Gait & Posture 42 (2015) 54–59

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length Article

Gait characteristics and sensory abilities of older adults are modulated by gender

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ARTICLE INFO

Article history:
Received 28 November 2014
Received in revised form 9 April 2015
Accepted 11 April 2015

Keywords:
Older adults
Gender
Gait quality
Sensorimotor abilities
Accelerometry

ABSTRACT

Despite the general perception that women and men walk differently, little is known about the reasons for these differences, especially in older adults. Previous work on gender differences in older adults has focused on spatiotemporal parameters. This study aims to assess gender-related differences in gait spatiotemporal and quality parameters when walking on a flat walkway at two different self-selected speeds: comfortable and fast. Sensorimotor abilities (Strength, agility, standing balance, reaction time) were also compared by gender, and gender-specific associations between spatiotemporal and sensorimotor parameters and gait quality were studied. Two tri-axial accelerometers were used at head and pelvis levels to investigate spatiotemporal parameters (step length, velocity and cadence), and gait quality (harmonic ratios (HR) and attenuation of accelerations between body levels) in 122 older adults (90 women, 69.7 ± 5.1 y.o. and 32 men, 71.6 ± 6.4 y.o.). Both men and women walked with similar speed; however women presented faster cadence and shorter steps than men at both walking speeds. Women also walked with greater vertical HR (head and pelvis), mediolateral pelvis HR, and attenuation (mediolateral and anteroposterior) than men. Women had better control of standing balance on foam (eyes open and closed) and tandem test. Moreover, balance on foam, tandem test, step length and cadence were associated to gender-specific gait quality parameters. The aging process seems to be affecting men and women differently, thus, gender differences should be considered when preparing intervention programs to improve balance and gait in older populations or when establishing normative data for balance and gait in older adults.

1. Introduction

Falls among older adults have become a major public health problem, with one third of persons aged over 65 falling at least once each year [1], and most of these falls occurring during locomotion [2]. Several studies have reported changes in gait patterns of older population. In general, older adults adopt a more conservative gait pattern, increasing double support time and decreasing both velocity and step length [3,4], especially when facing challenging conditions such as irregular surfaces [5] or downhill walking [6]. Apparently, this is a strategy to increase stability and gait quality features (e.g., harmonic ratios and attenuation of accelerations from pelvis to head) and decrease perturbations to the body; however, some of these persons still fall or present decreased stability. A decline in sensorimotor abilities that are important for the control of gait, such as muscle strength, reaction time and balance has been associated with greater variability in gait measures, slower speed and cadence, shorter steps and longer double support time [7–9]. Moreover, Menz et al. [10] used multivariate techniques to show that impaired sensorimotor function was associated to decreased head stability, but the effect was largely indirect, mediated by reduced step length.

Gait characteristics and sensorimotor function may in turn be affected by gender. Smith et al. [11] reported greater pelvic obliquity and less vertical COM displacement in young women

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http://dx.doi.org/10.1016/j.gaitpost.2015.04.002
0966-6362/

compared with men while walking. Mazzà et al. [12] reported gender differences in the control of upper body accelerations on level walking, with young women better controlling attenuation of accelerations from shoulder to head. Riva et al. [13] indicated that older women (75-84 years-old) were less stable than men in a single-leg balance test, whereas Era et al. [14] reported that older women had better performance in standing balance tests and mentioned gender differences in the association between sensorimotor and balance tests. Callisaya et al. [15] showed that gender modifies the associations between age and spatiotemporal gait variables. The last three studies suggest that the aging process may affect gait and balance differently in men and women. Prior studies taking into account the gender variable have been performed on young participants or have not looked at gait quality parameters.

In this paper we examined: (i) the effect of gender on gait characteristics (spatiotemporal and accelerometer-related gait quality parameters) and sensorimotor abilities in a group of older men and women. (ii) Whether there are gender-specific associations between sensorimotor abilities and gait quality, and between gait spatiotemporal parameters and quality.

2. Methods

2.1. Participants

A sample of 122 older adults (90 women, 32 men) was recruited from organized physical activity groups. All subjects wore their own footwear in order to recreate daily life conditions. Participants were physically active, had no known visual, vestibular, musculo-skeletal or neurologic impairment and provided written informed consent before completing testing sessions. Prior approval was obtained from the University Bioethics Committee. Personal information regarding health issues (chronic or acute) and number of falls over the last two years were obtained. Subject characteristics are presented in Table 1.

2.2. Motor and sensory testing

Subjects underwent tests including the timed-Up-and-Go test (TUG test) [16], the 30 s chair-rise test [17], and quadriceps and ankle dorsiflexors isometric strength. The latter were obtained with a hand-held dynamometer placed distally from the joint; values were normalized to body mass. Two repetitions of each test were performed. Sensory function was assessed with a simple reaction time test (performed on a laptop computer) and 5 standing balance test conditions: Eyes Open (EO), Eyes Closed (EC), Eyes open on foam (EOF) (middle density foam, 15 cm height), eyes closed on foam (ECF)), and a tandem stance test (*T*), all performed on a Wii Balance Board to quantify average velocity of the center of pressure for each condition by first obtaining the total displacement of the center of pressure (CoP) then dividing by the total performance time [18]. All balance conditions were held for a maximum of 30 s, except the Tandem test (10 s). Three repetitions of each condition were performed and then averaged for analysis. Smaller scores in sensory tests indicate better performance.

