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

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<ABS-HEAD>Highlights► The centre of pressure was measured during walking in 114 healthy older adults ► Stability was challenged more in females compared to males during terminal stance ► Lower COP velocity was associated for females ► Greater age was associated with increased centre of pressure variability

<ABS-HEAD>Abstract

<ABS-P>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 (1000Hz) 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.
<KWD>Keywords: Stability; Gait; Falls; Elderly; Balance

<H2>1.0 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 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.

<H2>2.0 Methods

<H2>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. Table 1 shows the descriptive statistics of the participants in this study.

insert table 1 and fig 1 here

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.

<H2>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 (Eq. 1-3) [3]:

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

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

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

*Insert fig 2 here**

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.

<H2>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 age and sex with COP variability, excursions, and velocities were determined by Pearson's correlation coefficient (age) and the point-biserial correlation coefficient (sex), respectively. All tests were two-sided and p-values ≤0.05 were considered statistically significant.

Multiple linear regression analyses were conducted to identify which variables (age and sex) independently contributed to the dependent variables (COP variability, COP excursion, and COP velocity) with walking speed as a confounder. A stepwise backward regression was used. Each step the variable with the highest p-value larger than 0.05 was removed. A p-value of ≤0.05 was required for a variable to remain in the model.

<H2>3.0 Results

The mean and standard deviation of the COP variability, COP excursion, and COP velocity for the whole group and split by sex is shown in table 2. For the whole group only, a comparison between phases was carried out. The COP variables were significantly greater for the LR and PSW compared to MSt and TSt phases (table 2).

The univariate analyses demonstrated that age was associated with COP variability and COP excursion (anterior-posterior COP and total COP) during loading response. There were no associations between age and COP velocity (table 3). The univariate analyses (table 3) also demonstrated that sex was associated with COP variability (anterior-posterior COP and total COP during mid-stance and terminal stance), COP excursion (anterior-posterior COP during mid-stance and terminal stance, and total COP terminal stance), and COP velocity (medial-lateral COP during loading response, anterior-posterior COP and total COP during loading response).

Multiple linear regression analyses were conducted to predict the dependent COP variables based on age and sex (independent variables) with walking speed as a confounder (table 4). A greater age was associated with a greater excursion (Dyi- and Dti – at loading response) and variability of COP (Dyi- and Dti – at loading response) regardless of walking speed (table 4). For sex, regardless of walking speed, greater COP variability (anterior-posterior and total COP) during MSt and TSt was significantly associated with females. Lower COP velocity was significantly associated for females for anterior-posterior and total COP during LR.

insert table 2 - 4 here

<H2>4.0 Discussion

The objective of this study was to establish if COP parameters, which are seen as indicators of stability during walking, were associated with sex and age in a group of older adults. Since walking speed effects a number of biomechanical gait parameters [16] we also controlled for walking speed. For sex, regardless of walking speed, greater COP variability (anterior-posterior and total COP) during MSt and TSt was significantly associated with females. A similar association was seen for COP excursions during TSt only. During MSt the limb goes into in single support and during TSt the ipsilateral heel rises, the contralateral limb is in swing and the bodyweight moves ahead of the ipsilateral forefoot. These phases challenge stability and this work suggests that this was a more destabilising phase for females compared to males and could result in trips or falls. Future work needs to look longitudinally to establish if these measures during this phase can predict falls.

A reduced COP velocity (anterior-posterior and total COP) during LR was significantly associated with females, which may be a strategy to facilitate stability before, and moving into, MSt and TSt. In younger adults (23.6 ± 2.7 yrs.) differences in COP velocities were not seen between sexes [17] and this was consistent with the majority of COP parameters during the other sub-phases of the gait cycle for older adults in this study.

