# The influence of walking speed and gender on trunk sway for the healthy young and older adults

SIR—Falls are a major problem for the elderly and others prone to fall [1–7], occurring frequently during walking [8, 9]. Maki *et al.* [10] suggested that the 'cautious' gait pattern, characterised by reduced walking speed and shortened step length, is adopted by older people to minimise the risk of falling. Somewhat paradoxically, these changes may predispose to trips and slips [11, 12].

Step width and length are influenced by walking speed [13]. It is difficult, however, to define stability during walking with these measures. Trunk sway may provide alternative measures as increased trunk sway is associated with an increased risk of falling [13–15]. Increased trunk sway occurs in the young when they walk slower or faster than normal [13], indicating that preferred walking speed is the most stable. A different conclusion was reached for older persons who show reduced sway velocities and angles with slower walking speeds [14]. Greater variability in trunk roll and pitch angle was observed at all speeds for older adults compared to younger people [16]. However, the effect of speed, on the amplitudes of trunk roll (side-to-side) and pitch (fore–aft) angle and angular velocity for both groups, has not been reported. In addition, there is a gender difference between the walking styles and the gait parameters [17–24], possibly for trunk sway too, at different walking speeds.

In order to provide more complete data, the current study investigated the influence of age, gender and walking speed on balance measures in the form of trunk sway angles and velocities. It was hypothesised that these measures increase across walking speeds for both young and older people with larger values for the elderly. This hypothesis was verified except that trunk sway angles were not less for slower walking speeds than the preferred.

## Methods

Twenty healthy young (mean age 23 years ± standard error of the mean (SEM) 0.57, 10 males) and 20 healthy older adults (mean age 71 ± SEM 0.79, 10 males) participated. Subjects were excluded if they used a walking aid or had cognitive, orthopaedic, visual or rheumatologic conditions likely to impair balance. Table 1 lists the participant characteristics. Written informed consent was obtained from all subjects prior to testing. This study was approved by the ethical committee of the University Hospital of Basel.

Subjects walked barefoot at five self-selected walking speeds and were aided with a visual scale from 1 to 10, in which (1) was walking very slowly but maintaining the natural way of walking, (3) was slow, (5) was normal, (7) was fast and (10) was as fast as possible without running and feeling unsafe. Two random orders were used: (A) normal, fast, very fast, slow, very slow and (B) normal, slow, very slow, fast, very fast. Each walking speed was tested serially three times. The walkway was 12.5 m long. The middle 7.5 m was used for analysis.

Trunk sway was measured with a SwayStar™ system (Balance Int. Innovations GmbH, Switzerland). This system registers angular velocities of the trunk at L1–3 [25] in the roll and pitch directions. The system is mounted on a converted motorcycle kidney belt and strapped around the lower back. Data were collected wirelessly via Bluetooth™. Peak-to-peak excursions of angular velocity samples and the integral thereof to yield angular position were calculated over the 7.5-m analysis window in the roll and pitch directions. Duration of walking the middle 7.5 m of the walkway was used to calculate gait speed (m/s).

Data for statistical analysis were obtained by first averaging each subject's measurements for the three walking trials at each speed. Statistics were performed using SPSS 15.0 software with significance level set at $P < 0.05$. A repeated measures ANOVA test was performed to examine the influence of speed, age and gender on trunk sway. Thereafter paired sample *t*-tests quantified the influence of different walking speeds on the trunk sway. Comparisons of trunk sway between both young and older, males and females, were performed using non-parametric Mann–Whitney tests.

To control for individual differences in preferred walking speeds and to make comparisons between groups at the same gait speed, quadratic regressions were constructed for each subject and for each measure, over the subjects' gait speeds.

