PASSIVE AND ACTIVE CONTRIBUTIONS TO JOINT KINETICS IN ELDERLY GAIT

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INTRODUCTION

Aging is associated with a shift in the source of joint power generation during walking. Older adults tend to exhibit reduced ankle power accompanied by increased power generation about the hip (DeVita and Hortobagyi, 2000). It is possible that hip flexion contractures in older adults may contribute to this redistribution of joint powers. Hip flexor tightness may inhibit hip extension in late stance, thereby reducing the effectiveness of plantarflexor push-off (Kerrigan, et al., 2003) while passively increasing net hip power (McGibbon and Krebs, 2004). The purpose of this study was to evaluate this hypothesis by investigating the effect of age on the passive and active contributions to hip and ankle powers during walking.

METHODS

Twenty healthy older (7 males, 13 females; age, 72±5y) and 20 healthy young (9 males, 11 females; age, 26±3y) adults participated in this study. All subjects performed a series of five walking trials across a 10m walkway at 80, 100, and 120% of preferred speed. Three-dimensional whole body kinematics were recorded at 100Hz using an 8 camera motion capture system. Ground reaction forces were synchronously collected for two successive foot strikes using three imbedded force plates. Inverse kinematics and inverse dynamics were used in conjunction with a scaled whole body model to estimate joint angles, moments, and powers throughout the gait cycle.

Passive joint moment-angle relationships about the hip, knee, and ankle were characterized for each subject (Silder, et al., 2006). Individuals were positioned side-lying with their dominant leg supported on a table via low-friction carts (Fig. 1). The lower limb was slowly manipulated through full ranges of hip, knee, and ankle motion using two 3D load cells over a series of 15 unique trials. Lower extremity EMG signals were monitored to ensure the muscles were relaxed such that passive properties were obtained. Kinematics and load cell forces were simultaneously measured and used to calculate joint angles and passive joint moments.

The passive joint moment-angle relationships were represented by a set of exponential functions that accounted for the stretch of both uni-articular tissues and bi-articular muscles (Silder, et al., 2006). Model parameters were estimated on a subject-specific basis using a least squares fitting routine. Joint angles measured during walking were then used in conjunction with the models to estimate passive joint moments and powers during walking. Active contributions were defined as the net power minus the passive contribution. Powers were integrated to estimate the work attributable to active and passive structures.

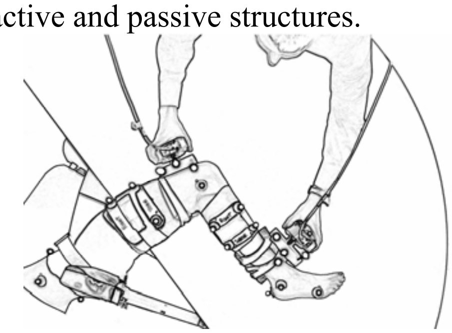

Figure 1: Passive joint moments were measured with the subject sidelying while the lower extremity was manipulated with two hand-held load cells (top view).

RESULTS

There were no significant differences between older and young adults with respect to walking speed, step length, or cadence (Table 1). Nevertheless, the older adults in this study exhibited greater peak hip extensor power (H3) and reduced peak ankle plantarflexor power (A2). This resulted in the older adults doing significantly more net work at the hip but less net work at the ankle at all walking speeds ($p<0.01$) (Table 1).

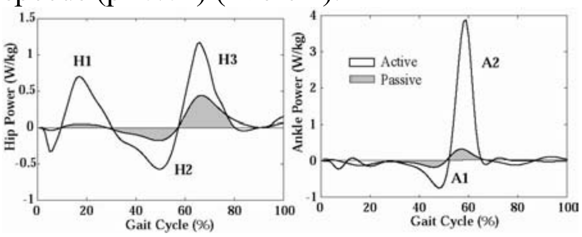

Figure 2: Representative plots of net and passive hip and ankle powers.

Passive structures about the hip provided an energy storage and return mechanism for both groups by contributing substantially to the negative hip power during late-stance (H2) and positively during initial swing (H3) (Fig. 2). Passive energy storage and return also occurred at the ankle during the A1 and A2 power bursts respectively, though the magnitudes were not as large as the hip. The work done by passive structures at the hip and ankle were not significantly different between groups at any of the speeds tested (Fig. 3).

CONCLUSIONS

Healthy older adults did not exhibit an increased reliance on the use of passive structures during walking when compared to young adults, suggesting that healthy older adults are more likely generating additional hip power actively rather than passively. Further research is needed to determine if these results extend to older adults who exhibit more pronounced impairments. We conclude that there must be alternative, underlying causes of the distal to proximal shift in joint power production seen in the gait of healthy older adults, which may include distal weakness, impaired sensory function, and/or balance concerns.

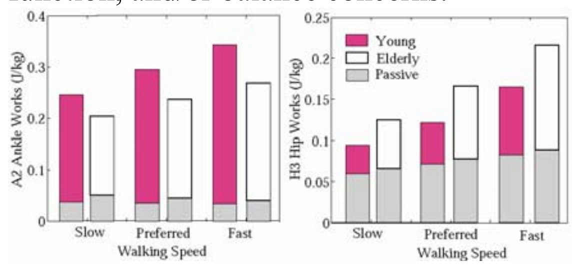

Figure 3: Passive and active work done during the A2 and H3 power bursts.

REFERENCES

DeVita, P., and Hortobagyi, T., (2000). *J Appl Physiol,* **88,** 1804-1811.

Kerrigan, C. et al, (2003). *Arch Phys Med Rehabil,* **84**, 1-6.

McGibbon, C. and Krebs, D., (2004). *J Appl Physiol*, **96**, 149-160.

Silder, A. et al, (2006). *J Biomech,* (in press).

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Table 1: Temporal gait characteristics and net works (mean±SD) done at the ankle and hip during the A2 and H3 power bursts, respectively (*denotes significant group difference $p<0.01$).

	Young Adults			Older Adults		
	Slow	**Preferred**	**Fast**	**Slow**	**Preferred**	**Fast**
Speed (m/s)	1.06±0.10	1.33±0.13	1.59±0.14	1.06±0.10	1.32±0.13	1.58±0.16
Step Length (m)	0.75±0.06	0.83±0.07	0.90±0.07	0.75±0.06	0.82±0.06	0.90±0.08
Cadence (steps/min)	99±10	112±10	122±10	100±6	115±7	125±8
A2 Work (J/kg)	0.24±0.07*	0.29±0.07*	0.34±0.09*	0.20±0.07*	0.23±0.08*	0.27±0.09*
H3 Work (J/kg)	0.09±0.04*	0.12±0.04*	0.17±0.05*	0.13±0.04*	0.17±0.04*	0.22±0.05*