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Age-associated differences in the gait pattern changes of older adults during fast-speed and fatigue conditions: results from the Baltimore longitudinal study of ageing

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Abstract

Objective: the present study investigated the effects of walking under different challenges and kinematics and kinetics generated during these activities and how these vary with age. We hypothesised that age-associated changes in gait speed and kinetics are more pronounced during fast-speed walking and post-activity walking, compared with usual-speed walking.
Methods: investigated walking under three conditions: (i) usual speed, (ii) fast speed and (iii) post-activity in 183 Baltimore Longitudinal Study of Aging participants (mean 73 ± 9 years) who could walk unassisted.
Results: across all tasks, gait speed decreased with older age and this decline rate was exacerbated in the fast-speed walking task, compared with usual-speed walking ($P < 0.001$). Medial–lateral (ML) hip-generative mechanical work expenditure declined with age and the rate of decline was steeper for walking at fast speed and post-activity during hip extension ($P =$ 0.032 and 0.027, respectively), compared with usual-speed walking.
Conclusions: these findings indicate that older adults experience exacerbated declines in gait speed and ML control of the hip, which is explicitly evident during challenging walking. Exercise programmes aimed at improving gait speed and ML joint power from hip and ankle may help reverse age-associated changes in gait pattern among older adults.

Keywords: *gait analysis, ageing, medial-lateral control, exacerbated decline, mechanical work expenditure, elderly*

Introduction

Customary gait speed in older adults is a good measure of overall walking performance. In general, it reflects energetic efficiency, muscle strength, balance control and endurance [1]. Self-chosen usual gait speed requires the selection of a certain stride length, joint angular displacement [2, 3] and the appropriate joint torque and power [4–6]. There is evidence that the selection of these elements is aimed at maximising energetic efficiency [7]. Changes in gait patterns with ageing have been described in previous studies and a decline in gait speed appears as one of the most consistent age-associated changes [5, 6]. Slower walking of older adults was related to fear of fall [8], muscle weakness [9] and impairment of motor control [10]. However, it is still not clear whether the speed decline with ageing is a compensatory effort to improve safety [6] or it is merely the reflection of deteriorated muscle activity performance. It is reasonable to hypothesise that age-related gait changes are even more evident during challenging walks, compared with self-selected usual walking. However, age-associated changes in gait during challenging conditions have been studied only seldom.

Reduced ankle joint power during fast-speed walking among older adults was reported [5, 11]. A slower gait speed among older adults with fatigue was also previously reported [12]. It is, nonetheless, not clear whether changes in gait performance are more strongly affected by ageing under challenging conditions, such as walking at a fast speed or in a post-activity state (i.e. a possible marker of fatigue) compared with customary, self-selected walking. It is likely that these challenging conditions place a greater demand on motor control and hence may be more sensitive to age-associated declines. For example, fast-speed walking likely requires relatively rapid generation of high peak power from the joints of lower extremities.

In the present study, gait parameters in the form of spatiotemporal measurement, range of rotation and mechanical work expenditure (MWE) were investigated to determine age-associated changes in gait during challenging walks. We assessed three-dimensional (3D) gait parameters of older adults during three different tasks, namely usual-speed walking, fast-speed walking and post-activity walking. We examined the *a priori* hypothesis that age-related changes in gait performance were more pronounced for fast-speed walking and post-activity walking, compared with usual-speed walking.

Methods

Participants

The data reported here were collected in 183 (age 60–96 years) participants of the Baltimore Longitudinal Study of Aging (BLSA; longitudinal cohort study conducted by the Intramural Research Program of the NIH, NIA) who were studied in our gait laboratory between January and July of 2008. All participants who did not have a hip or knee joint prosthesis, severe joint osteoarthritis, pain or history of stroke or Parkinson's disease and who could follow instructions and safely complete a 4 m walk unaided were included in this study. Participants who had a body mass index (BMI, kg/m^2) over 40 were not included in this study because of technical difficulty of positioning the pelvic markers needed in gait analysis. The BLSA protocol was approved by the Medstar Research Institution Review Board. Participants were given a detailed description of the study and consented to participate.