A number of studies have examined the effect of age on gait variability (spatial-temporal parameters) comparing younger with older adults [18–21]. Some have reported greater gait variability [18,19] while others found no differences between the young and older adults [20,21]. A few studies of older adults have reported greater variability with advancing age [22,23]. Past research has tended to compare younger to older adults and as such grouped older adult's together, yet walking speed has been reported to decline by 1% per year from the age of 60 years [24]. Because of this, a more appropriate approach is to look at a wide range of ages of older adults such as the sample included in this present study, rather than group 'old' together and compare to 'young'. This will give greater insights into how older adults walk. This is the first study to look at COP parameters during walking in older adults and as such, comparisons to the literature are difficult. Bizovska et al. [3] and Svoboda et al. [25] showed that COP variability was greater for middle aged females (age 56.6 ± 4.8 yrs.)

compared to younger females (age 22.1 ± 1.8 yrs.) in both AP and ML directions, suggesting that stability was worse for the older group. However, these studies did not examine older adults (60 yrs. and over) and whether age-related differences in gait variability continue into older age as was the approach in this current study. This study showed that a greater age was significantly associated with greater COP variability and excursions during LR for anterior-posterior and total COP. During the LR phase, a component of double support, weight is transferred from the contralateral limb to the ipsilateral limb and this suggests that this is the least stable phase of the gait cycle with greater age. During the second double support phase at PSw, where the ipsilateral limb is being unloaded, there was no association with age for any of the COP parameters.

The COP variability was comparable to Bizovska et al. [3] in some directions during some of the sub-phases (Dx_i; LR, MSt, and TSt, Dy_i; LR and PSw, Dt_i; LR) but notably lower for others. Furthermore, the significant association with age for LR phase only in this present work was in contrast with the earlier findings of Bizovska et al. [3] and Svoboda et al. [25] who stated that COP movement variability was greater with age when comparing younger to middle-aged adults during LR, MSt and PSw. A notable finding was the lack of any association with age or sex for COP parameters in the medial-lateral plane. This contrasts Bizovska et al. [3] who reported significant differences in this plane between young and middle-aged participants during LR, MS and PSw. This difference between the above studies and the present work might be explained by difference in walking speed (1.22 $m \cdot s^{-1}$ vs. 1.42 $m \cdot s^{-1}$) or footwear (barefoot vs. shod). By combining our findings with that of Bizovska et al. [3] it could be suggested that greater COP variability at LR continue into older age, but during MSt and PSw changes to COP variability occur before the age of 55 years and these are maintained in healthy older adults, or, age in healthy older adults has little effect upon COP variability (and also COP excursions and COP velocity) in this group of community dwelling older adults.

This study was in agreement with Bizovska et al[3] and showed that variability was significantly less during MSt and TSt compared to LR and PSw. This suggests that LR and PSw are the least stable sub-phases during stance. This is consistent with the functional division of the stance phase where LR and PSw are components of double support which is characterised by rapid weight transfer from one lower limb to the other (indicated by the greater excursions and velocities of the COP) seen during these phases. Furthermore, COP velocity during standing has been shown to correlate with COM acceleration [26] and since COM accelerations are greatest during LR and PSw this may partly explain why COP velocity was also greater during these phases.

A smooth and stable gait involves the integration and coordination of individual degrees of freedom from the neuromuscular system [27]. A key component of this is variability as it provides means of quantifying the variety of ways through which walking is maintained [28]. A reason why there were few associations in COP parameters for age and sex is that COP variability during walking is the product of the actual movement – i.e. end-point variability [27]. From this standpoint variability would be, for example, less in healthy compared to impaired individuals [4], or a greater association with age which was seen during LR only in this current study. However, the COP trajectory represents the cumulative neuromuscular response that controls the movement of the centre of mass during walking [1]. It is therefore possible that while there were only a few associations with age and sex for this end-point variability (i.e. COP variability, excursions, velocities), there may be further associations in coordinative variability i.e. in segmental co-ordination over many gait cycles [27], which help maintain a similar end-point. Future work should explore these two approaches (end-point and coordinative) to variability in older adults during walking as they may reveal more about stability when ageing.

A limitation to this study is that we measured only 3-5 foot contacts on the force plate per participant. A different approach would be to measure multiple foot contacts using a force plate mounted treadmill. Furthermore, the COP movement can be influenced by foot morphology [29] which was not assessed in this study. The majority of our participants were right-footed (85%) and it is possible that using only the right foot in this analysis may impact upon the results since differences in COP displacements have been reported between dominant and non-dominant limbs [30].

