INTRODUCTION

Synchronous arm and leg swing maintains dynamic stability during walking and is hypothesized to be controlled by limb-specific neural circuits [1]. However, the coordination between arm and leg swing appears to be dependent upon gait speed [2]. Advances in rehabilitation technology have led to the use of split-belt treadmills which allow the speed of the belt under each limb to be controlled independently. This independent control provides a unique means to perturb the walking pattern and to evaluate adaptation in arm and leg coordination. Because of the dynamic, everyday environments in which humans must ambulate, the ability to flexibly adapt gait patterns to maintain stability is crucial. The purpose of this study was to investigate whether interlimb coordination changes during split-belt treadmill walking. Typical human gait consists of hip flexion paired with contralateral shoulder flexion. However, as gait speed is decreased, multiple arm swings per step are observed [2]. It is unknown what effect split-belt treadmill gait, which places different demands on each leg, has on coordination.

We utilized hip and shoulder angles to calculate two measures of interlimb coordination. To investigate the effect of the split-belt perturbation on gait, one discrete measure, the point estimate of relative phase (PRP, or the relationship between two segments based on the time required to reach a maximum or minimum value, which can range from 0° (in phase) to 180° (out of phase)), and one continuous measure in cross-covariance (COV, a measure ranging from -1 (out of phase) to 1 (in phase), with zero indicating no phasic relationship between the two signals (Fig. 1)), were used. Additionally, spatiotemporal gait parameters which have previously been described in the split-belt treadmill literature [3] were calculated.

METHODS

Seventeen participants (22±3 years, 10 female), in accordance with the Vicon Plug-In Gait model, were fitted with 35 retro-reflective markers and walked on a split-belt treadmill (Bertec Corporation, Columbus, OH). Kinematic data were collected using an 8 camera motion capture system (Vicon, Oxford, UK), sampling at a rate of 120 Hz. Self-selected Fast walking speed (FS) was determined when the participant identified the fastest speed which could be maintained for 10 minutes. Participants then walked at each Split and Tied condition for 90 seconds. During Split, the belt under the participant’s non-dominant leg was set at FS, and the dominant-side belt moved at 90%, 70%, 50%, and 30% of FS. Both belts rotated at the same speed (90%, 70%, 50%, and 30% of FS) during the Tied Conditions. To allow for sufficient adaptation [3], only data from time 0:30-1:30 at each condition were analyzed. Outcome measures were calculated using a customized MATLAB (MathWorks, Natick, MA) script. A series of two-way and one-way ANOVAs, and Bonferroni post-hoc tests, were performed (GraphPad Prism, La Jolla, CA) using an α-level of 0.05.

RESULTS AND DISCUSSION

Statistical analysis revealed significant Condition (Split or Tied) X Speed (90%, 70%, 50%, or 30%) interactions among all contralateral limb COV and PRP measures. All gait measures resulted in significant Condition X Speed interactions except for the Fast leg Step Length. Within-measure results of all coordination and gait cycle measures can be found in Table 1.

Participants not only maintained coordination patterns throughout Split, but displayed improved coordination on all Split 30% measures when compared to Tied 30%. Consistent with previous
literature, arm and leg swings became less coordinated as the Tied speeds decreased, particularly when treadmill was set at 30% of FS. These data support the hypothesis of multi-limb neural connections. Gait cycle measures mirrored past split-belt treadmill work. Longer stride lengths and shorter stance percentages were measured on the fast belt, and the slow belt elicited shorter stride lengths and greater stance percentages. These data indicate that the speed difference in belts should be taken into consideration when designing rehabilitation and research protocols.

REFERENCES

Figure 1: Flexion/extension and corresponding COV values of one participant’s right (slow side) hip and left (fast side) shoulder during 3 speed configurations.

Table 1: Coordination and gait cycle results. † indicates a significant Condition X Speed interaction. Superscripts indicate within-measure significant differences of at least P<0.05.