

# LOCOMOTOR TRAINING: THE EFFECTS OF TREADMILL SPEED AND BODY WEIGHT SUPPORT ON LOWER EXTREMITY JOINT KINEMATICS

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## INTRODUCTION

Body Weight Supported Treadmill Training (BWSTT) is a rehabilitation method that can help individuals with incomplete Spinal Cord Injuries (SCIs) regain the ability to walk. In BWSTT, patients are supported by a harness above a treadmill while therapists provide manual assistance to help approximate normal gait. Recovery of function is achieved by reorganization of neural pathways in the spinal cord, and depends on task-specific rehabilitation. To be effective, BWSTT must simultaneously provide elements of both weight-bearing and rhythmic movements; providing one without the other has been shown ineffective for recovery of walking ability after SCI [1].

Despite the need to replicate normal gait characteristics, techniques for selecting key training parameters, such as treadmill speed and percentage of body weight support (BWS), have not been established. Previous studies (eg. [2]) have explored the effect of BWS on lower extremity kinematics at constant speeds, but not the combined effect of BWS and speed. In this study, we determined the effect of altering treadmill speed and BWS on stance phase duration, peak knee angles, and peak ankle plantar and dorsi flexion angles.

## METHODS

We obtained informed consent from four healthy subjects (3 male,  $25.25 \pm 3.3$  y). Subjects performed a ten meter over ground walk to determine self-selected (SS) walking speed. Reflective markers were then placed on their skin using the Point-Cluster Technique [3].

Subjects walked on a split belt instrumented treadmill (Bertec Corp., Columbus, OH) at three speeds (SS, 0.5 x SS, and 1.5 x SS) and four levels of BWS (0%, 30%, 50%, and 70%). Conditions were randomized for each subject. Ground reaction

forces were collected at 200 Hz and low-pass filtered with a fifth order Butterworth filter (10 Hz cutoff frequency). Body weight support was provided by a medical harness and a closed-loop pneumatic force control system (Vigor Equipment, Stevensville, MI; Tescom, Elk River, MN). Kinematic gait data were collected using a seven camera VICON motion analysis system (Vicon Mx cameras, Vicon, Inc.).

Kinematic data were processed in Vicon Nexus and OpenSim (Stanford University, Stanford, CA). We determined knee and ankle angles using the inverse kinematics tool in OpenSim, which uses a least squares approach to minimize the difference between experimental marker location and virtual markers on the model while maintaining joint constraints [4].

We determined the effects of BWS and treadmill speed on stance phase duration, knee angle, and ankle angle using a 3 x 4 repeated-measures analysis of variance (ANOVA). Duration of stance was defined as the percent of the gait cycle taken up by stance. Post-hoc tests were performed, using a Bonferroni adjustment for multiple comparisons, for factors that were significantly changed at the  $p < 0.05$  level. Statistical tests were performed with a statistical software package (SPSS Inc, Chicago, IL).

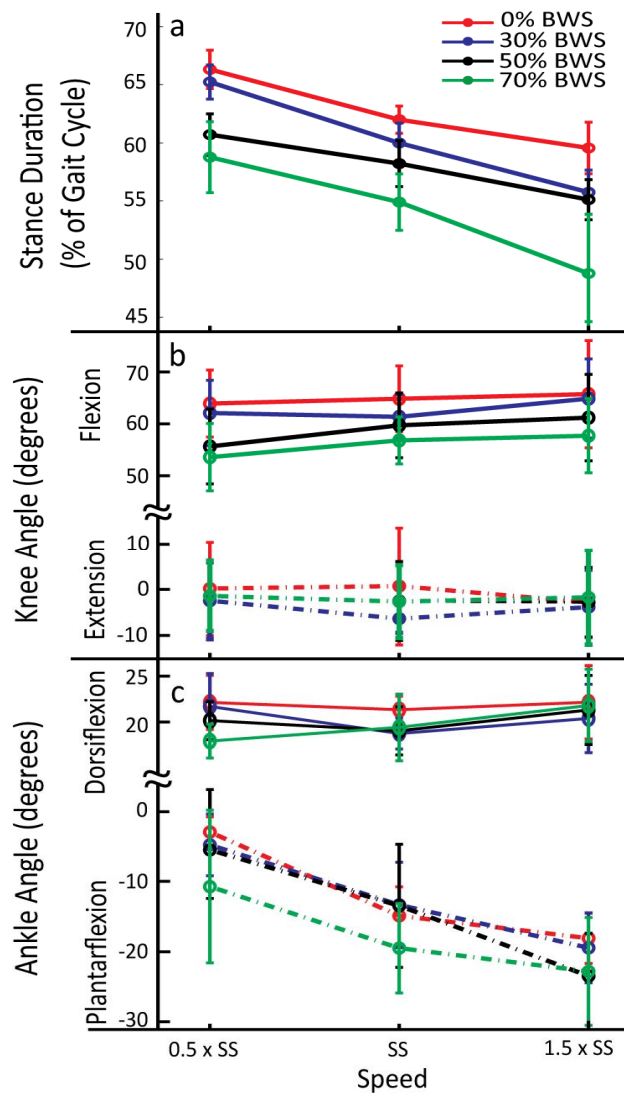
## RESULTS AND DISCUSSION

The repeated measures ANOVA revealed that all variables of interest were significantly affected ( $p < 0.001$ ) by increasing BWS at a constant speed, by altering treadmill speed at a constant level of BWS, and by the interaction effect of altering treadmill speed and BWS.

When either speed or BWS increased, the stance duration decreased (Figure 1a). This trend was

compounded when both speed and BWS increased together. Mean stance duration for the baseline condition (0% BWS, SS speed) was  $61.99\% \pm 1.18$ . The mean stance duration for 70% BWS, 1.5 x SS was  $48.77\% \pm 5.10$ , suggesting that a flight phase occurred for some subjects at this condition. Nine of eleven combinations of BWS and treadmill speed resulted in a significantly different ( $p < 0.001$ ) stance duration when compared to the baseline condition.

Maximum knee flexion angles increased with increasing BWS and with increasing treadmill speed (Figure 1b) and were significantly different from



**Figure 1:** Mean and standard deviations for a) percent of stance, b) maximum and minimum knee flexion angle and c) maximum ankle dorsiflexion and plantarflexion angles at three treadmill speeds and four levels of body weight support.

the baseline condition in five of the eleven conditions. Hyperextension occurred for some subjects at the 30% BWS condition, but did not occur for any other conditions.

Ankle plantar flexion experienced larger changes than did ankle dorsiflexion (Figure 1c). Plantar flexion increased in magnitude as treadmill speed increased and also as BWS was applied. Less than a  $5^\circ$  difference was observed for dorsiflexion with the application of BWS over all treadmill speeds. Six of the eleven training conditions produced significantly different peak plantarflexion angles when compared with the baseline condition, but only two training conditions produced significantly different peak dorsiflexion angles.

## CONCLUSIONS

Because BWSTT seeks to replicate normal gait, understanding the effects of speed and BWS on kinematics is an important step in selecting training parameters. While we found statistically significant changes in all gait characteristics due to changes in BWS and treadmill speed, it is interesting to note that we observed larger changes in the magnitude of ankle plantar flexion due to changes in speed than changes in BWS. Also, small dorsiflexion angle differences noted across conditions indicate that altering speed and BWS may not significantly influence this motion during locomotion in controls. Additional analysis of ankle motion is required.

In order to optimize BWSTT parameters for functional locomotor recovery, further work is required to investigate biomechanical mechanisms underlying these altered joint kinematics demonstrated during BWS conditions over a range of speeds.

## REFERENCES

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