In conclusion, differences in COP parameters, when controlling for walking speed, and therefore stability between sexes were reported in this present study. A reduced COP velocity during LR was significantly associated with females, which may be a strategy to facilitate stability before, and moving into, MSt and TSt. These two phases were potentially more destabilising phase for females than males. However, based on the COP measure alone we cannot say if this predisposes females to greater instability during walking compared to males. These results also showed that during LR, in this population of healthy older adults, greater COP variability and excursions were associated with age, suggesting that stability is maintained during the majority of the stance phase through a relatively large age range, or any changes to COP that do occur do so before the age of 55 years.

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<Figure>**Figure 1** Inclusion of participants in the study

<Figure>**Figure 2** Sub phases of the stance phase identified from the vGRF: LR – loading response, MSt – Mid-stance, TSt – Terminal-stance, PS – Pre-swing, vGRF – vertical ground reaction force.

<Table>Table 1 Participants (a) split into gender groups (b)

	N	Age Range (years)	Mean Age (years ±SD)	Walking Speed Range ($m \cdot s^{-1}$)	Walking Speed Mean ($m \cdot s^{-1}$ ±SD)
Whole group data					
a)	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

<Table>Table 2 Descriptive data for COP variability, excursion, and velocity

	Total group (n=114)	**Male group (n=41)**	**Female group (n=73)**
Variability (SD)			
Dx_i – LR	0.90 ± 0.37^{abc}	0.91 ± 0.39	0.89 ± 0.36
Dx_i – MSt	0.08 ± 0.03^{bcd}	0.08 ± 0.02	0.08 ± 0.03
Dx_i – TSt	0.07 ± 0.02^{cd}	0.07 ± 0.02	0.08 ± 0.03
Dx_i – PSw	0.43 ± 0.20	0.43 ± 0.26	0.43 ± 0.17
Dy_i – LR	1.74 ± 0.78 ^{abc}	1.80 ± 0.96	1.70 ± 0.67
Dy_i – MSt	0.18 ± 0.08 ^{bcd}	0.16 ± 0.06	0.20 ± 0.08
Dy_i – TSt	0.15 ± 0.06 ^{cd}	0.13 ± 0.04	0.17 ± 0.06
Dy_i – PSw	0.88 ± 0.32	0.89 ± 0.39	0.88 ± 0.28
Dt_i – LR	1.83 ± 0.76 ^{abc}	1.90 ± 0.92	1.79 ± 0.65
Dt_i – MSt	0.17 ± 0.07 ^{bcd}	0.15 ± 0.06	0.18 ± 0.07
Dt_i – TSt	0.15 ± 0.05 ^{cd}	0.12 ± 0.04	0.16 ± 0.06
Dt_i – PSw	0.92 ± 0.36	0.93 ± 0.45	0.92 ± 0.29
Excursion (mm)			
Dx_i – LR	4.62 ± 2.13 ^{abc}	4.69 ± 2.34	4.58 ± 2.02
Dx_i – MSt	0.32 ± 0.12^{c}	0.31 ± 0.11	0.33 ± 0.12

