Kinematic Differences Between Motorized and Nonmotorized Treadmill Locomotion

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INTRODUCTION

There are few scientific publications comparing human locomotion between motorized and nonmotorized treadmills. Lakomy (1987) and Gamble et al (1988) reported that forward lean is greater on a nonmotorized treadmill to aid in the generation of horizontal force necessary for belt propulsion, but there are no data concerning lower limb kinematics.

During long-term spaceflight, astronauts use locomotive exercise to mitigate the physiological effects caused by long-term exposure to microgravity. A critical decision for mission planners concerns the requirements for a treadmill to be used during potential trips to the Moon and Mars. Treadmill operation in an un-powered configuration could reduce mission resource demands, but also may impact the efficacy of treadmill exercise countermeasures. To ascertain the most appropriate type of treadmill to be used, it is important to understand biomechanical differences between motorized (M) and nonmotorized (NM) locomotion.

The purpose of this evaluation was to test for differences in lower limb kinematics that occur during M and NM treadmill locomotion at two speeds. It was hypothesized that hip and knee joint angle trajectories would differ between the conditions.

METHODS

Twenty subjects (10 males/ 10 females; 31±5 yrs, 172±10 cm, 68±13 kg, mean±SD) performed locomotion during M and NM conditions on a ground-based version of the treadmill currently used onboard the International Space Station. Subjects completed three 8-stride trials at 2 velocities (1.34 and 3.13 m·sec^{-1}) in each condition. NM an M trials were completed on different days.

Motion capture data were collected (60 Hz) via the Smart Elite Motion Capture System (BTS Bioengineering SPA., Milan, Italy) and smoothed with a 4th order digital filter at specific cutoff frequencies chosen for each 3-D point (2-15.5 Hz). Ankle, knee, and hip range of motion (ROM), and trunk sagittal plane angles were computed. Stride time was calculated as the duration between successive heel strikes of the left foot.

Comparisons of joint range of motions were made between M and NM within each speed using paired t-tests. Wilcoxon Rank-Sum tests were used when the data were not normally distributed.

RESULTS AND DISCUSSION

All subjects chose to walk during the 1.34 m·sec^{-1} trials and run during the 3.13 m·sec^{-1} trials for both M and NM conditions. M and NM gait styles were different (see Table 1). Figure 1 depicts typical joint positions at heel strike and toe off for each treadmill mode.

Figure 1: Typical limb positions at heel strike and toe off.

Although speed was not different between conditions, the subjects chose differing kinematic patterns. Ankle and hip ROM, as well as maximum trunk lean (with respect to the vertical), were larger during NM. Subjects also took shorter strides during NM.

Hip and knee angle trajectories for each condition at each speed are depicted in Figures 2 & 3. While knee ROM was similar at both speeds (approximately 3° different), coordination strategies between the hip and knee were condition dependent. It appears that the hip operated in different amounts of flexion relative to knee angle. The difference in the hip trajectory was especially apparent during the 3.13 m·sec^{-1} trials.

SUMMARY/CONCLUSIONS

NM treadmill gait requires different lower limb coordination patterns than M locomotion. Therefore, long-term training using NM treadmill modes may result in different physiological adaptations than M modes.

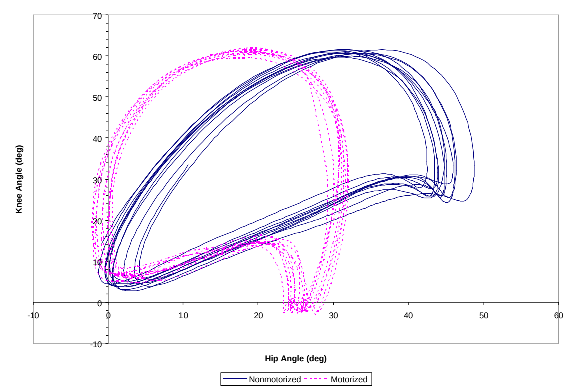

Figure 2: Typical Knee-Hip Angle trajectory of nonmotorized (NM) and motorized (M) locomotion at 1.34 m·sec^{-1}.

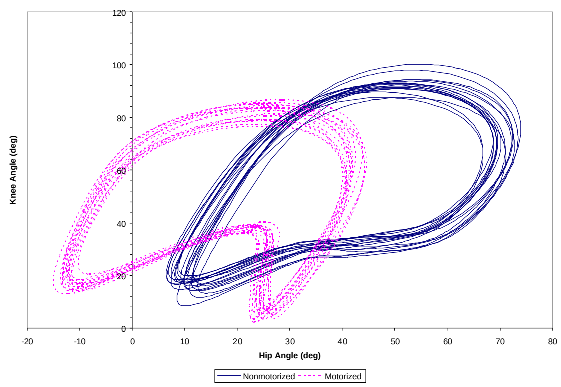

Figure 3: Typical Knee-Hip Angle trajectory of nonmotorized (NM) and motorized (M) locomotion at 3.13 m·sec^{-1}.

REFERENCES

Lakomy, H.K.A. (1987). **Ergonomics, 30(4)**, 627-637.

Gamble, D.J. et al. (1988). *Biomech Sport,* 25-32.

Table 1: Stride time and joint ROM for each speed and condition (mean± SD).

Speed (m·sec^{-1})		**Stride Time (msec)**	**Ankle ROM (deg)**	**Knee ROM (deg)**	**Hip ROM (deg)**	**Trunk Lean (deg)**
1.34	NM	902.2 ± 56.1*	39.1 ± 5.6**	57.4 ± 4.1*	48.4 ± 4.6**	20.2 ± 4.6*
	M	987.1 ± 52.9	29.8 ± 2.9	60.6 ± 3.8	34.4 ± 3.2	7.6 ± 1.8
3.13	NM	593.1 ± 64.1*	53.5 ± 5.7*	74.4 ± 10.2	62.4 ± 6.0*	27.6 ± 3.5*
	M	685.5 ± 39.6	48.5 ± 4.3	76.9 ± 7.2	49.8 ± 5.4	12.8 ± 3.3

* p<.05 (paired t-test); **p<.05 (Wilcoxon Rank Sum test)