Toe Strength Predicts Ankle Joint Mechanical Contributions during Gait

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Summary

This exploratory analysis aimed to identify relationships between toe strength and aging gait mechanics. Twelve healthy adults (43-70 years old) completed a gait analysis and two different hallux flexion strength measures. Subjects with greater hallux strength, as assessed with flexion at the metarsophalangeal joint only, demonstrated greater mechanical contributions from the ankle during gait. Hallux flexion strength may help optimize propulsion at toe-off and attenuate the redistribution of joint mechanics in aging gait.

Introduction

Changes in gait with healthy aging are characterized by a distal-to-proximal shift in joint mechanics (D2P) [1] that has been hypothesized to increase the metabolic cost of walking [2]. D2P has been observed as early as middle age [2] and is modulated by muscle strength [1]. While existing work has explored the effects of leg strength on D2P [1], the effect of toe strength remains unknown. Toe strength is an independent predictor of fall risk and has been targeted in interventions to improve gait and balance with age [3]. Hallux weakness may compromise propulsion and ankle joint mechanics at toe-off, increasing demand at the knee and hip joints to maintain gait speed. Thus, the purpose of this analysis was to investigate the relationship between hallux strength and ankle joint mechanics during gait among middle-aged and older adults.

Methods

Twelve healthy adults (9F/3M; age: 55.2 ± 9.2 years; BMI: 26.6 ± 4.8 kg/m^2) completed a barefoot walking gait analysis on an instrumented treadmill at their preferred speed (1.2 ± 0.2 m/s) and two hallux flexion strength tests on their dominant leg. The first strength test (T1) involved flexion at the metarsophalangeal (MTP) and interphalangeal joints; the second (T2) involved flexion at the MTP joint only. Both measures were performed seated and normalized to body size (height*mass). Gait was measured for 30 seconds using 3D motion capture. Ankle, knee, and hip joint power were calculated as the product of the joint angular velocity and joint moment. Joint work was calculated as the integral of joint power. Ratios for positive and negative joint to total lower limb work were calculated for each joint. Pearson correlation coefficients (r) were used to identify relationships between age, hallux strength, and joint work ratios ($\alpha = 0.05$).

Results and Discussion

Ratios for joint to total lower limb positive and negative work are presented in Table 1. Mean hallux flexion strength was 0.36 ± 0.2 and 0.66 ± 0.6 N/kg*m for T1 and T2, respectively. Strength measures were not correlated with each other or age ($p > 0.05$, $r \leq 0.25$). Positive knee work ratio had a strong but non-significant correlation with age ($p = 0.06$, $r = -0.55$); no other joint work ratios were associated with age. T2 strength was strongly and directly correlated with positive ($p = 0.04$, $r = 0.60$) and negative ($p = 0.03$, $r = 0.63$) ankle work ratios (Figure 1), with a strong but non-significant relationship between positive knee work ratio and strength ($p = 0.07$, $r = -0.54$). T1 strength was not associated with any kinetic outcomes, nor were any outcomes related to gait speed.

Adults with greater hallux "pressure" (i.e., T2) strength demonstrated greater mechanical contributions from the ankle joint during walking. The relationship between joint mechanics and T2 strength, but not T1 strength, may be explained by the greater task specificity of T2, which closely mimics foot function during gait. Further, T1 recruits the intrinsic foot muscles more than T2. Given the benefits of intrinsic foot muscle strengthening for balance among older adults [3], it is possible that greater T2 strength mitigates the need for compensations (e.g., D2P) to enhance gait stability.

Table 1: Mean (SD) ratios for joint to total lower limb work.

	Ankle:Total	**Knee:Total**	**Hip:Total**
Positive Work	0.366 (0.10)	0.281 (0.08)	0.353 (0.07)
Negative Work	0.618 (0.12)	0.239 (0.09)	0.143 (0.09)

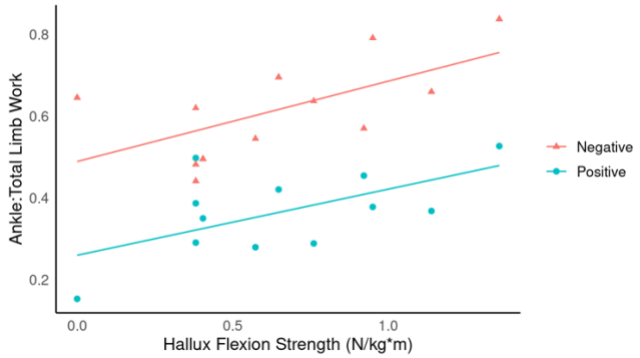

Figure 1: T2 hallux flexion strength and ankle:total limb work.

Conclusions

D2P is attenuated in healthy middle-aged and older adults with greater hallux flexion strength. Future research should consider the effect of toe strengthening interventions targeting intrinsic foot muscles on aging gait mechanics.

References

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