**Table 1.** Anthropometric data

| | Total sample (*n*=20) | | Men (*n*=10) | | Women (*n*=10) | |
|---|---|---|---|---|---|---|
| **Young** | Mean | SEM | Mean | SEM | Mean | SEM |
| Age (years) | 23 | 0.57 | 22 | 1.20 | 24 | 0.99 |
| Height (kg) | 175 | 1.34 | 181 | 2.28 | 169 | 1.39 |
| Weight (m) | 67 | 1.33 | 73 | 1.96 | 61 | 1.86 |
| BMI (m/kg$^2$) | 22 | 0.29 | 22 | 0.43 | 22 | 0.69 |
| Gait speed, very slow (m/s) | 0.7 | 0.03 | 0.7 | 0.06 | 0.7 | 0.05 |
| Gait speed, slow (m/s) | 1.0 | 0.02 | 1.0 | 0.04 | 1.0 | 0.04 |
| Gait speed, preferred (m/s) | 1.3 | 0.02 | 1.3 | 0.05 | 1.3 | 0.03 |
| Gait speed, fast (m/s) | 1.6* | 0.03 | 1.7 | 0.06 | 1.6 | 0.06 |
| Gait speed, very fast (m/s) | 2.1* | 0.04 | 2.2 | 0.08 | 2.1 | 0.09 |
| | **Total sample** (*n*=20) | | **Men** (*n*=10) | | **Women** (*n*=10) | |
| **Elderly** | Mean | SEM | Mean | SEM | Mean | SEM |
| Age (years) | 71 | 0.79 | 71 | 1.83 | 71 | 1.38 |
| Height (kg) | 169 | 1.23 | 174 | 2.03 | 164 | 1.83 |
| Weight (m) | 68 | 1.80 | 74 | 2.95 | 62 | 3.19 |
| BMI (m/kg$^2$) | 24 | 0.46 | 24 | 0.62 | 23 | 1.15 |
| Gait speed, very slow (m/s) | 0.7 | 0.03 | 0.7 | 0.06 | 0.7 | 0.04 |
| Gait speed, slow (m/s) | 1.0 | 0.03 | 1.0 | 0.05 | 1.0 | 0.06 |
| Gait speed, preferred (m/s) | 1.2 | 0.05 | 1.3 | 0.12 | 1.2 | 0.07 |
| Gait speed, fast (m/s) | 1.5 | 0.04 | 1.5 | 0.07 | 1.5 | 0.09 |
| Gait speed, very fast (m/s) | 2.0 | 0.06 | 2.0 | 0.11 | 2.0 | 0.12 |

SEM, standard error of the mean; BMI, body mass index.
*$P < 0.05$ young versus elderly.

Estimates of each trunk sway were then calculated from each regression at four normalisation speeds, 0.8, 1.2, 1.6 and 2.0 m/s. The preferred walking speed was 1.2 m/s of the older subjects, and a separation of 0.4 m/s achieved four equally spaced speeds over the older subjects' range of walking speeds (Table 1). When a subject's data failed to include points >2 m/s or <0.8 m/s, no estimate was included in the analysis.

## Results

Significant differences in all four trunk sway measures across the five requested walking speeds were observed for the young and older subjects, as well as a clear age effect. Similar effects were noted when measures were compared at fixed gait speeds (Figure 1). Trunk roll and pitch angle and angular velocity were greater when walking faster than normal (1.2 m/s) in both the young and older subjects (Figure 1). Angles were not changed when walking slower than normal but were slightly less in roll for older subjects (Figure 1).

The older subjects exhibited greater roll angle and angular velocity than the young at all gait speeds. Pitch angle and velocity were greater for the elderly at all walking speeds, except the normalised slow speed (Figure 1). However, at slow requested speeds, pitch angle and velocity were greater in the older subjects.

No gender effects emerged for the older subjects. Young women showed significantly greater trunk roll and pitch than men when walking at 0.8 m/s. Young men showed significantly greater trunk pitch at 1.6 and at 2.0 m/s than young females.

## Discussion

The influence of walking speed on trunk sway was demonstrated by an increase in trunk angle deviations when walking faster than normal. Walking slower than normal did not change peak-to-peak trunk angular displacements. These findings are contradictory to those of Dingwell and Martin [13] who found greater trunk linear displacements when walking both slower and faster than normal. Our findings are also contrary to those of Van Iersel *et al.* [14] who revealed a trunk stability in the form of reduced angles when walking slower than normal. A reason for the differences in the results of sway angles might be the tendency for faster walking speeds in the Van Iersel study [14].