Dx_i – TSt	0.31 ± 0.11 [c]	0.27 ± 0.08	0.32 ± 0.12
Dx_i – PSw	1.94 ± 0.88	1.95 ± 1.11	1.93 ± 0.74
Dy_i – LR	8.97 ± 3.93 [abc]	9.54 ± 4.87	8.65 ± 3.28
Dy_i – MSt	0.65 ± 0.25 [bcd]	0.59 ± 0.22	0.69 ± 0.25
Dy_i – TSt	0.58 ± 0.21 [cd]	0.51 ± 0.17	0.62 ± 0.22
Dy_i – PSw	3.62 ± 1.25	3.77 ± 1.56	3.54 ± 1.04
Dt_i – LR	9.07 ± 3.54 [abc]	9.52 ± 4.25	8.82 ± 3.08
Dt_i – MSt	0.61 ± 0.22 [bcd]	0.56 ± 0.21	0.63 ± 0.23
Dt_i – TSt	0.55 ± 0.19 [cd]	0.47 ± 0.13	0.59 ± 0.20
Dt_i – PSw	3.46 ± 1.36	3.57 ± 1.75	3.40 ± 1.10
Velocity ($m \cdot s^{-1}$)			
Dx_i – LR	0.45 ± 0.18 [abc]	0.50 ± 0.24	0.42 ± 0.12
Dx_i – MSt	0.09 ± 0.03 [bcd]	0.10 ± 0.03	0.09 ± 0.03
Dx_i – TSt	0.07 ± 0.02 [cd]	0.07 ± 0.02	0.07 ± 0.02
Dx_i – PSw	0.24 ± 0.09	0.24 ± 0.07	0.24 ± 0.10
Dy_i – LR	1.13 ± 0.38 [abc]	1.24 ± 0.55	1.07 ± 0.23
Dy_i – MSt	0.38 ± 0.09 [bcd]	0.37 ± 0.10	0.38 ± 0.09
Dy_i – TSt	0.30 ± 0.09 [cd]	0.32 ± 0.10	0.29 ± 0.08
Dy_i – PSw	0.67 ± 0.16	0.67 ± 0.15	0.68 ± 0.17
Dt_i – LR	1.29 ± 0.41 [abc]	1.42 ± 0.59	1.21 ± 0.24
Dt_i – MSt	0.40 ± 0.09 [bcd]	0.39 ± 0.10	0.40 ± 0.09
Dt_i – TSt	0.32 ± 0.09 [cd]	0.34 ± 0.10	0.31 ± 0.08
Dt_i – PSw	0.75 ± 0.17	0.74 ± 0.15	0.75 ± 0.18

	Age		Sex	
	Pearson correlation coefficient	**p value**	**Point-biserial correlation coefficient**	**p value**
Variability (SD)				
Dx_i – LR	0.011	0.907	-0.017	0.854
Dx_i – MSt	-0.147	0.118	0.098	0.299
Dx_i – TSt	-0.060	0.525	0.213	0.052
Dx_i – PSw	-0.103	0.276	0.000	0.996
Dy_i – LR	0.277	**0.003**	-0.065	0.493
Dy_i – MSt	-0.175	0.062	0.256	**0.006**
Dy_i – TSt	0.092	0.329	0.301	**0.001**
Dy_i – PSw	-0.108	0.252	-0.021	0.827
Dt_i – LR	0.267	**0.004**	-0.068	0.471
Dt_i – MSt	-0.189	0.055	0.204	**0.029**
Dt_i – TSt	0.108	0.252	0.329	**0.001**
Dt_i – PSw	-0.121	0.201	-0.020	0.831

LR – Loading response, MSt – Mid-stance, TSt – Terminal-stance, PSw – Pre-swing, Dx_i (Dy_i) – COP variability/excursion/velocity in the medial – lateral (anterior – posterior) direction, Dt_i – total COP variability/excursion/velocity. [a] indicates significant difference compared MSt, [b] indicates significant difference compared to TSt, [c] indicates significant difference compared PSw, [d] indicates significant difference compared comparted LR.

Excursion(mm)				
Dx_i – LR	0.034	0.717	-0.026	0.786
Dx_i – MSt	-0.118	0.215	0.084	0.370
Dx_i – TSt	-0.104	0.269	0.226	0.055
Dx_i – PSw	-0.076	0.423	-0.006	0.946
Dy_i – LR	0.321	**0.000**	-0.108	0.249
Dy_i – MSt	-0.172	0.067	0.203	**0.030**
Dy_i – TSt	0.042	0.658	0.266	**0.004**
Dy_i – PSw	-0.088	0.353	-0.086	0.358
Dt_i – LR	0.294	**0.001**	-0.095	0.315
Dt_i – MSt	-0.190	0.053	0.152	0.105
Dt_i – TSt	0.055	0.564	0.304	**0.001**
Dt_i – PSw	-0.086	0.364	-0.061	0.516
Velocity ($m\ s^{-1}$)				
Dx_i – LR	-0.078	0.407	-0.228	**0.014**
Dx_i – MSt	-0.048	0.614	-0.137	0.145
Dx_i – TSt	0.182	0.052	-0.015	0.876
Dx_i – PSw	-0.063	0.506	0.027	0.773
Dy_i – LR	-0.112	0.235	-0.211	**0.024**
Dy_i – MSt	0.026	0.784	0.078	0.408
Dy_i – TSt	0.053	0.579	-0.158	0.092
Dy_i – PSw	-0.118	0.213	0.024	0.795
Dt_i – LR	-0.113	0.229	-0.235	**0.011**
Dt_i – MSt	0.015	0.871	0.057	0.547
Dt_i – TSt	0.064	0.499	-0.158	0.092
Dt_i – PSw	-0.116	0.221	0.026	0.783