Gait measurement

The protocol for gait analysis used in our laboratory has been described elsewhere [13]. Briefly, participants were instrumented with 20 reflective markers positioned according to anatomical landmarks including: anterior and posterior superior iliac spines, medial and lateral knees, medial and lateral ankles, toe (second metatarsal head), heel and lateral wands over the mid-femur and mid-tibia. A Vicon 3D motion capture system with 10-digital cameras (Vicon 612 system, Oxford Metrics Ltd, Oxford, UK) measured the movements of the segments for lower extremity, where the reflective markers were attached (60 Hz sampling frequency). During the walking task, ground reaction forces were measured with two sequentially staggered AMTI force platforms (Advanced Mechanical Technologies, Inc., Watertown, MA, USA; 1080 Hz sampling frequency). After all markers were positioned on the skin and non-reflective firm fitting spandex short pants, participants were asked to walk across a 10 m long laboratory walkway at their usual and fast speeds. The usual-speed walking task was based on a gait test at the self-preferred customary gait speed, whereas fast-speed walking task was based on a gait test where subjects were asked to walk as fast as possible without running. After approximately 30 min of additional tasks (e.g. 10 trials of fast walking, 4 trials of walking over obstacles, 8 trials of narrow-based walking; all of these are not included in the present study), participants were asked to perform a final walking task at their customary, self-selected gait speed. This task, referred in this report as the post-activity walking task, can be considered a functional measure of typical daily life walking that occurs after a fair amount of activity, reflecting a potential marker of fatigue; here, the amount of activity was standardised across all subjects, but the specific effects on muscle and aerobic function were not controlled. Participants were not informed about the presence and location of the force platforms on the walking path. Trials were performed until at least three gait cycles of the left and right sides with complete foot landing on the force platform were obtained from usual-speed, fast-speed and post-activity walking tasks. These three measurements were taken for guaranteeing the standardised assessment of gait characteristics with property of variability (we are not reporting variability in this paper) in BLSA database. The raw coordinate data of marker positions were digitally filtered with a fourth-order zero-lag Butterworth filter with a cutoff at 6 Hz.

Data process and statistical analysis

Three dimensional kinematic and kinetic gait parameters were measured and calculated as previously reported [13]. Dominant gait periods within the stance phase, which were used in this study as the temporal measurement and the duration for MWE calculation.

Statistical analyses were performed using SAS 9.1 Statistical Package (SAS Institute, Inc., Cary, NC, USA). Because all subjects did not complete all tasks, an unbalanced design in sample sizes was handled by generalised estimating equations (GEE) [14]. In the GEE method, all non-missing pairs of tasks were used for the estimations of missing task. An advantage of this approach is that it makes maximal use of the available data set. Nonetheless, we confirmed that similar results were obtained if only the sub-set of participants who had no missing task were analysed. Multilevel regression models were used to compare age-associated gait parameters for the fast-speed walking and post-activity walking to the usual-speed walking task. These models included appropriate interaction terms to test the hypotheses that the effect of age on the different parameters varied significantly across tasks. Regression models were adjusted for gait speed, sex, weight and height. Statistical significance was defined with a *P*-value less than 0.05.

Results

The 183 individuals (48% women) who participated in this study were aged 60–96, with an average BMI of 26.9 (±4.2 kg/m^2). Spatiotemporal gait parameters and their associations with age in the three walking tasks are summarised in Table 1. With increasing age, gait speed and stride length were significantly lower, whereas cadence was significantly higher for all walking tasks ($P < 0.001$, for all). Stride width and stance percent of the gait cycle (PGC) were higher with older age in the usual-speed walking and post-activity walking, but not in the fast-speed walking. PGC for hip flexion and ankle plantar flexion were higher with older age for the usual-speed walking ($P < 0.001$ and $P = 0.003$, respectively).

Range of rotation and MWE for the three walking tasks from the hip, knee and ankle in the anterior–posterior (AP) plane and medial–lateral (ML) plane are summarised in Table 2. The range of rotations for the hip, knee and ankle in the AP plane were lower with older age in all walking tasks. With older age, MWE during hip extension in the AP plane was higher in the usual-speed walking ($P = 0.036$), while MWE during hip flexion in the AP plane was higher in the usual-speed and post-activity walking tasks ($P < 0.001$ and $P = 0.002$). AP ankle-generated MWE during ankle plantar flexion in late stance was lower with older age only in the fast-speed walking ($P = 0.043$). AP hip absorption MWE during hip extension was lower with older age in the usual-speed walking ($P < 0.001$) and post-activity walking ($P = 0.022$).

