BALANCE CONTROL AND PROPULSION IN GAIT OF HEALTY YOUNG AND ELDERLY SUBJCTS

Heydar Sadeghi (1,2,3), Paul Allard (1,4), Francois Prince (4,5), Hubert Labelle (1,2)

(1) Research Center
Sainte Justine Hospital
Montreal, Quebec
Canada

(2) Department of Medicine
University of Montreal
Montreal, Quebec
Canada

(3) Department of Kinesiology
Tabiat Moallem University
Tehran, Tehran
Iran

(4) Kinesiology Department
University of Montreal
Montreal, Quebec
Canada

(5) Marie-Enfant Hospital
Sainte Justine Hospital
Montreal, Quebec
Canada

INTRODUCTION

Changes in stereotypic movements such as walking patterns have been reported as early as 60 years old (1). Hence, attempts have been made to better understand the mechanism of these changes in the geriatric population, particularly for body support against gravity (balance control) and forward propulsion (propulsion) (2). To our knowledge, while the lack of balance control has been recognized as a major potential cause of falls and significant risk for injury (3), less attention has been paid to providing insight into propulsion or understanding how both balance control and propulsion are modified in the gait of the elderly population. Using 3D kinetic data, this study was undertaken to determine whether similar muscle power activities or mechanical energies are developed for balance control and propulsion during the gait of healthy elderly and young individuals.

METHODS

Eighteen elderly (71±6.8 years) and 18 young (25±4.1 years) able-bodied male subjects walked along a 10 m walkway at a freely-chosen speed. Data acquisition was performed with a Motion Analysis system and with a three Optotrak position sensors while one AMTI force platform recorded ground reaction forces. Spatio-temporal parameters as well as 22 peak muscle powers and their corresponding mechanical energies were calculated for each gait cycle. T-tests for independent samples were applied to determine significant differences between the elderly and young subjects with a $p<0.05$ threshold.

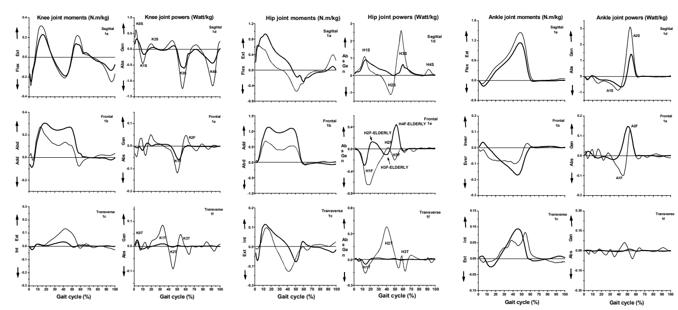
RESULTS

Significant differences were noted between all the corresponding temporal and spatial characteristics (Table 1).

Table 1: Spatio-temporal gait parameters (P <0.05).

PARAMETERS	Elderly		Young	
	MEAN	SD	Mean	SD
Speed (m/s)	0.93*	0.20	1.30*	0.12
Stance phase (%)	63.00*	3.00	60.70*	1.70
Step length (m)	0.61*	0.06	0.73*	0.04
Stride length (m)	1.23*	0.10	1.45*	0.07
Cadence (step/min)	91.70*	12. 20	106.50*	7.03

Figure 1: Average hip, knee and ankle muscle moments (N.m/kg) and powers (W/kg) calculated for healthy elderly (thick solid lines) and young (thin solid lines) subjects.



Of the 22 peak powers, 16 were significantly lower in the elderly group than the corresponding values in the young subjects. Nonetheless, most of the peak values occurred almost simultaneously.

DISCUSSION

Using 3D kinetic gait data, the main objective of this study was to characterize elderly gait based on the actions taken by the muscles to achieve control and propulsion and compare them with young able-bodied subjects.

Table 3: Average and standard deviation of the total energy in J/kg $10e^{-2}$ generated and absorbed in all three planes.

Joint	Elderly			Young		
	Gen	Abs	Total work	Gen	Abs	Total work
Hip	37.72 (11.17)	-12.62 (3.57)	50.34 (8.06)	57.54 (13.74)	-37.88 (8.55)	95.42 (10.01)
Knee	1.85 (1.18)	-17.21 (3.54)	18.94 (3.19)	6.25 (2.46)	-38.46 (7.16)	44.71 (6.19)
Ankle	13.65 (7.16)	-17.32 (11.78)	30.97 (8.03)	27.66 (17.58)	-21.09 (11.24)	48.75 (12.19)
Total	52.78 (18.04)	-47.75 (2.94)	100.25 (15.84)	91.45 (25.76)	-97.43 (9.87)	188.88 (28.18)

Table 4: Average 3D peak muscle powers (W/kg) and mechanical energies (J/kg 10^{-2}) and their standard deviation developed during walking of elderly and young able-bodied male subjects. [(*, power), (⊥, work) p<0.05.]

