Is Toe Flexor Strength a Determinant of Submaximal Walking Propulsion in Young Adults?

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Summary

Growing evidence suggests that the toe flexor muscles may play an important role conveying leverage to enhance ankle moments and gait propulsion. In a cohort of 15 young adults, we evaluated whether toe flexor strength correlated with ankle muscle leverage, ankle moments, trailing limb angle, and propulsive force at two submaximal walking speeds. Neither propulsive force nor any determinant of gait propulsion correlated with toe flexor strength. Those lack of correlations may be due to the submaximal nature of habitual walking speeds, homogeneity of our cohort, and/or neural control independent of strength. We intend to investigate these associations in populations with known toe flexor disfunction and gait propulsion deficits.

Introduction

The human foot is a vital adaptation enabling habitual bipedal gait. With a robust hallux and a distinctly thick plantar aponeurosis, it is classically understood to facilitate gait propulsion (i.e. anterior ground reaction force [F_P]) through the forefoot-stiffening windlass mechanism during push-off. However, recent studies revealed that forefoot stiffness is also influenced by active moments from the toe flexor muscles acting at the metatarsophalangeal joint (MTPj) [1]. Toe flexion moments have the potential to increase the ankle plantarflexors' external moment arm (R_{Ext}), thereby augmenting propulsion via larger peak ankle moments (M_A) and trailing limb angle (TLA) during push-off. Indeed, stronger toe flexors are associated with faster maximal walking speeds [3]. As peak ankle moment and trailing limb angle are known determinants of gait propulsion [2], toe flexion strength may play a biomechanical role in facilitating gait propulsion – an intuitive extension that is currently unclear. Thus, the purpose of this study was to quantify the correlations between maximum voluntary isometric toe flexor torque (MTP_T) and F_P via its modifying influence on R_{Ext}, M_A, and TLA. We hypothesized that individuals with stronger toe flexors (i.e. larger MTP_T) would demonstrate larger: (*i*) R_{Ext}, (*ii*) M_A, (*iii*) TLA, and (*iv*) F_P (peak and positive impulse). Accepting these hypotheses would implicate toe flexion strength as a target for future intervention in individuals with toe flexor disfunction and/or gait propulsion deficits.

Methods

15 younger adults (26.7 ± 5.4 yrs, 79.9 ± 15.5 kg) walked on an instrumented treadmill for 2 min each at 1.0 m/s and 1.4 m/s. We measured MTP_T as the peak of two maximal voluntary isometric toe contractions performed in a custom dynamometer at 20° of ankle plantarflexion and 60° of MTPj extension. Using motion capture and force plate data, we calculated EMA as the Euclidian distance between the ankle joint center and GRF vector, M_A, F_P (peak and positive impulse), and TLA. All gait variables were averaged over the last 10 steps of each trial. We correlated toe flexor strength with gait variables at each speed and with their respective change due to walking faster. The critical alpha value was adjusted using Holm's rank-ordered corrections for 15 tests.

Results and Discussion

Though toe flexor strength showed a positive trend for M_A, neither propulsive force nor any determinant of gait propulsion significantly correlated with toe flexor strength (Table 1). Thus, habitual walking speeds may not be sufficiently demanding to reveal the role of toe flexor strength in governing gait propulsion. Other possibilities include insufficient variance in our outcome measures among healthy younger adults and/or a disproportionate role of neural control independent of toe flexion strength during walking.

Conclusions

Toe flexor strength appears to be an inadequate biomechanical determinant of gait propulsion at submaximal walking speeds, at least among younger adults without propulsive deficits.

Acknowledgments

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References

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Table 1. Correlation and *p*-values for toe flexor strength and gait propulsion and its determinants.

		R_{Ext}		M_A		TLA		F_P		F_P Impulse	
	Velocity	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
MTP_T	1.0 m/s	0.294	0.287	0.516	0.049	0.249	0.371	0.152	0.590	0.250	0.368
	1.4 m/s	0.230	0.409	0.246	0.376	0.080	0.778	0.081	0.774	0.193	0.491
	Δ (1-1.4)	-0.277	0.318	-0.533	0.041	-0.190	0.498	-0.038	0.894	0.020	0.945