INTRODUCTION

Split belt treadmills (SBT) consist of two independently-controlled belts (one under each leg) and have recently been used to induce locomotor adaptation in various populations. During SBT studies, gait speed is independently manipulated for each limb with one limb typically walking 2 times faster than the other. While spatiotemporal adaptation during SBT walking has been frequently analyzed in the sagittal plane, little is known about the changes in frontal plane mechanics that occur during SBT walking. However, because SBT walking requires one leg to walk twice as fast as the contralateral leg, we may be able to gather insight from previous work related to slow and fast walking. Indeed, prior research has indicated that gait speed may also alter frontal plane kinetics in healthy adults, particularly the knee adduction moment (KAM). KAM reflects the loading in the medial compartment of the knee joint and is also related to progression of OA.

The aim of this study was to examine the frontal plane mechanics during SBT walking in the propulsive and braking phases of stance for the ankle, knee, and hip joints bilaterally.

METHODS

Thirteen healthy participants walked on an instrumented SBT (Bertec Corporation, Columbus, OH) during three conditions: slow, fast and split. Participants initially selected his/her fastest comfortable walking speed (“fast” speed), then walked for two minutes with both belts moving at 50% of the fast speed (“slow” speed/slow condition) and two minutes with both belts moving at the fast speed (fast condition). The participants then walked for ten minutes with the self-reported nondominant leg moving at the fast speed and the dominant leg moving at the slow speed (split condition). Kinematic and kinetic data were recorded during the last 30 seconds of the slow, fast, and split conditions. Sixteen passive reflective markers were attached to the lower body in accordance with the Vicon Plug-in-Gait lower body marker system. Kinematic data were collected using a 7-camera motion capture system (120 Hz; Vicon Nexus, Oxford, UK).

Force recordings, marker position data and the individuals anthropometrics were used to calculate the frontal plane moments for the ankle, knee, and hip during the propulsive and braking phases of gait via inverse dynamics.

Joint moments and GRFs were normalized to body mass (kg) and temporally to 100% of the gait cycle. Braking phase was defined as the period from heel-strike to the first 50% of single-limb stance period. Propulsive phase was defined as the period from second 50% of the single-limb stance to toe off. Frontal joint moment impulses for the ankle, knee and hip were calculated as the time integrals of the AP GRFs over the braking and propulsive phases, respectively.

Several 2x3 (limb x condition) repeated measures ANOVA with Bonferroni correction for pairwise comparisons was used to analyze mean differences among conditions and between limbs (α = .05).

RESULTS AND DISCUSSION

Table 1 displays the means and standard deviations of frontal joint moment impulses for the ankle, knee, and hip for the non-dominant and dominant limbs during slow, fast, and SBT walking. There were no bilateral differences in the braking or propulsive GRF impulses during the slow, fast, and SBT conditions (p > .05).

Bilateral differences during slow and fast conditions

During the slow condition, hip adduction moment impulses were significantly higher for the “slow” versus the “fast” limb during the braking phase (p = .027).

Slow condition versus fast condition

During the slow condition, the non-dominant limb ankle adduction moment and KAM impulses, along with the dominant limb KAM impulses were significantly smaller compared to the fast condition during the braking phase (p = .032, p
During slow walking, the dominant limb ankle adduction moment impulses were significantly higher compared to non-dominant limb walking during the propulsive phase ($p = .006$).

### Fast limb vs. slow limb during SBT walking

During the split condition, KAM impulses along with hip adduction moment impulses were significantly larger for “slow limb” compared to the “fast” limb during braking phase ($p = .006, p < .001$, respectively). KAM impulses were significantly larger for the “fast limb” versus the “slow limb” during the propulsive phase ($p = .011$).

### Fast limb during SBT walking vs. fast limb during fast walking

The “fast limb” ankle adduction moment, KAM and hip adduction moment impulses during SBT walking were smaller compared to the same limb during the fast condition for the braking phase ($p = .035, p = .002, p = .007$, respectively). The “slow limb” ankle adduction moment impulses were smaller compared to “slow limb” during the slow condition for the propulsive phase ($p = .018$).

The “fast limb” ankle, knee, and hip adduction moment impulses were all smaller during the split condition versus the same limb for the fast condition during the braking phase (116%, 34%, and 23% lower for slow, respectively). While the “slow limb” knee and hip adduction moment impulses were larger during the split condition compared to the same limb during the slow condition for the braking phase (30% and 23% smaller during the slow condition, respectively). “Slow limb” ankle adduction moment impulses were 96% smaller compared to the same limb during the slow condition for the propulsive phase.

Joint adduction moment impulses represent the amount of time exposed to a load in a specific joint. A smaller moment impulse would represent a shorter exposure time to a load, and a larger moment impulse would imply a longer exposure time. The results of this study indicate that while walking on a SBT, adduction moment impulses may be smaller for the “fast limb” compared to fast conventional treadmill walking, and larger for the “slow limb” compared to slow conventional treadmill walking. The findings of this study demonstrate that participants can walk (with one limb) at a fast speed with lowered joint adduction moment impulses. Lowering frontal plane joint moment impulses particularly at the knee is important in patients with knee OA to prevent further progression or development of the disease. In addition, simultaneously maintaining and/or restoring a fast walking speed while reducing or preserving healthy joint adduction moment impulses is clinically important to perhaps reduce the incidence or progression of knee OA. However, further longitudinal research that addresses the disease process of OA specifically is needed to verify this statement.

### REFERENCES


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**Table 1. Ankle, Knee, and Hip Adduction Moment Impulses during Braking and Propulsive phases for Slow, Fast, and Split walking.**

<table>
<thead>
<tr>
<th></th>
<th>Braking</th>
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<tbody>
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<td></td>
<td>Ankle</td>
<td>Knee</td>
<td>Hip</td>
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<td>Slow limb</td>
<td>Fast Limb</td>
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<tr>
<td>Slow</td>
<td>1.50 (1.82)</td>
<td>-0.07 (1.96)</td>
<td>10.9 (4.71)</td>
<td>8.23 (3.51)</td>
<td>16.9 (4.16)</td>
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<td>Fast</td>
<td>1.79 (1.60)</td>
<td>0.61 (2.31)</td>
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<td>11.6 (3.99)</td>
<td>19.8 (3.69)</td>
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<td>-0.10 (1.91)</td>
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<td>7.63 (3.01)</td>
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<td></td>
<td>Propulsive</td>
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<td></td>
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<td>Knee</td>
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<td></td>
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<td>Slow</td>
<td>1.43 (1.88)</td>
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