INTRODUCTION

Our previous study [1] challenged the notion that a minimized vertical displacement of the body's center of mass (COM) coincides with reduced energy expenditure. In that study, subjects walked on a flat treadmill and a curved treadmill. The curved treadmill has an arc shaped walking platform similar to the path of motion of the COM when walking overground but inverted. Thus, this design counters the arc motion of the COM, reducing the vertical displacement of the COM. We believed this experimental design allowed a more natural walking motion as opposed to requiring subjects to alter their gait by either taking shorter steps or walking with increased knee flexion [2]. By either reducing step length or utilizing increased knee flexion, an increase in energetics may have occurred as a secondary effect of the altered gait. Our previous study did not examine the gait beyond an anecdotal report of similar walking patterns. Therefore, the purpose of this study was a retrospective analysis of the kinematics of our previous study to determine if individuals walked with similar gaits between the two conditions. We hypothesized that joint angles would be similar between the two treadmills due to the more natural gait utilized.

METHODS

Five subjects (age: 23.00 ± 2.61 years, ht: 183.39 ± 4.23 cm, mass: 84.63 ± 9.72 kg) walked (random order: 0.67, 1.12, and 1.56 m/s) on both a standard flat treadmill and a curved treadmill (Woodway®, Waukesha, WI, shown in Figure 1). Three different speeds were chosen based upon previous work[3]. Subjects walked for three minutes with breaks between trials as necessary to prevent fatigue. Twenty-seven retroreflective markers affixed to the lower limbs were used to record three-dimensional kinematics (60Hz; Motion Analysis Corp., Santa Rosa, CA). Ankle, knee, and hip joint range of motion for each gait cycle were calculated and averaged over the entire trial through custom Matlab software. Significant differences for joint angle ranges of motion for the right leg were tested for each joint through 2x3 (treadmill x speed) fully repeated measures ANOVA (α=0.05).

RESULTS AND DISCUSSION

The knee flexion range of motion for the curved treadmill was significantly less than the flat treadmill (p=0.032). The hip flexion range of motion for the curved treadmill was significantly greater than the flat treadmill (p=0.047). The ankle joint range of motion was not significantly different between treadmills (p=0.479). Differences between speeds did not reach significance nor were there any interactions (Figure 2).

In our previous study [1], we found that the difference in energy expenditure between the two treadmills was greatest at 1.56 m/s, which was also the greatest difference in terms of displacement for
the COM. We hypothesized that the curved treadmill and the flat treadmill permitted similar natural gaits for the subjects. Our hypotheses were not supported. Subjects ambulated with different ranges of motion at the hip and knee joints. However, to the contrary of what we found with energy expenditure [1], there was not a significant effect of speed. Previously as speed increased, subjects had a greater increase in energy expenditure on the curved treadmill than the flat treadmill [1]. Thus, if altered gait mechanics between the treadmills had been the cause of the increased energy expenditure measured with the curved treadmill, then we would have expected a similar effect of speed on the gait kinematics. Furthermore, our previous study examining energy expenditure found the differences between the curved and flat treadmill were not significant at the slowest speed (0.67 m/s) [1]. This further highlights the lack of impact from the changes in joint ranges of motion at the hip and knee since these were different at 0.67 m/s. A closer examination of the group means (Figure 2), would suggest that while the effect of speed was not significant, the slowest speed had ranges of motion that were least similar.

CONCLUSIONS

The consequences of a completely reduced displacement of the COM need to be better understood to improve rehabilitation protocols. Specifically, outlining a potential "optimal" amount of displacement during gait that results in minimal energy expenditure is important. By using the unique curved treadmill, we were able to minimize vertical displacement of the body’s COM and measure a coinciding increase in energy expenditure [1]. Our results in this study indicate that the curved treadmill does cause changes in joint ranges of motion. Importantly, these changes were not the result of speed manipulation. This contrasts our findings with energy expenditure and vertical displacement of the COM which showed a significant effect for speed (i.e. differences in energy expenditure and vertical displacement of the COM between the flat and curved treadmills increased with faster speed). Thus, while we found significant differences at the hip and knee joint between the treadmills, our results support the notion that overly minimized vertical displacement of the COM can cause increased energy expenditure.

REFERENCES


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