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WALK TO RUN GAIT TRANSITIONS TRIGGERED BY FLEXOR MUSCLES: INSIGHTS FROM UNILATERAL, TRANSTIBIAL AMPUTEES

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INTRODUCTION

Able-bodied propulsive force production during walking has been shown to decrease at speeds above the walk-to-run transition [1]. Transitioning from a walk to a run greatly reduces fascicle shortening velocities in the plantarflexor muscles, resulting in increased propulsive force production [2]. Preliminary data indicates persons with unilateral transtibial amputations (AMP), who are effectively missing these muscles in one leg, transition from a walk-to-run at significantly lower absolute speeds than able-bodied controls (CON). In CON subjects, the performance limit of muscular force production due to muscle fascicle shortening velocity coincides nicely with the gait transition speed (GTS), however this is not the case in AMP subjects. Unlike CON subjects, AMP subjects are able to continue generating higher propulsive forces at speeds beyond their preferred gait transition, suggesting that a limit in plantarflexor force production does not dictate the transition to a running gait [3]. To this point, it is likely that the fascicle shortening velocities of the AMP intact plantarflexors are a function of absolute speed, rather than speed relative to the GTS. In able-bodied subjects, the walk-to-run gait transition has also been attributed to an increased sense of effort necessary to meet the swing-related mechanical demands (joint moments) of fast walking (speeds > GTS). Swing-phase muscle moments during walking were found to be higher than those of running at the same speeds. The walk-to-run transition also appears to be correlated with increased swing-phase activation of the tibialis anterior, rectus femoris, and hamstrings, as these are all flexor muscles acting in swing phase during walking [4].

By studying AMP subjects in gait transition testing, we are able to decouple the previously identified performance limit of impaired propulsive force production due to increased muscle fascicle shortening velocities from a perceived sense of effort due to muscle activations. The purpose of this study was to evaluate the walking vs. running muscle activations at speeds relative to the gait transition in AMP subjects, compared to controls to evaluate the muscle activations relative to the GTS. We hypothesized that AMP subjects will transition between gaits at lower speeds than controls in order to minimize muscle activations due to higher mechanical demands in AMP subjects.

METHODS

Fourteen subjects, 7 healthy, unilateral, transtibial amputee (AMP) subjects (male=3) and 7 healthy, able-bodied control (CON) subjects (male=3) gave informed written consent prior to completing the GaTech IRB approved protocol. Great care was taken in matching CON subjects to each of the AMP subjects. Between the two groups there was no significant difference in leg length, weight, and age. Subjects were also matched for gender and qualitatively matched on activity level. Testing was completed over two days no more than one week apart. GTS was determined for subjects on day 1 by an incremental protocol similar to the one described by Prilutsky and Gregor, 2001. Subjects were asked to walk and run at a variety of speeds (1.3-2.6 m/s for CON and 1.0-2.3 m/s for AMP). On day 2 subjects completed 30 second walking trials at speeds of 50, 60, 70, 80, 90, 100, 110, 120, and 130% of their previously determined GTS as part of a larger protocol. Electromyographic data (EMG) (1080Hz, Noraxon 16-channel) were collected on tibialis anterior (TA), soleus (SO), medial gastrocnemius (MG), biceps femoris long head (BF), and rectus femoris (RF). At each speed, data from 10 steps were bandpassed 20-450Hz, demeaned, rectified, 10 Hz lowpass filtered, and normalized to the 130% walking trial peak for each subject. A 40 ms shift in the EMG data was applied to account for electromechanical delay. Only 6 of the 7 subjects were averaged for AMP subjects' intact side (AMP-Intact) BF and RF activations. Kinematic data were collected using a 6-camera Vicon Motion Analysis System (120 Hz). GRF data were measured using a custom built, instrumented, dual-belt treadmill (1,080 Hz, AMTI). Paired t-tests were used to compare walking and running at each speed with a Bonferroni corrected α -level of 0.05.

RESULTS AND DISCUSSION

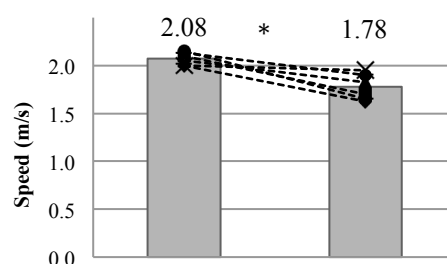


Figure 1:
Average GTS
($p=0.002$).
Dashed lines-
relationship
between CON
and AMP.

Consistent with preliminary data, AMP subjects transition between gaits at lower speeds than CON subjects (Fig. 1). CON and AMP data were consistent with previous literature in showing higher EMG magnitudes for walking speeds >GTS for the TA and lower magnitudes of the SO at speeds <GTS compared to running (Fig 2). MG results were similar to those of SO. Swing phase RF and BF activation patterns are comparable between CON, AMP-Intact and AMP subjects' residual side (AMP-Residual) (Fig. 3). Significantly greater TA and RF EMG magnitudes for walking compared to running at speeds >GTS in all groups suggests that swing phase muscle activation of the TA and RF are highly correlated with the walk-to-run transition. The lower absolute walk-to-run transition speed in AMP subjects due to swing related activations is further supported by AMP subjects having to generate higher moments than CON subjects at any given speed (Fig 4). Although BF swing-phase activation maintains an activation pattern similar to TA and RF, significant results were only found for speeds <GTS. The relative activation patterns for RF and BF during stance phase are comparable between all three groups (Fig. 5). Significance was only found at speeds <GTS in the AMP-Intact and AMP-Residual RF activation.

