



Postural Sway, Balance Confidence, and Fear of Falling in Women With Knee Osteoarthritis in Comparison to Matched Controls

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1 Title: **Postural sway, balance confidence and fear of falling in women with knee**
2 **osteoarthritis in comparison to matched controls**

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24

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26 **osteoarthritis in comparison to matched controls.**

27

28 **ABSTRACT**

29 **Background:** Osteoarthritis (OA) is a chronic degenerative disease that commonly affects
30 the knee joints. Individuals over 65 years with knee OA have a greater risk of falls.

31 However, there has been limited examination of the parameters of postural sway (increased
32 time, speed and postural sway area (center of pressure area (CoP)), and OA of the knee.

33 **Objectives:** Primary: to determine whether the CoP variables discriminate between patients
34 with knee OA and matched healthy volunteers, and to correlate the CoP variables with the
35 Activities-Specific Balance Confidence Scale (ABC) and Falls Self-Efficacy Scale (FES);
36 Secondary: to compare the CoP of the older women with OA with a control group in bipedal
37 support condition with eyes opened and closed.

38 **Design:** Cross-sectional study.

39 **Setting:** University Biomechanics Laboratory.

40 **Participants:** Twenty-two participants were divided into two groups of 11: OA group (\bar{x} =68
41 years (SD=7.4) and a control group (\bar{x} =66 years (SD=4.4).

42 **Methods:** Static postural balance was measured by a portable force platform. Data were
43 collected in both visual conditions (eyes open and closed), in a random order. Three attempts
44 of 30 seconds were allowed for each participant on the force platform, with a one minute
45 interval between attempts.

46 **Main outcome measure:** Variables the CoP: total displacement of sway (TDS, in cm),
47 anteroposterior amplitude displacement (APAD, in cm), medial-lateral amplitude
48 displacement (MLAD, in cm), total mean velocity (TMV, in cm/s) and dispersion of the
49 center of pressure (AREA, in cm²).

50 **Results:** The postural sway analysis found statistically significant differences in the eyes
51 open condition for the TDS ($p=.020$), APAD ($p=.042$), TMV ($p=.010$), and AREA ($p=.045$).
52 In the discriminant analysis none of CoP variables were able to classify the groups ($p= .15$).
53 The correlation analysis showed only the AREA with eyes closed was associated with the
54 ABC Scale ($\rho=-0.42$).

55 **Conclusions:** Women with knee OA had greater postural sway when compared to a control
56 group for the eyes open condition. CoP variables could not discriminate between the groups.
57 The AREA (dispersion of the center of pressure) was negatively correlated with the ABC
58 Scale, when the eyes were closed.

59

60 **Keywords:** Osteoarthritis; Aged; Postural Balance; Knee.

61

62 INTRODUCTION

63

64 Osteoarthritis (OA) is a chronic degenerative joint disease commonly affecting the
65 knee joint. OA leads to changes in the subchondral bone, cartilage loss, osteophyte
66 development, inflammation of the synovium, meniscus injury, ligament laxity and muscle
67 weakness [1]. For those affected, these joint changes often result in pain, functional
68 limitation, decreased quality of life and work loss, which has a major economic impact [2].
69 Among the elderly, the prevalence of knee OA is approximately 12.2%, with a higher
70 prevalence in women (14.9%) than in men (8.7%) [3,4]. Additionally it is reported that 11%
71 of men and 17.9% of women may require knee arthroplasty due to changes caused by knee
72 OA [3].

73 Postural or balance disturbance normally prompts an equilibrium reaction that may
74 involve adjustments at the ankle, hip or stepping, depending on the muscle activation and

75 the degree of postural disturbance. Postural sway can be assessed by questionnaires,
76 physical/functional tests and computer software or directly from a force platform [5-8].
77 Although the relationship between knee OA and reduced balance is not fully understood,
78 studies have shown that reduced quadriceps function and diminished proprioception are
79 associated with a deterioration in balance (that is the ability to maintain the center of gravity
80 within base of support with minimal sway or maximal steadiness) and can take the knee OA
81 patient to an increased risk of falls [9-12].