	Age	Gender
	βCoefficient +SE	**βCoefficient + SE**
Variability (SD)		
Dx_i – LR	0.000+0.006	0.012+0.073
Dx_i – MSt	0.000+0.000	0.004+0.005
Dx_i – TSt	0.000+0.000	-0.010+0.005
Dx_i – PSw	-0.006+0.003	0.001+0.040
Dy_i – LR	**0.045+0.012**	0.090+0.145
Dy_i – MSt	0.001+0.001	**-0.035+0.011**
Dy_i – TSt	0.002+0.001	**-0.037+0.010**
Dy_i – PSw	-0.005+0.005	0.020+0.063
Dt_i – LR	**0.033+0.011**	0.090+0.143
Dt_i – MSt	0.001+0.001	**-0.024+0.010**
Dt_i – TSt	0.002+0.001	**-0.038+0.010**
Dt_i – PSw	-0.007+0.006	0.021+0.070

<Table>Table 3 COP correlations for age and sex
LR – loading response. MSt – Mid-stance. TSt – Terminal-stance. PSw – Pre-swing. Dx_i (Dy_i) – COP variability/excursion/velocity in the medial – lateral (anterior – posterior) direction. Dt_i – total COP variability/excursion/velocity.

LR –

PSw –

the

COP
Bold

Excursion (mm)		
Dx_i – LR	0.005+0.035	0.082+0.418
Dx_i – MSt	0.000+0.002	0.015+0.021
Dx_i – TSt	0.000+0.002	-0.047+0.020
Dx_i – PSw	-0.019+0.014	0.010+0.172
Dy_i – LR	**0.206+0.058**	0.752+0.731
Dy_i – MSt	0.002+0.003	-0.088+0.037
Dy_i – TSt	0.005+0.003	**-0.109+0.038**
Dy_i – PSw	-0.020+0.020	0.240+0.245
Dt_i – LR	**0.176+0.053**	0.573+0.669
Dt_i – MSt	0.002+0.003	-0.054+0.032
Dt_i – TSt	-0.005+0.003	**-0.114+0.033**
Dt_i – PSw	0.023+0.022	-0.186+0.268
Velocity ($m \cdot s^{-1}$)		
Dx_i – LR	-0.002+0.003	0.086+0.034
Dx_i – MSt	0.000+0.000	0.009+0.006
Dx_i – TSt	0.001+0.000	0.000+0.004
Dx_i – PSw	0.000+0.001	-0.004+0.017
Dy_i – LR	-0.005+0.005	**-0.168+0.073**
Dy_i – MSt	0.001+0.002	-0.015+0.018
Dy_i – TSt	0.000+0.001	0.028+0.017
Dy_i – PSw	-0.002+0.003	-0.004+0.032
Dt_i – LR	-0.007+0.007	**-0.203+0.078**
Dt_i – MSt	0.001+0.002	-0.01+0.018
Dt_i – TSt	0.000+0.001	0.027+0.017
Dt_i – PSw	-0.002+0.003	-0.005+0.033

<Table>Table 4

Multiple linear regression analyses for age and sex. loading response. MSt – Mid-stance. TSt – Terminal-stance. Pre-swing. Dx_i (Dy_i) – COP variability/excursion/velocity in medial – lateral (anterior – posterior) direction. Dt_i – total variability/excursion/velocity. indicate significance.

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