REDUCED VERTICAL DISPLACEMENT REVERSES EFFECT OF SPEED ON ENERGY EXPENDITURE

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INTRODUCTION

Previous work utilizing a curved treadmill demonstrated that minimized vertical displacement of the body’s center of mass (COM) did not coincide with reduced energy expenditure [1]. The curved treadmill translated the arc motion of the path of the COM bed of the treadmill to below the feet, thereby reducing vertical displacement of the COM in a more natural manner rather than having subjects adjust their gait to minimize movement. However, a limitation of this previous work was the fact that the curved treadmill was not motorized and the flat treadmill used for comparison was motorized. Thus, the purpose of this study was to address this limitation. It was hypothesized that reduced vertical displacement of the COM would still not coincide with reduced energy expenditure in a motorized curved treadmill. This hypothesis would be consistent with the original contention that reducing vertical displacement of the COM, beyond a yet to be determined "optimal" amount, results in reduced gait efficiency.

METHODS

Five subjects (age: 23.8 ± 5.6 years, ht: 170.5 ± 5.9 cm, mass: 67.9 ± 12.9 kg) walked on both a standard motorized flat treadmill and a curved treadmill (Woodway®, Waukesha, WI, USA) with three different speeds; 1.12, 1.56, and 2.01 m/s. The order of the conditions was randomized. The curved treadmill was motorized with the motor from a separate treadmill (Trackmaster® Jas Fitness System, Newton, KS, USA) by replacing the timing belt with a longer belt that was attached externally to an axle that drove the curved treadmill (Figure 1). Three different speeds were initially chosen [3]. Gear ratio limitations, however, prevented the utilization of a speed of 0.67 m/s for the curved treadmill, therefore a speed of 2.01 m/s was added on our conditions. Subjects walked at each speed for three minutes on both treadmills with breaks as needed in between each trial to reduce fatigue. Steady state oxygen consumption relative to body mass (VO2) (K4b2, Cosmed, Chicago, IL) was measured.

Figure 1: Setup for a flat treadmill motor powering the curved treadmill.

Vertical displacement of COM was recorded through sacral marker movement (60Hz; Motion Analysis Corp., Santa Rosa, CA, USA). Vertical displacement of the sacral marker was quantified as the dispersion about the individual's mean COM height (i.e. standard deviation) as well as maximum range of displacement through all steps within each trial. Significant differences for dispersion and range of sacral marker displacement and VO2 were tested through separate 2x3 fully repeated measures ANOVAs (treadmill x speed). When main effect or
interaction was significant, Tukey tests were used for post-hoc analysis (PASW 18.0, IBM Corp., Armonk, NY).

RESULTS AND DISCUSSION

Consistent with previous findings, energy expenditure increased on the curved treadmill ($p=0.002$, Figure 2). There was a significant interaction, for which post-hoc analysis revealed that VO2 was significantly higher at 1.12 m/s ($p<0.05$) and 1.56 m/s ($p<0.05$) on the curved treadmill but not for the 2.01 m/s ($p>0.05$).

![Figure 2: Energy expenditure displayed an interaction between speed and treadmill type.](image)

Results for normalized COM displacement (Figure 3) showed a similar pattern as our previous work with increased discrepancy in COM displacement as speed increased [1]. However, the speeds utilized in this study were increased due to limitations of the adjusted treadmill. Specifically, we previously found increased COM displacement for the flat treadmill at 1.12 m/s but in the current study there was no difference ($p<0.05$). There is an overall significantly higher COM on the flat than the curved treadmill ($p=0.05$) Post hoc revealed no significance between individual speeds and treadmills. Thus, we see from the 1.12 m/s and 1.56 m/s conditions that reduced (or equal) vertical COM displacement did not coincide with reduced VO2. However, the interaction that we now see for VO2, not previously seen in the non-motorized testing, may offer additional insight. It appears that as speeds increase, the excessive motion of the COM on the flat treadmill rapidly increases VO2.

![Figure 3: Center of mass displacement in terms of standard deviation increased as speed increased normalized by leg length.](image)

CONCLUSIONS

Walking on a motorized, curved treadmill reduces vertical displacement of the COM but results in increased VO2 compared to a standard, flat treadmill. However, at higher speeds, motion of the COM on the flat treadmill grows considerably greater than on the curved treadmill at which point VO2 on the motorized curved treadmill is no longer different from the standard flat treadmill. This seems to coincide with the notion of an ‘optimal’ amount of vertical displacement with regards to energy expenditure during locomotion.

REFERENCES


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