The range of rotation for the hip and ankle in the ML plane and ML hip-generated MWE during hip extension and flexion were lower with older age for all three walking tasks ($P < 0.001$). ML knee-generated MWE during knee flexion was lower with older age in the fast-speed walking ($P < 0.001$). ML ankle-generated MWE during ankle plantar flexion for the usual-speed walking was higher with older age ($P = 0.009$). ML hip absorption MWE during hip flexion for the usual-speed walking and post-activity walking was higher with older age ($P < 0.001$). ML ankle absorption MWE during ankle plantar flexion was lower with older age for all three walking tasks ($P < 0.001$).

Figure 1 illustrates the exacerbated declines in gait speed and ML MWEs for the fast-speed walking and post-activity walking, compared with usual-speed walking. In the fast-speed walking, age-associated declines in gait speed, stride length, ML hip-generated MWE during hip extension and ML ankle absorption MWE during ankle plantar flexion were exacerbated ($P < 0.001$, $P = 0.003$, 0.032 and 0.004, respectively) compared with usual-speed walking. Similarly, in the post-activity walking, age-associated declines in the ML hip-generated MWE during hip extension and flexion were exacerbated ($P = 0.027$, 0.003, respectively) compared with usual-speed walking. We also repeated the analyses on the subgroup of subjects who completed all three walking tasks ($N = 141$). The results were essentially identical (data not shown).

Discussion

Consistent with previous studies, slower gait speed and shorter stride length with older age were confirmed in this study in a usual-speed walking task as well as in fast-speed walking and post-activity walking [5, 15, 16]. Wider stride width with older age, already reported from previous studies [17, 18], was also confirmed in the present study in the usual-speed walking and post-activity walking tasks. Consistent with our hypotheses, we observed that the declines in gait speed and ML MWEs with older age were significantly sharper for the challenging walks (i.e.

Table 1. Spatiotemporal gait measures during the usual-speed, fast-speed and post-activity walking tasks and their relationship with age

Spatiotemporal parameters	Regression analysis with advanced age[a]									Interactions of fast-speed and post-activity condition[b]			
	Usual-speed ($n = 183$)			Fast-speed ($n = 162$)			Post-activity ($n = 147$)			Fast-speed vs. usual-speed		Fatigue-condition vs. usual-speed	
	Mean	β^c	*P*-value	Mean	β^c	*P*-value	Mean	β^c	*P*-value	β^c	*P*-value	β^c	*P*-value
Speed and distances													
Gait speed (m/s)	1.11	−0.014	**<0.001**	1.66	−0.024	**<0.001**	1.27	−0.015	**<0.001**	−0.01	**<0.001**[d]	−0.001	0.353
Stride length (m)	1.19	−0.014	**<0.001**	1.42	−0.016	**<0.001**	1.30	−0.014	**<0.001**	−0.003	**0.003**[d]	−0.000	0.456
Cadence (steps/min)	111.78	0.641	**<0.001**	140.20	0.741	**<0.001**	116.77	0.615	**<0.001**	0.101	0.287	−0.026	0.660
Stride width (cm)	11.08	0.078	**0.007**	10.35	0.012	0.668	10.06	0.050	**0.049**	−0.066	**<0.001**	−0.028	0.061
PGC													
Stance	63.83	0.063	**<0.001**	62.33	0.016	0.188	63.02	0.044	**<0.001**	−0.048	**<0.001**	−0.019	**0.048**
Hip extension	51.02	0.027	0.277	48.45	0.033	0.256	49.99	0.051	**0.043**	0.06	0.769	0.024	0.131
Hip flexion	10.87	0.050	**<0.001**	12.18	0.023	0.232	10.95	0.016	0.258	−0.027	0.083	−0.035	**<0.001**
Knee extension	27.39	0.037	0.357	25.42	−0.025	0.378	26.79	0.007	0.825	−0.062	**0.029**	−0.030	0.167
Knee flexion	23.19	0.030	0.441	22.57	0.009	0.762	22.74	0.015	0.640	−0.021	0.486	−0.015	0.545
Ankle dorsiflexion	38.90	0.031	0.296	29.69	0.093	0.076	36.15	0.038	0.239	0.062	0.146	0.008	0.753
Ankle plantar flexion	18.93	0.083	**0.003**	27.28	−0.054	0.322	20.56	0.020	0.516	−0.137	**0.002**	−0.063	**0.023**

Bold indicates significance with $P < 0.05$.