Joint	Power burst	Muscle Contraction	Elderly Power	Elderly Energy	Young Power	Young Energy
Hip	H1S	Extensors	0.96 (0.38)	25.31$^{\perp}$ (9.99)	1.10 (1.02)	18.74$^{\perp}$ (18.12)
	H2S	Flexors	-0.10* (0.09)	-8.20$^{\perp}$ (1.45)	-1.12* (0.82)	-17.47$^{\perp}$ (14.65)
	H3S	Flexors	0.65* (0.27)	8.45$^{\perp}$ (2.81)	2.60* (1.26)	31.83$^{\perp}$ (19.56)
	H1F	Abductors	-0.40* (0.21)	-3.10$^{\perp}$ (2.28)	-0.59* (0.32)	-16.41$^{\perp}$ (8.00)
	H2F	Abductors	0.10 (0.07)	3.13$^{\perp}$ (3.43)	0.02 (0.2)	0.94$^{\perp}$ (1.22)
	H3F	Abductors	-0.15* (0.07)	-1.32 (1.43)	-0.20* (0.09)	-1.29 (1.13)
	H1T	Medial rotators	-0.09* (0.07)	-0.42$^{\perp}$ (0.67)	-0.16* (0.13)	-1.61$^{\perp}$ (1.46)
	H2T	Lateral rotators	0.03* (0.02)	0.39$^{\perp}$ (0.40)	0.38* (0.28)	6.03$^{\perp}$ (4.73)
	H3T	Medial rotators	0.002* (0.02)	-0.02 (0.25)	-0.16* (0.12)	-1.10 (1.24)
Knee	K1S	Extensors	-0.24* (0.19)	-1.85 (1.79)	-0.45* (0.34)	-4.75 (2.95)
	K2S	Extensors	0.10* (0.07)	1.76 (1.52)	0.22* (0.16)	4.91 (3.82)
	K3S	Extensors	-0.67* (0.27)	-7.64 (3.73)	-1.24* (0.64)	-13.95 (8.12)
	K4S	Flexors	-0.47* (0.21)	-6.86 (1.93)	-1.15* (0.64)	-16.82 (13.18)
	K1F	Adductors/Abductors	-0.06* (0.07)	-0.78 (0.83)	-0.03* (0.02)	-0.89 (0.85)
	K2F	Adductors/Abductors	0.005 (0.004)	-0.08 (0.08)	0.05 (0.03)	-1.20 (2.24)
	K1T	External rotators	0.02* (0.01)	0.09 (0.11)	0.09* (0.04)	0.95 (0.74)
	K2T	Internal rotators	-0.004* (0.001)	–	-0.09* (0.05)	-0.85 (0.68)
	K3T	External rotators	0.003* (0.001)	–	0.06* (0.05)	0.39 (0.45)
Ankle	A1S	Dorsiflexors	-0.73 (0.20)	-16.99 (5.52)	-0.87 (0.28)	-18.49 (3.68)
	A2S	Plantarflexors	1.45* (0.46)	11.89 (3.90)	3.11* (0.67)	26.26 (6.32)
	A1F	Evertors	-0.005 (0.03)	-0.33 (0.94)	-0.010 (0.07)	-2.60 (1.70)
	A2F	Invertors	0.15 (0.14)	1.76 (2.00)	0.13 (0.12)	1.40 (0.90)

Our spatio-temporal data were in general agreement with those presented in the literature for elderly and young individuals (4). Generally, the shape and magnitude of muscle moment and power curves presented in this study are similar to those previously published for the gait of elderly and young subjects (2,5).

The hip extensor (H1S) was recognized as the first source of both balance and propulsion. The hip extensors give the body a push from behind (2,6) and also contribute to controlling the movement of the head, arms and trunk (6) and preventing stance collapse (7). The longer phasic duration for the hip extensors (H1S, 5-35% of GC) observed in the elderly could be attributed to muscle compensation in the frontal plane power activity (H1F) which is recognized as the main element in maintaining stability during single limb support (8). The hip abductors (H1F) provided 81% less negative energy in the elderly (-3.10 J/kg 10^{-2}) than the young (-16.41 J/kg 10^{-2}) subjects, while the H1F eccentrically contracted for up to 20% of the gait cycle to control the dropping pelvis during weight acceptance for young subjects (10). Therefore, the hip extensors (H1S) should not just be considered as a main source to assist the elderly in preventing stance collapse (7) but also as a source of muscle power helping to push the body forward (6).

During midstance, the hip power generation (H1S) coupled with the H2S power burst absorption helped to decelerate the backward rotation of the thigh (9) and trunk, while the H2F generation activity raised the pelvis and trunk to their neutral position (9). The absence of the H2S in the elderly group could be associated with a shorter stride length and slower walking speed and to a forward inclination of the trunk as is commonly observed in this population (10).

Ankle plantarflexor (A2S) and hip flexor (H3S) at push-off have been recognized as a major source for propelling the body forward in the plane of progression in healthy young (9) and elderly subjects (11). However, the smaller (71%) power burst (H3S) in the elderly group compared to the young subjects may be indicative of a muscle weakness in pulling the leg up and forward which could be associated with decreased cadence and slower walking speed. Meanwhile, the energy generated at the ankle during the propulsion phase (A2S, 11.89 J/kg 10^{-2}) in the elderly group was larger than that at the hip (H3S, 8.45 J/kg 10^{-2}). Therefore, it seems that ankle muscle power in the elderly group makes a major contribution to propulsion while the hip flexors play a secondary role during the propulsion phase. Since energy absorption during gait is associated with the balance control (11), these results might explain in part the role of the ankle and knee muscles in maintaining balance in the elderly, while for the younger subjects this was provided by the knee and hip.

CONCLUSION

For the younger subjects, propulsion was initiated by hip muscle activity shortly after heel-strike, maintained throughout midstance (lateral rotators, H2T) and completed at pull-off and by the ankle at push-off. In elderly gait, the propulsion task was limited to muscle activity at the ankle in push-off and at the hip during pull-off. For the elderly subjects, balance during the stance phase could be considered an additional task for the hip extensors. This is because of the contribution of hip frontal muscle power to compensate for the lack of hip sagittal muscle power activity during elderly ambulation.

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