Asymmetric gait training with a Tied-Belt Treadmill

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I. INTRODUCTION

Walking post-stroke is frequently characterized by slower speeds, due in large part to a precipitous decrease in paretic limb push-off [1]. This decrease in push-off, frequently quantified as the peak of the anterior component of the ground-reaction force vector (F_P), often requires persons post-stroke frequently rely on compensatory gait strategies such as vaulting and increased push-off from their healthy leg [2]. A critical target for rehabilitation, therapy frequently aims to elicit volitional improvements in paretic limb push-off with unfortunately lackluster results. Therefore, rehabilitation approaches that do not require volitional changes in gait are needed. To address this need, we aim to develop a novel dynamic treadmill training approach. Our dynamic treadmill controller uses changes in tied-belt treadmill speed to modulate the magnitude of paretic and non-paretic push-off. For example, accelerating the treadmill during paretic push-off should increase the magnitude, as push-off magnitude scales linearly with walking speed [3]. Similarly, decreasing the speed during non-paretic push-off should decrease compensatory push-off from that limb. Importantly, we can customize the treadmill speeds and timing of the speed changes to shape each individual's push-off. As such, we hypothesized that walking in our dynamic treadmill would result in greater push-off from the leg moving quickly during push-off than that moving slowing during push-off in young healthy participants. The results will be used to refine treadmill control for persons post-stroke.

II. METHODS

10 healthy young adults (mean±SD; age: 22.3±3.6 years, 4M/6F) participated. Subjects first walked normally for 2 minutes each at 0.75 – 1.5 m/s on a dual-belt instrumented treadmill (Motek Medical, Amsterdam, NL) while we collected motion capture and ground reaction force data. Subjects then walked for 10 minutes using our closed-loop dynamic treadmill controller. For all trials, a motion capture system (Vicon Nexus, Denver, CO) recorded the trajectories of markers placed on subjects' pelvis and lower extremities for estimating joint kinetics. Briefly, the dynamic treadmill controller alternated the tied-belt speeds within a gait cycle between 0.75 m/s and 1.5 m/s based on participants' anterior-posterior ground reaction forces. More specifically, the controller set the belt speeds to 0.75 m/s during the braking phase of the right leg then to 1.5 m/s during the propulsive phase of the right leg. Given the tied-belt nature, this resulted in speeds of 1.5 m/s through braking and 0.75 m/s through propulsion for the left leg.

III. RESULTS

Speed linearly modulated bilateral F_P and trailing limb angle. The dynamic treadmill condition resulted in 22% greater F_P ($p<0.01$) but 8% smaller trailing limb angle ($p=0.02$) in the left leg (when treadmill moved at 0.75 m/s) than the right leg (when treadmill moved at 1.5 m/s).

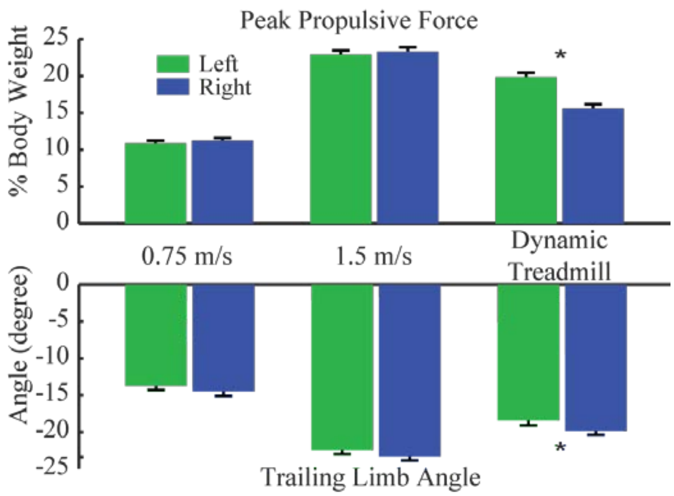

Fig. 1. Peak propulsive force and trailing limb angle for left and right legs. During the Dynamic Treadmill condition, treadmill speed was 0.75 and 1.5 m/s at push-off for left (green) and right (blue) legs, respectively.

IV. DISCUSSION

Our dynamic treadmill controller elicited differential effects in push-off between the left and right legs using only changes in tied-belt treadmill speed. Nevertheless, we completely reject our hypotheses such that a fast treadmill speed actually resulted in significantly lesser push-off than the slow speed. These confounding but exciting results are seemingly due to disruptions to the pendular center of mass mechanics. We look forward to presenting this and follow up experiments specifically exploring joint-level and center of mass mechanics of walking with speed-modulated push-off demands.

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