[a] Adjusted for gait speed, height, weight and sex (gait speed: adjusted for height, weight and sex).

[b] Gait parameter differences in walking tasks at fast-speed and post-activity condition compared with usual-speed walking.

[c] Estimated coefficient for linear regression.

[d] Exacerbated decline compared with the usual-speed walking (only for the case both compared walking tasks already showed negative associations with older age).

Table 2. Age-associated changes in gait parameters for the rotations of lower extremities in the usual-speed, fast-speed and post-activity condition

Gait parameters in kinematics and kinetics	Regression analysis with advanced age									Interactions of fast-speed and post-activity condition[a]			
	Usual-speed ($n = 183$)			Fast-speed ($n = 162$)			Post-activity ($n = 147$)			Fast speed versus usual speed		Post-activity versus usual-speed	
	Mean	β[b]	P-value	Mean	β[b]	P-value	Mean[c]	β[b]	P-value	β[b]	P-value	β[b]	P-value
AP side													
Range of motion (°)													
Hip	39.67	−0.176	**<0.001**	45.39	−0.141	**0.004**	42.33	−0.173	**<0.001**	0.035	0.246	0.003	0.829
Knee	53.68	−0.254	**<0.001**	56.77	−0.205	**<0.001**	55.39	−0.248	**<0.001**	0.050	0.050	0.006	0.716
Ankle	23.49	−0.138	**<0.001**	24.19	−0.160	**<0.001**	24.56	−0.144	**<0.001**	−0.022	0.373	−0.005	0.766
Generated MWE, 1,000 J/kg for mean in													
Hip extension	103.49	1.077	**0.036**	156.32	0.189	0.799	107.27	0.960	0.091	−0.889	0.159	−0.117	0.805
Hip flexion	90.67	1.063	**<0.001**	177.51	0.431	0.236	106.24	0.827	**0.002**	−0.632	**0.048**	−0.236	0.174
Knee extension	71.17	−0.119	0.769	110.17	−0.080	0.911	89.74	−0.139	0.770	0.039	0.948	−0.020	0.956
Knee flexion	7.81	−0.019	0.869	7.78	−0.133	0.347	7.45	0.004	0.974	−0.113	0.288	0.024	0.800
Ankle dorsiflexion	7.69	−0.015	0.833	10.05	0.013	0.908	10.82	0.141	0.161	0.028	0.812	0.156	0.126
Ankle plantar flexion	156.72	−0.144	0.750	219.89	−1.377	**0.043**	173.80	−0.856	0.115	−1.233	**0.015**	−0.712	0.074
Absorption MWE, 1,000 J/kg for mean in													
Hip extension	235.58	−2.629	**<0.001**	309.39	−2.000	0.083	276.36	−2.109	**0.022**	0.628	0.534	0.519	0.486
Hip flexion	1.75	0.058	0.127	2.91	−0.041	0.158	1.65	−0.031	0.095	−0.099	0.094	−0.090	0.078
Knee extension	11.44	−0.172	0.117	15.61	−0.118	0.426	13.16	−0.038	0.731	0.054	0.666	0.134	0.160
Knee flexion	178.39	−0.299	0.629	243.39	0.096	0.908	199.78	−0.271	0.735	0.395	0.574	0.028	0.962
Ankle dorsiflexion	131.91	0.019	0.987	105.23	−0.135	0.820	117.57	−0.046	0.922	−0.154	0.773	−0.064	0.886
Ankle plantar flexion	5.52	0.043	0.372	5.64	−0.037	0.246	5.18	−0.010	0.757	−0.080	0.120	−0.054	0.265
ML side													
Range of motion (°)													
Hip	9.80	−0.064	**<0.001**	12.06	−0.094	**<0.001**	10.88	−0.082	**<0.001**	−0.030	0.054	−0.018	0.122
Knee	10.53	−0.072	**0.031**	10.62	−0.033	0.362	10.72	−0.064	0.068	0.040	0.089	0.008	0.591
Ankle	8.42	−0.095	**<0.001**	8.70	−0.093	**<0.001**	9.04	−0.097	**<0.001**	0.001	0.939	−0.002	0.896
Generated MWE, 1,000 J/kg for mean in													
Hip extension	62.30	−1.079	**<0.001**	70.58	−1.434	**<0.001**	68.89	−1.370	**<0.001**	−0.356	**0.032**[d]	−0.291	**0.027**[d]
Hip flexion	14.64	−0.361	**<0.001**	9.54	−0.353	**<0.001**	15.65	−0.537	**<0.001**	0.008	0.879	−0.177	**0.003**[d]
Knee extension	6.57	−0.001	0.989	9.66	0.007	0.945	8.01	−0.026	0.693	0.008	0.901	−0.026	0.407
Knee flexion	3.33	−0.033	0.229	4.00	−0.116	**<0.001**	3.61	−0.069	**0.017**	−0.083	**<0.001**	−0.037	**0.024**
Ankle dorsiflexion	5.24	−0.029	0.364	5.86	−0.080	0.197	6.20	−0.006	0.896	−0.051	0.425	0.023	0.599
Ankle plantar flexion	4.45	0.061	**0.009**	3.95	−0.005	0.848	3.42	0.007	0.787	−0.066	**0.020**	−0.054	**0.030**
Absorption MWE, 1,000 J/kg for mean in													
Hip extension	44.75	0.305	0.125	64.88	0.068	0.820	49.52	0.211	0.355	−0.238	0.266	−0.094	0.463
Hip flexion	2.47	0.122	**<0.001**	7.70	0.043	0.307	3.26	0.127	**<0.001**	−0.080	**0.015**	0.005	0.760
Knee extension	7.98	0.023	0.630	8.35	−0.061	0.311	7.79	−0.011	0.822	−0.085	**0.024**	−0.035	0.181
Knee flexion	7.81	−0.031	0.669	6.67	0.019	0.795	7.31	−0.030	0.686	0.050	0.425	0.001	0.980
Ankle dorsiflexion	8.81	0.120	0.340	8.46	0.021	0.742	8.20	−0.106	**0.045**	−0.099	0.446	−0.226	0.082
Ankle plantar flexion	7.13	−0.145	**<0.001**	10.91	−0.292	**<0.001**	8.63	−0.183	**<0.001**	−0.147	**0.004**[d]	−0.037	0.362