Table 1
Participant characteristics.

Characteristics[a]	Women (F) ($N = 90$)	Men (M) ($N = 32$)
Age (years)	69.7 ± 5.1	71.6 ± 6.4
Body mass (kg)	65.5 ± 11.6	75.2 ± 11.2[*]
Height (cm)	155.3 ± 6.3	168.6 ± 6.5[*]
BMI	27.1 ± 4.4	26.4 ± 3.3
Leg length (LL)[b]	74.5 ± 3.6	78.1 ± 4.8[*]
Falls[§] (%)	34 (37.7%)	11 (34.4%)
Motor tests results		
Timed Up and Go test (TUG)(s)	6.0 ± 1.3	5.9 ± 1.8
30 s Chair rise test (reps)	14.2 ± 3.6	14.7 ± 4.1
Quadriceps strength (N/kg)	2.24 ± 0.58	2.47 ± 0.56
Dorsiflexors strength (N/kg)	0.98 ± 0.34	0.99 ± 0.29
Sensory test results		
EO (cm/s)[c]	1.54 ± 0.38	1.52 ± 0.32
EC (cm/s)[c]	1.86 ± 0.57	1.79 ± 0.36
EOF (cm/s)[c]	2.34 ± 0.87	2.77 ± 1.06[*]
ECF (cm/s)[c]	3.79 ± 1.48	4.66 ± 2.02[*]
T (cm/s)[c]	4.60 ± 1.68	5.59 ± 1.78[*]
Reaction time (s)	0.46 ± 0.17	0.52 ± 0.31

[a] Data are mean ± S.D.
[*] $p < 0.05$, difference between F and M.
[b] Leg length is defined as the distance from the greater trochanter to the lateral malleolus.
[c] Score indicates center of pressure (CoP) average velocity.
[§] Participants reporting at least one fall in the past two years.

2.3. Gait data collection and analysis

Participants were asked to walk at two different self-selected speeds: "comfortable" and "fast", in random order on a flat outdoor walkway. Distance traveled was 15 m, with the middle 10 m marked for step counting. Procedures have been previously described [6]. Briefly, inertial measurement units (Technaid SL, ±5 g), were used to collect three-dimensional linear accelerations from pelvis and head levels, fixed with tight elastic bands in the pelvis and the posterior part of the head, sampled at 50 Hz and processed with a custom-written algorithm (Matlab, Mathworks Inc.). Three trials were performed for each condition and steps were counted over the 10m-marked distance in every trial (rounded to the nearest half step), step length was obtained from the numbers of steps and walked distance and further combined with average step time (from accelerometer data) to calculate speed. Five strides from the middle of each trial were chosen. Data was low-pass filtered with a 4th order Butterworth filter (cut-off frequency of 20 Hz) [19]. Heel strikes were identified using the positive peaks of the anteroposterior pelvic accelerations [19] and used to segment every step. Sensors were level in the frontal but not the sagittal plane, thus, tilt angle was obtained from the average vertical output of the accelerometer (a_v) during a gait trial in which the gravitational acceleration (g) is projected in the local coordinate system, then the cosine of the tilt angle (θ) was defined by: $\cos\theta = a_v/g$. Then, the absolute values of accelerations in the vertical and anteroposterior directions were obtained by multiplying the obtained accelerometer data by $\cos\theta$. Tilt angle was obtained for each device in every trial and then used to adjust the components to a global coordinate system [20].

The following variables were then calculated:

(1) **Walking velocity** (m/s): Average step length/average step time
(2) **Cadence** (steps/min): CAD = 60/(average step time).
(3) **Average step length** (cm): distance/number of steps.

Gait spatiotemporal data was scaled to body size, using leg length (LL) as the scaling factor, according to Hof [21]. "Scaled" step length is step length divided by LL; "scaled" velocity is velocity divided by the square root of ($g \times$ LL). "Scaled" cadence was the obtained cadence value divided by the square root of (g/LL).

(4) **Coefficient of attenuation**: (ATT) [22] was calculated to study the ability to attenuate accelerations from pelvis (P) to head (H) (called "attenuation" in the rest of the manuscript), and obtained in the three directions of motion:

$$\mathrm{ATT}(\%) = (1 - \mathrm{RMSH}/\mathrm{RMSP}) \times 100.$$

(5) **Harmonic ratio (HR)**: an indication of gait pattern smoothness [20], rythmicity [7] and step to step symmetry [23], and calculated according to Menz et al. [20]. Greater HR represents a smoother gait. HR was obtained for every stride, 5 values per trial, then the average of three trials (15 strides) was obtained.