INFLUENCE OF THE GLUTEUS MAXIMUS TO GENERATE LARGER TRAILING LIMB ANGLES OBSERVED WITH A REAL-TIME ADAPTIVE TREADMILL CONTROLLER

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INTRODUCTION

Treadmill gait training is a common method of gait rehabilitation because it allows for high repetition at a low cost and in a small space [1]. However, commonly used fixed speed treadmills lead to decreased kinematic variability and increased variability is desired for effective gait rehabilitation [2]. In response to this limitation, a real-time adaptive treadmill control was created to enable changes in speed based on gait mechanics [3].

Ray et al. analyzed changes in walking kinematics in response to a novel real-time adaptive treadmill control and found that the participants tended to choose a faster self-selected (ss) walking speed with a larger trailing limb angle (TLA) at the time of peak anterior ground reaction force (AGRF) [4]. This could have implications for rehabilitation as TLA is a major factor in forward propulsion and linearly contributes to increases in propulsive force during changes in speed [5]. While larger TLA is believed to be due to faster ss walking speed, the mechanism by which TLA is increased is unknown.

Musculoskeletal simulations have been used to understand how individual muscles contribute to normal walking over a range of walking speeds [6]. <u>The purpose of this study is to examine if the force and activation of the primary hip extensor muscle, the Gluteus Maximus (GMAX), is affected by the real-time adaptive treadmill control to assist in generating larger TLA and thereby promote faster ss walking speed.</u>

METHODS

Five healthy adults (26 ± 6 years, 1.78 ± 0.03m, 73 ± 7.85 kg, 3 male) participated in this study. Motion capture (100 Hz) and force data (2000 Hz) was previously collected for participants walking on the same treadmill at self-selected speeds chosen uniquely for the fixed speed and adaptive treadmill controls [1].

Using the Visual 3D (C-Motion, MD, USA) export to OpenSim tool, simulations were generated for three gait cycles for each treadmill condition, for a total of six for each subject. A generic musculoskeletal model with 23 degrees of freedom and 92 musculotendon actuators [7] in OpenSim 4.0 [6] was scaled by the participants' dimensions. Residual reduction analysis and computed muscle control were run to find the muscle activation of the GMAX and hamstring muscles for each of the simulations with the subtalar and metatarsophalangeal joints locked at neutral anatomical angles.

Finally, using MATLAB, the GMAX muscle force and activation and joint angle data were normalized to percent gait cycle and averaged to generate one representative gait cycle for each treadmill control condition per participant. Trailing limb angle was calculated at the instant of the peak anterior ground reaction force as the angle between vertical and the line connecting the hip joint center and the 5th metatarsal (Figure 1). Statistical analysis was not conducted due to small sample size.

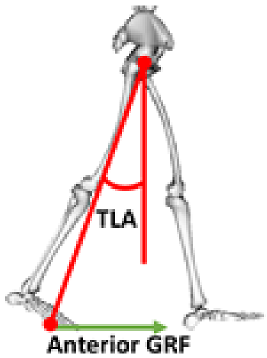

Fig 1: Definition of AGRF and TLA.

RESULTS AND DISCUSSION

Participants chose faster ss walking speed with the adaptive treadmill (Fixed: 1.1 ± 0.06m/s, Adaptive: 1.23 ± 0.11 m/s) and larger TLA at the instant of peak AGRF force (Figure 2a). Peak GMAX activation (Figure 2b), where 0 is no muscle contraction and 1 is maximal muscle contraction, was slightly greater on the user-driven control compared to the fixed speed treadmill (Fixed: 0.38 ± 0.12, Adaptive: 0.43 ± 0.11). No noticeable trend was observed in GMAX force. Three participants used a higher GMAX peak force with the adaptive treadmill (Difference: 44.79 ± 11.57 N). The other two participants used a higher GMAX peak force with the fixed speed treadmill (Difference: 31.55 ± 4.05 N).The peak forces and peak activations for the GMAX occurred during early stance phase (0-20% gait cycle) with no difference in timing.

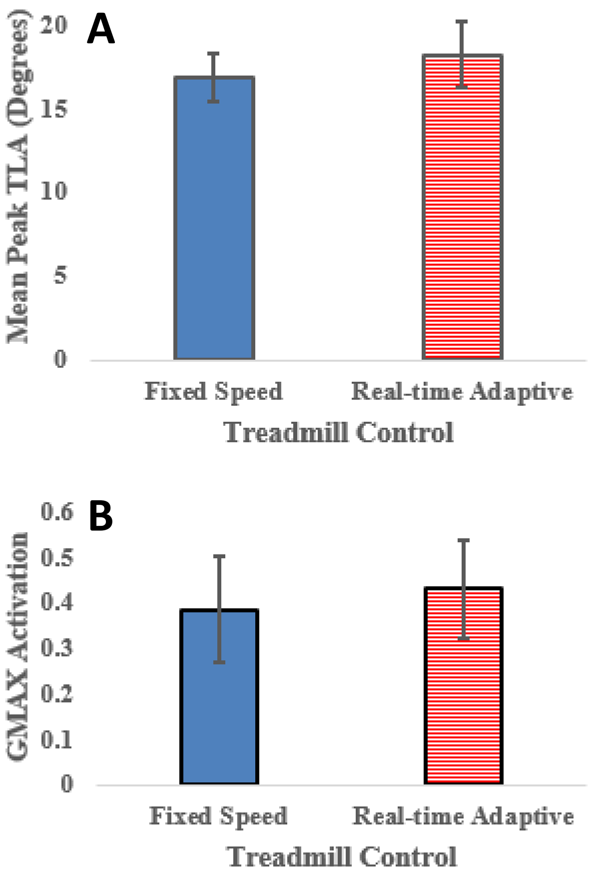

Fig 2: Average and standard deviation of peak trailing limb angle (A) and peak GMAX activation (B) for the two treadmill controls.

Participants generated slightly larger peak hip and knee extension angles measured relative to the vertical axis with the real-time adaptive treadmill. No consistent trend was observed for the pelvis tilt or ankle angles.

Previous studies have shown that with an increase in walking speed, contribution to vertical support from the gluteus maximus should increase [8]. However, our results suggest that even though the ss walking speed is faster with the real-time adaptive treadmill, only slight changes in activation and force are associated with increased TLA, which may suggest better mechanical efficiency of the GMAX when TLA is increased.

Changes in trailing limb angles in this healthy population are primarily due to the increased walking speeds on the real-time adaptive treadmill and not to the change in controller [4]. Because the activation of the GMAX only changed slightly and no noticeable trend was observed with GMAX force, this motivates the use of an induced acceleration analysis as a next step to determine the contribution of the GMAX to the increased walking speed. It is also possible however that these results suggest that the adaptive treadmill passively pulls the leg backwards further, causing increased hip and knee extension and a larger TLA.

These findings promote the use of the real-time adaptive treadmill as a rehabilitation tool to assist the hip and knee with extension and promote faster ss walking speeds, a sign of effective rehabilitation [1]. Because no trend was found with ankle kinematics, other therapeutic interventions, such as functional electrical stimulation, would be recommended for ankle control.

CONCLUSIONS

Only slight increases in GMAX force and activation are associated with the larger trailing limb angles observed with a real-time adaptive treadmill controller versus a fixed speed treadmill control. Based on the current results it is hypothesized that the larger TLA is primarily due to increased hip and knee extension with the real-time adaptive treadmill, which will be explored further with induced acceleration analyses. Future work will quantify passive and active changes in GMAX function with increased TLA, and determine whether results apply to individuals with neurological impairment.

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