Bold indicates significance with $P < 0.05$.

[a] Gait parameter differences in walking tasks at fast-speed and post-activity condition compared with usual-speed walking.

[b] Estimated coefficient for linear regression.

[c] Adjusted for gait speed, height, weight and sex (gait speed: adjusted for height, weight and sex).

[d] Exacerbated decline compared with the usual-speed walking (only for the case both compared walking tasks showed negative associations with older age).

fast-speed walking and post-activity walking), compared with self-selected usual-speed walking, supporting the idea that age-associated changes in gait are especially more evident during these challenging walking conditions.

In the AP plane, all three walking tasks revealed similar age-associated patterns in the range of rotations, whereas age-associated changes in mechanical energy usages had different patterns by walking tasks (Table 2). Higher AP hip-generated MWEs during hip flexion with older age in the usual-speed walking and post-activity walking are consistent with a previously reported study [19] and can be thought of as a compensatory effort to maintain the same gait speed in spite of significantly reduced ranges in the rotational motion. Lower AP ankle-generated MWE during ankle plantar flexion of late stance for the fast-speed walking with older age may represent reduced ankle propulsion before swing that can cause shorter swing or lack of foot clearance. This result coincides with the previous reports examined by inverse dynamics [20] and electromyography (EMG) [21]. This also suggests that older adults

