larger subjects. Some subjects have difficulty reaching and maintaining higher speeds starting at around 14 km/h. The ground reaction force profile for BD-1 locomotion shows peak propulsive forces comparable to 1g, but the heel strike peak appears to be absent during running on the BD-1 in weightlessness. These observations have implications for exercise prescriptions for BD-1 treadmill use on-board ISS.

PHOTOGRAPHS:

JSC2004E39833 to JSC2004E39876
JSC2004E40321 to JSC2004E40346
JSC2004E40660 to JSC2004E40683
JSC2004E40904 to JSC2004E40964

VIDEO:

- Zero-g August 30 – September 9, 2004, Reference Master: 718586

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

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