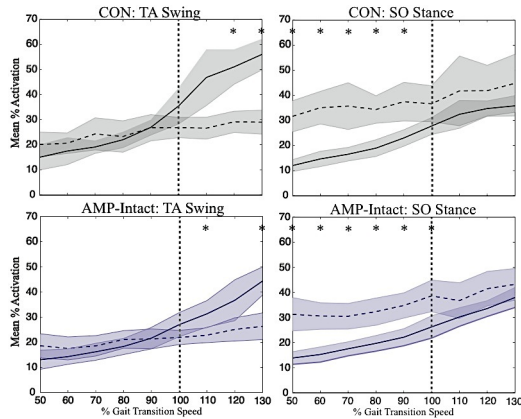


Figure 2: TA swing and SO stance activation *Solid lines: walking, dashed lines: running, vertical dashed line: GTS*

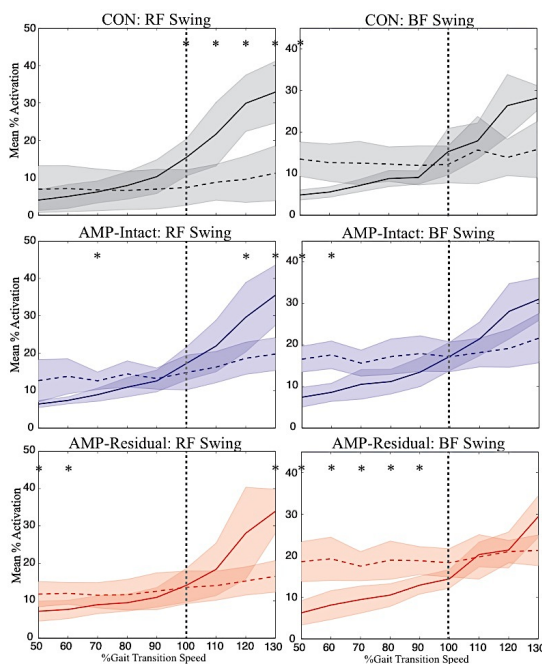


Figure 3: Swing phase RF and BF activation *Solid lines: walking, dashed lines: running, vertical dashed line: GTS*

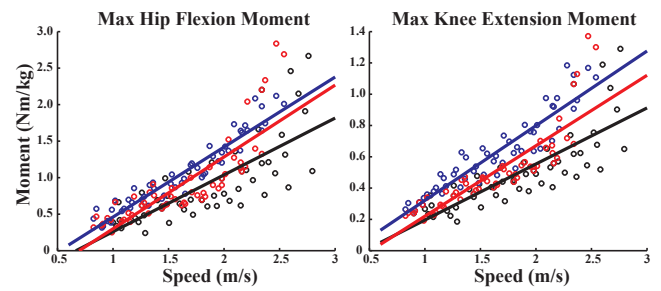


Figure 4: Max swing phase moments during walking plotted on an absolute speed scale. *Black: CON, Blue: AMP-Intact leg, Red: AMP-residual leg*

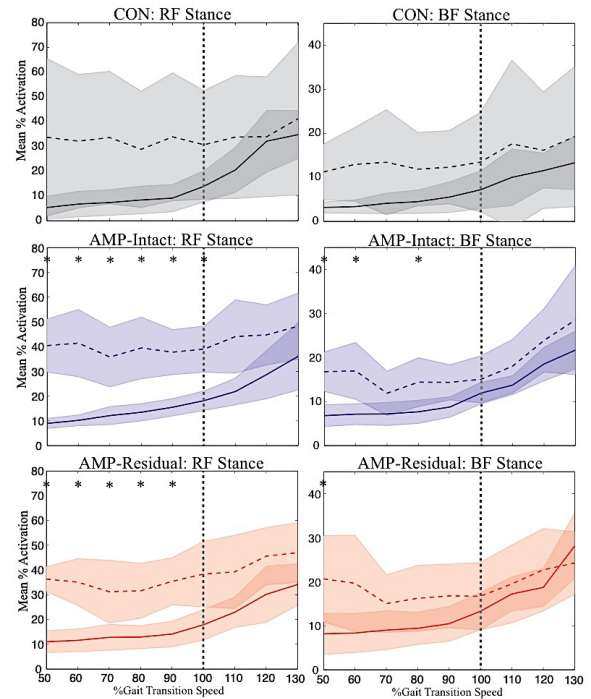


Figure 5: Stance phase RF and BF activation *Solid lines: walking, dashed lines: running, vertical dashed line: GTS*

CONCLUSIONS

Unilateral, transtibial amputees transition between gaits at lower speeds than able-bodied controls. AMP subjects experience higher mechanical demands during the swing phase of walking than CON subjects at similar speeds. The similar patterns of muscle activations in control and amputee subjects at speeds relative to the gait transition suggest that swing-phase activation of tibialis anterior and rectus femoris are important factors triggering the walk-to-run gait transition.

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REFERENCES

1. Neptune RR and Sasaki K, *J. Exp. Biology*. **208**:799-808, 2004.
2. Farris DJ and Sawicki GS, *PNAS*. **109**(3):977-982, 2012.
3. Norman TL and Chang YH, *ASB Abstract*, 2012.
4. Prilutsky BI and Gregor RJ, *J.Exp.Biol.* **204**:2277-2287, 2001.