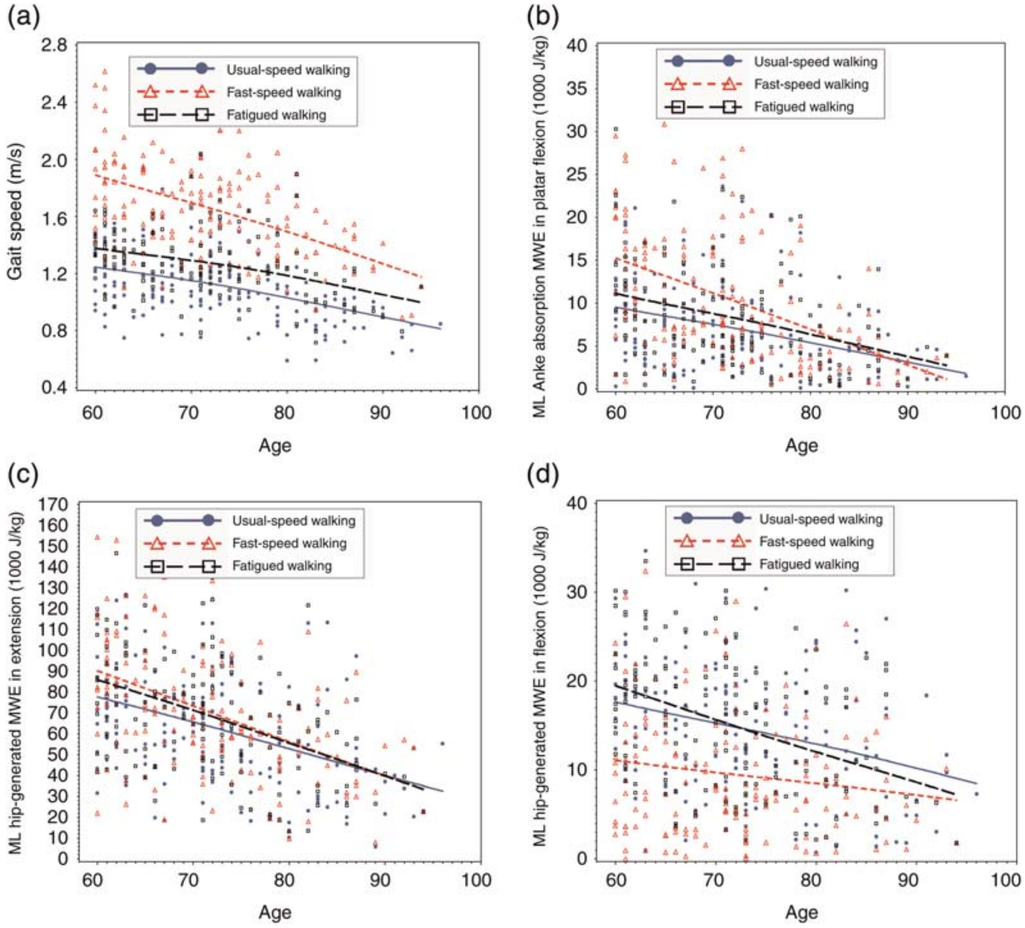

Figure 1. Exacerbated declines in gait speed (a), ML ankle MWE in plantar flexion (b), ML hip MWE in extension (c) and ML hip MWE in flexion (d) during challenging walking tasks.

may have difficulty in fast-speed walking because of reduced mechanical energy from ankle joint. Reduced AP hip absorption MWE during hip extension with older age, observed in the usual-speed walking and post-activity walking, may represent a substantial functional loss because this occurs during a critical weight supporting period.

Lower range of rotations from the hip and ankle joints in the ML plane for all walking tasks are likely one of the reasons for the lower ML-generated MWEs in the hip and ankle with older age. The negative associations with age of ML hip-generated MWEs during hip extension and hip flexion for all three walking tasks are probably related to lower angular speed and strength in the hip abductor muscle group. Such an age-associated decline of hip generated MWE in the ML plane may be one of the keys to mobility performance decline in older adults. Hip abductor contraction during the stance period is essential for maintaining ML stability and a robust support from the ipsilateral leg movement. At the same time, hip-generated MWE in the ML plane is important to allow enough clearance space for the contralateral foot during swing [22, 23]. In general, ML hip-generated MWE and AP hip-generated MWE are generated from hip abductors and hip flexors, respectively, and those alignments of muscle groups are relatively aligned against each other for their movements in the ML plane. Therefore, positively age-associated AP hip-generated MWE during hip flexion, which was observed in the present study in the usual-speed and post-activity walking tasks, might have affected the ML hip-generated MWE during hip flexion, which was lower with older age.