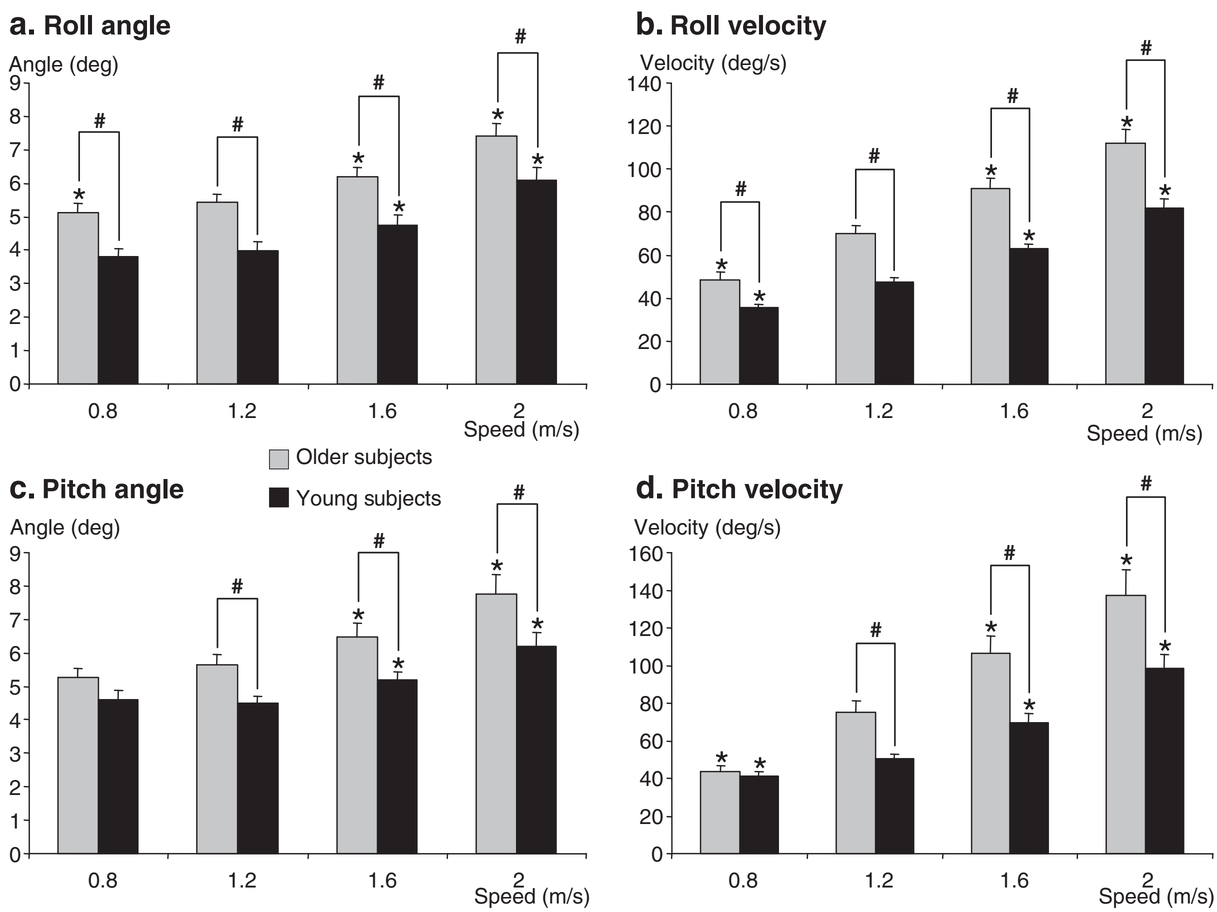


**Figure 1.** Mean trunk sway measures after normalisation to four gait speeds. Mean values of roll and pitch angle and velocity at the four-point estimates are shown for the older (grey columns) and subjects (black columns). Vertical lines on the columns represent SEM. *$P$ < 0.05 difference versus 1.2 m/s values, #$P$ < 0.05 differences between young and older subjects.

The walking speeds of the subjects in the Van Iersel study were slow (1.03 ± SD 0.18 m/s), normal (1.46 ± 0.18 m/s), fast (1.63 ± 0.24 m/s) and very fast (2.00 ± 0.19 m/s). These walking speeds of older subjects were faster than those of the current study (see Table 1). Nevertheless, our findings concerning the trunk angular velocities are in accordance with those of Van Iersel *et al.* [14]. Angular velocity reduced when walking slower than normal. This suggests that walking slower than normal could theoretically increase a person's stability in the form of reduced sway velocities. This is in contrast to the subjective feeling of instability of most our subjects experienced when walking slowly. It is possible that walking slower demands more muscular strength because one-leg stance duration increases. This may make walking slowly be more difficult for older persons, as absolute muscle force generation capacity decreases with age [26].

