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Are there associations with age and sex in walking stability in healthy older adults?

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ABSTRACT

The variability of the centre of pressure (COP) during walking can provide information in relation to stability when walking. The aim of this study was to investigate if age and sex were associated with COP variability, COP excursions, and COP velocities during walking. One-hundred and fourteen older adults (age 65.1 ± 5.5 yrs.) participated in the study. A Kistler force platform (1000 Hz) recorded the ground reaction forces and COPs during walking at a self-selected walking speed. The stance phase was divided, using the vertical GRF, into four sub-phases: loading response (LR), mid-stance (MSt), terminal stance (TSt), and pre-swing (PSw). The standard deviations of the COP displacement (variability), the COP velocity, and COP excursion in the medial–lateral and anterior–posterior directions, as well as the resultant magnitude were assessed. When controlling for walking speed, a greater age was associated with a higher variability and excursion of the COP during LR only suggesting that stability is maintained during the majority of the stance phase. During LR lower COP velocity was significantly associated for females for anterior-posterior and total COP, which may be a strategy to facilitate stability before, and moving into, MSt and TSt.

1. Introduction

The trajectory of the centre of pressure (COP) represents the cumulative neuromuscular response that controls the movement of the centre of mass (COM) to help maintain forward progression and upright balance [1]. The anterior–posterior (AP) COP trajectory indicates the control of the forward progression of the COM during stance. The medial–lateral (ML) COP movement reflects the control process to regulate lateral stability, especially in single-support. COP excursion, COP velocity, and COP variability provide useful information about COP characteristics during walking [2,3], with greater COP variability indicating possible difficulties in controlling stability during walking [2,3].

Variability of gait measures during walking may reflect the underlying neural control of gait indicative of sensitivity to ageing and pathological processes [4]. Such data add to the understanding of gait and motor control in older age and assist in defining older adults who have an unstable gait and may be at a greater risk of falls. A view of gait variability may be a reflection upon the central neuromuscular control systems ability to maintain steady walking, thus measures of gait variability may indicate instability or falls risk [5]. For example, a more varied gait, indicted by COP variability, may predispose an individual to greater instability [5]. Although evidence suggests that falls in older adults mostly occur during dynamic movement rather than when standing still [6], little is known about the movement of the COP of older adults (55 years of age and over) under dynamic conditions such as walking. This indicates that there is a need to assess dynamic characteristics during activities of daily living among older adults and between sexes. Since walking is a common activity of daily living, this study considered walking. The COP during walking in older adults has not been reported in the literature. Nevertheless, this is an important variable to evaluate because almost half of the population over the age of 65 years report some difficulty with stability or walking [7]. This reduced ability to maintain balance is associated with a greater risk of falling [8] which, in the UK, accounts for approximately 14,000 deaths and costs the National Health Service £1.7 billion/year [9].

Gait differences between the sexes are seen for some kinematic and kinetic parameters during walking [10]. These differences may be further exacerbated, for falling, with females more prone to fall than males [11], and the differences in gait and balance between the sexes may be a reason for this [12,13]. Despite these differences in gait, the association of sex to COP movement, and in particular variability, in older adults has not been reported in the literature.

Little is known regarding the natural history of COP movement variability of older adults during walking and even though females are more likely to fall, differences in COP variability between sexes have

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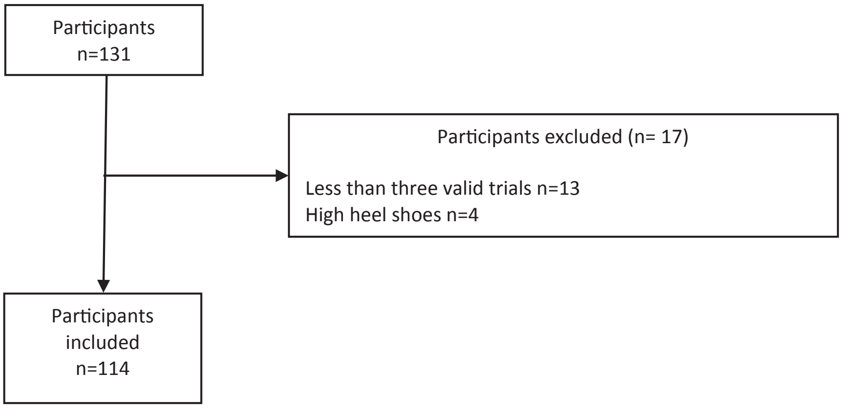

Fig. 1. Inclusion of participants in the study.

not been reported in the literature. Therefore, the aims of this study were to investigate if age and sex were associated with COP variability, COP excursions, and COP velocities during walking when controlling for walking speed.