The fast-speed and post-activity conditions revealed exacerbated declines in gait performance with older age, compared with usual-speed walking task. Declines in the gait speed and ML MWE from the hip and ankle joints can be interpreted as decreased potential capacity to manoeuvre and control ML locomotion in older adults, respectively. Thus, these findings can be thought of as risk factors for the mobility limitations, falls or injuries among older adults. This hypothesis should be tested in longitudinal studies. The comparisons between different walking tasks in this study revealed elements of gait that are influenced by age under usual and different walking conditions. Causal pathways between the characteristics identified here and longitudinal age association with mobility limitation remain to be established. However, if the hypothesis raised by this study is confirmed, gait tests that focus on different walking conditions can be developed and translated into clinical practice. In addition, specific exercise programmes aimed at improving gait speed for the fast-speed walking or enhancing ML controllability from the hip and ankle joint could be developed with the aim of improving function and energetics among older adults.

This study has limitations. We did not measure the metabolic energy consumption during gait analysis in the BLSA participants, so information about efficiency in energy utilisation of older adults cannot be assessed. Also, because gait speed was observed to be faster for the post-activity walking task, when compared with usual-speed walking task, the 30 min of interim testing may not have been adequate to cause a condition of 'fatigue' in our participants. Repeated walking tests before the post-activity walking task may have caused different changes in other factors such as apprehension, learning (or familiarity) and motivation in older adults. To more completely describe the observed age-associated effects of fatigue, it might be helpful to also investigate these associations after controlling for changes in muscle properties as measured by EMG or maximum voluntary contraction. Still, the exacerbated age-related declines observed in the post-activity state suggest that some element in this state likely did play a role, perhaps reflecting fatigue. Finally, the cross-sectional nature of these data allows for the study of correlation but not causality. The BLSA is currently collecting longitudinal data that are designed to overcome this limitation.

Key points

- Age-associated gait pattern change.
- Exacerbated gait speed decline.
- Decline in ML control.

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Conflicts of interest

All the authors declare that non financial and personal relationships were conducted with other people or organizations that could inappropriately influence or bias this work.

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References

1. Friedman PJ, Richmond DE, Baskett JJ. A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. Age Ageing 1988; 17: 227–35.
2. Graf A, Judge JO, Ounpuu S, Thelen DG. The effect of walking speed on lower-extremity joint powers among elderly adults who exhibit low physical performance. Arch Phys Med Rehabil 2005; 86: 2177–83.
3. Kerrigan DC, Lee LW, Collins JJ, Riley PO, Lipsitz LA. Reduced hip extension during walking: healthy elderly and fallers versus young adults. Arch Phys Med Rehabil 2001; 82: 26–30.
4. DeVita P, Hortobagyi T. Age causes a redistribution of joint torques and powers during gait. J Appl Physiol 2000; 88: 1804–11.
5. Judge JO, Davis RB III, Ounpuu S. Step length reductions in advanced age: the role of ankle and hip kinetics. J Gerontol A Biol Sci Med Sci 1996; 51: M303–12.
6. Winter DA, Patla AE, Frank JS, Walt SE. Biomechanical walking pattern changes in the fit and healthy elderly. Phys Ther 1990; 70: 340–7.
7. McNeill A, lexander R. Energetics and optimization of human walking and running: the 2000 Raymond Pearl memorial lecture. Am J Hum Biol 2002; 14: 641–8.
8. Chamberlin ME, Fulwider BD, Sanders SL, Medeiros JM. Does fear of falling influence spatial and temporal gait parameters in elderly persons beyond changes associated with normal aging? J Gerontol A Biol Sci Med Sci 2005; 60: 1163–7.
9. Busse ME, Wiles CM, van Deursen RW. Community walking activity in neurological disorders with leg weakness. J Neurol Neurosurg Psychiatry 2006; 77: 359–62.
10. Kaya BK, Krebs DE, Riley PO. Dynamic stability in elders: Momentum control in locomotor adl. J Gerontol A Biol Sci Med Sci 1998; 53: M126–34.
11. Kerrigan DC, Todd MK, Della Croce U, Lipsitz LA, Collins JJ. Biomechanical gait alterations independent of speed in the healthy elderly: Evidence for specific limiting impairments. Arch Phys Med Rehabil 1998; 79: 317–22.
12. Vestergaard S, Nayfield SG, Patel KV *et al* Fatigue in a representative population of older persons and its association with functional impairment, functional limitation, and disability. J Gerontol A Biol Sci Med Sci 2009; 64: 76–82.
13. Ko S, Ling SM, Winters J, Ferrucci L. Age-related mechanical work expenditure during normal walking: the Baltimore Longitudinal Study of Aging. J Biomech 2009; 42: 1834–9.
14. Lipsitz SR, Fitzmaurice GM, Orav EJ, Laird NM. Performance of generalized estimating equations in practical situations. Biometrics 1994; 50: 270–8.
15. Dingwell JB, Marin LC. Kinematic variability and local dynamic stability of upper body motions when walking at different speeds. J Biomech 2006; 39: 444–52.
16. Olney SJ, Griffin MP, McBride ID. Temporal, kinematic, and kinetic variables related to gait speed in subjects with hemiplegia: a regression approach. Phys Ther 1994; 74: 872–85.
17. Dean JC, Alexander NB, Kuo AD. The effect of lateral stabilization on walking in young and old adults. IEEE Trans Biomed Eng 2007; 54: 1919–26.
18. Schrager MA, Kelly VE, Price R, Ferrucci L, Shumway-Cook A. The effects of age on medio-lateral stability during normal and narrow base walking. Gait Posture 2008; 28: 466–71.