In older subjects, we found significantly greater trunk roll and pitch angle and angular velocity than for young subjects, regardless of walking speed. Similar results were seen after gait speed normalisation.

We did not note a gender difference in the older subjects which would account for the greater risk to fall in elderly women [4, 15]. We found a gender difference in trunk sway between young men and women. These findings contrast with the findings of Smith *et al.* [24] who showed gender differences to be present in the elderly, but not in the young. Our findings indicate that young female subjects walk with more sway in the roll direction than young men at slow walking speeds. This could be due to the anatomical hip differences, as women have broader hips and therefore a greater inertial effect during walking [19]. Young men walked with greater movements in the pitch direction than young women at faster than normal speeds. This might be linked to differences in gait pattern between men and women. As men tend to take larger strides, especially when increasing their walking speed [27], this could influence the movement of the upper body. To take longer steps, the upper body has to bend further forward to maintain stability, causing a greater pitch angle.

This study showed that older subjects had, especially at faster walking speeds, greater angular and angular velocity trunk sway in the roll and pitch planes. Based on this result, we concluded that the balance of older subjects during gait is more unstable than that of the young. A possible explanation for this difference might be that older subjects may have less muscle strength compared to young. These results could be useful for developing strategies for the prevention of falls in older subjects, although further studies are required to determine whether the reduced sway velocities but not angles of slow walking are correlated with a lower likelihood of falling.

## Key points

- Trunk sway velocity increases with gait speed in young and older persons.
- Trunk sway angle is unchanged for slower gait velocities in young and older adults.
- Trunk sway angles and velocities are greater in older than young persons.
- Gender differences were only observed in young persons.
- Walking slowly brings increased stability for sway velocity only.

## Acknowledgements

This work was supported by StudEx grants to K.T.M. Goutier and S.L. Jansen and by a Swiss National Research foundation grant 320000-117950 to J.H.J. Allum.

## Conflicts of interest

The authors report that J.H.J. Allum worked as a consultant for the company producing the equipment used in this study.

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doi: 10.1093/ageing/afq066
Published electronically 17 June 2010

## Leukocytosis increases length of inpatient stay but not age-adjusted 30-day mortality, after hip fracture

SIR—Ninety-six percent of proximal femoral fractures (PFF) occur in patients aged over 65 years [1]. Twenty-eight to thirty-five percent of over 65 year olds fall each year, and 10–20% of falls result in fracture. In the United Kingdom, approximately 80,000 patients with PFF require surgery annually, which is associated with a 30-day post-operative mortality of approximately 10%, a mean inpatient length of stay of 20 days and a treatment cost per patient of £25,424 [2].

Whilst the majority of falls in elderly people are biomechanical in aetiology, acute illness, including infection *per se* or infection as a cause of delirium, can increase the risk of fall precipitation in at-risk individuals [3].

Minimal research has investigated infection as an aetiological factor for falls resulting in hospitalisation. The few studies that have been performed relating to infection in patients with PFF have focussed on outcomes after post-operative infection [4, 5]. Only one previous study of patients with PFF has suggested a prognostic effect of preoperative white cell count (WCC), noting that among 126 patients, low total lymphocyte count predicted death before discharge [6].

Anecdotally, however, leukocytosis and neutrophilia are relatively common findings among the patient population admitted to hospital with PFF. This study was designed to characterise perioperative white cell populations in this population and determine whether abnormal WCC are related to 30-day post-operative mortality and length of post-operative hospital stay.

## Methods

All patients aged 50 and over who underwent PFF surgery at the Royal Sussex County Hospital between 17 December 2005 and 30 November 2009 were identified from a computerised, double password protected, hospital-located Microsoft Access audit database [7].

The following data were transferred manually from the computerised hospital pathology service reporting facility to a Microsoft Excel spreadsheet for analysis (transcription accuracy verified by S.W.): sex, age and admission WCC and differential (neutrophil, lymphocyte, monocyte, eosinophil and basophil counts). Mortality and length of stay data were recorded from the Trust Patient Administration Service (PAS) database, 3 months after completion of the WCC data collection, to allow for any time lag between death and PAS database recording of death and discharge data.

Thirty-day mortality data for the normal/raised WCC/neutrophil count (NC) groups were analysed using a two-tailed Fisher's exact test and multivariate analysis, and length of post-operative stay was compared using the Mann–Whitney rank-sum test. A value for $P < 0.05$ was taken to denote statistical significance.