2. Methods

2.1. Participants and experimental set-up

Following ethical approval, n = 131 community dwelling older adults (aged 55–84 years of age) recruited from the local area participated in this cross-sectional study. All participants lived independently. Eligibility criteria required all participants to be aged fifty-five years or over, to have no surgical procedures occurring in the last six months, and be able to walk at least 10 m unaided. These criteria were broad to capture a representative sample of this age range (55–84 yrs.). By self-report participants were free of any neurological or musculoskeletal disorder at the time of measurement. Seventeen participants were excluded due to wearing high heels and an insufficient number of valid walking trials (Fig. 1). Table 1 shows the descriptive statistics of the participants in this study.

All participants wore their own footwear and walked along a 10 m walkway at a self-selected comfortable walking speed (measured via Brower Timing gates). Embedded midway along the walkway was Kistler force plate 9281CA (sampling at 1000 Hz) flush to the ground. The force plate measured the ground reaction forces and movement of the COP. A right foot strike was analysed for this study. Three-to-five successful trials per participant were captured. A successful trial was one where the participant did not target the force plate.

2.2. Data analysis

The data were filtered and processed using Matlab software (MATLAB R2015a, Mathworks, Inc., Natick, MA, USA). A third order low pass Butterworth filter with a cut-off frequency of 30 Hz was used. The COP parameters were assessed within the sub-phases of the stance phase [3], which were defined by the vertical ground reaction force (vGRF) [14]. The reason for this division was that different phases are associated with different functional tasks [15]. The sub-phases of stance – loading response (LR), mid stance (MSt), terminal stance (TSt) and pre-swing (PSw) – were identified from the vGRF (Fig. 2). LR is the time interval between initial contact (heel strike) and the first peak of the vGRF (F1); MSt is the time interval from the first peak of the vGRF to the minimum of the vGRF (F2); TSt is the time interval from F2 to the second peak of the vGRF (F3); and PSw is the time interval from F3 to toe-off [14]. Displacement in the medial–lateral (Dx_i) and anterior–posterior (Dy_i) directions and the total displacement (Dt_i) of COP movement were computed for each sub-phase within the time interval (Eqs. (1)–(3)) [3]:

$$Dx_i = X_i - X_{i-1} \quad (1)$$

$$Dy_i = Y_i - Y_{i-1} \quad (2)$$

$$Dt_i = \sqrt{Dx_i^2 + Dy_i^2} \quad (3)$$

Subsequently, the standard deviations (variability), excursions, and velocities were determined for the medial-lateral, anterior-posterior and total COP displacement. COP excursion was calculated by subtracting the minimum COP displacement value from the maximum COP displacement value in both respective planes and total COP displacement. COP velocity was determined, for both planes and total COP displacement, by dividing the mean displacement by the sample time for each phase.

2.3. Statistical analysis

The means of the 3–5 trials from each participant were used for statistical analysis using R *(R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria)*. To compare the differences between gait phases repeated measures ANOVA were used. Univariate associations of

Table 1
Participants (a) split into gender groups (b).

		Whole group data			
a)	N	Age Range (years)	Mean Age (years ± SD)	Walking Speed Range (m s^{-1})	Walking Speed Mean (m s^{-1} ± SD)
	114	55–82	65.1 ± 6.12	0.92–1.86	1.42 ± 0.18
		Grouped by sex			
b)					
Female	73	55–80	64.8 ± 6.28	0.92–1.86	1.44 ± 0.19
Male	41	55–82	65.6 ± 5.85	1.05–1.79	1.41 ± 0.17