19. McGibbon CA. Toward a better understanding of gait changes with age and disablement: neuromuscular adaptation. Exerc Sport Sci Rev 2003; 31: 102–8.
20. Silder A, Heiderscheit B, Thelen DG. Active and passive contributions to joint kinetics during walking in older adults. J Biomech 2008; 41: 1520–7.
21. Schmitz A, Silder A, Heiderscheit B, Mahoney J, Thelen DG. Differences in lower-extremity muscular activation during walking between healthy older and young adults. J Electromyogr Kinesiol 2009; 19: 1085–91.
22. Chen HL, Lu TW, Wang TM, Huang SC. Biomechanical strategies for successful obstacle crossing with the trailing limb in older adults with medial compartment knee osteoarthritis. J Biomech 2008; 41: 753–61.
23. Perry J. Gait Analysis: Normal and Pathological Function. Thorofare, NJ: SLACK Incorporated, 1992.

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Age and outcome in acute emergency medical admissions

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Abstract

Background: there is a lack of outcome information with respect to older health service users. The purpose of this study was to examine 30-day in-hospital mortality and its predictors in all elderly patients admitted as a medical emergency to our hospital.

Methods: all patients admitted between 2002 and 2008 were studied, linking anonymised clinical, administrative, laboratory and mortality data. Significant univariate predictors of outcome, including co-morbidity and illness severity score, were entered into a multivariate logistic regression model, adjusting the univariate estimates of the effect of age on in-hospital mortality.

Results: we admitted 23,114 consecutive acute medical admissions between 2002 and 2008; 30-day in-hospital mortality was 20.7% in the over 75 age category versus 4.5% in those younger. The unadjusted OR for a 30-day in-hospital mortality in the over 75 category of 5.21 (95% CI 4.73, 5.73) fell to 4.69 (95% CI 4.04, 5.44) when adjusted for outcome predictors excluding acute illness severity and 2.93 (95% CI 2.50, 3.42) when acute illness severity was added as a covariate. When the interaction between age and co-morbidity is examined, the odds ratio adjusts to 3.22 (95% CI 2.63, 3.6).

Conclusion: acute illness severity is more important than co-morbidity in explaining the outcome in older patients admitted as medical emergencies. Service planning for acute elderly care should be based on effective disease management programmes but recognise the contribution of acute illness severity to outcome when conditions deteriorate.

Keywords: *in-hospital mortality, acute illness severity, age, elderly*

Introduction

Sixteen percent (82 million people) of the European Union's population are over the age of 65 years. Twenty-four percent of whom are over the age of 80 years. Trends indicate that the over 65-year age group will increase by 21%, by the year 2020 (18.4 million in real terms), whereas the rate of increase in the over 80 group, the 'old–old', will be faster at 34% representing an absolute increase of 7.5 million in this age category alone [1]. Health planners have recognised that the ageing profile of Europe's population poses problems for the acute health sector as well as challenges in relation to