82 It has also been reported that those with knee OA were more unstable, more disabled
83 and had poorer functional performance than asymptomatic individuals [6,13,14]. Muscle
84 performance, balance, and mobility impairments have been identified as factors that
85 contribute to the risk of falls therefore, promoting regular physical activity may improve
86 outcomes from treatment. A high prevalence of falls among those with knee OA is one
87 factor that may contribute to the mobility limitations and difficulties with activities of daily
88 living reported by Levinger et al. [15]. These authors showed that almost 50% of adults with
89 severe knee OA had experienced a fall in the previous year, further Williams et al. [16],
90 reported that in women, this number increased to two-thirds of those surveyed. Risk of falls
91 is a major issue for those with knee OA [15,16].

92 The relationship between balance and knee OA was explored by Khalaj et al. [6] who
93 compared asymptomatic individuals with patients with knee OA. These authors found that
94 there was a decrease in static and dynamic balance and greater impairment and higher risk of
95 falls in individuals with moderate knee OA, when assessed by Overall Stability Index. This
96 Index assesses subject's balance control using the Biodex Stability System on either static or
97 unstable surface. Stability is determined from the center of mass excursion about the
98 anterior- posterior and medial- lateral axes from the center point [17]. Hurley et al [13] also
99 reported that people with OA (n=103) had weaker quadriceps, poorer voluntary muscle

100 activation and impaired acuity of knee joint position sense. These authors reported that of
101 the 103 individuals with OA, only seventy six were able to complete the balance test,
102 indicating poor stability and decreased balance control when compared to the control group,
103 with a consequent increased risk of falls [13,18]. Wegener et al. [7] reported significant
104 differences in postural sway between the OA and control group in the bipedal and unipodal
105 conditions, with eyes closed. Similarly, Masui et al. [19] reported greater displacement in
106 the center of pressure (CoP) in those with OA, with eyes closed and Hassan et al. [20] found
107 that individuals with OA demonstrated increases in CoP displacement in the medial-lateral
108 and anteroposterior direction.

109 In addition to the above mentioned changes, OA can lead to psychological changes
110 due to the coping strategies adopted in the presence of chronic disease. The presence of
111 chronic pain, can lead to an exacerbation of the sensation of pain and hypervigilance on
112 bodily sensations which can contribute to fear avoidance beliefs and behaviours [21-23]. A
113 study of 32 people with knee OA found that there was a moderate correlation between fear
114 avoidance beliefs and pain, and a strong correlation between fear avoidance beliefs and
115 functional limitation [24]. The psychological factors associated with chronic pain and OA
116 reflect the individuals' perception and evaluation of their condition, directly influencing
117 beliefs regarding ability to perform tasks (self-efficacy).

118 A number of authors have reported differences in CoP variables between those with
119 OA and healthy controls, however, there are no studies to date that clearly demonstrate
120 which CoP variables are able to discriminate between patients with knee OA and healthy
121 individuals. Additionally further work is required to explore the relationship between direct
122 measures of balance (force platform) and subjective measures of confidence in balance and
123 risk of falls in those with knee OA. Thus, the primary aims of this study were: to determine
124 whether the CoP variables discriminate between patients with knee OA and healthy

125 individuals and to correlate the CoP variables with the Activities-Specific Balance
126 Confidence Scale (ABC) and Falls Self-Efficacy Scale (FES). The secondary aim of this
127 study was to compare the CoP of the older women with knee OA and a control group in
128 bipedal support condition with eyes opened and closed.

129

130 METHOD

131

132 Twenty-two participants in this cross-sectional study were equally divided into two
133 groups: OA group (\bar{x} =68 years (SD=7.4) and \bar{x} =30.2 kg/m² (SD=6.3)) and a control group
134 (\bar{x} =66 years (SD=4.4) and \bar{x} =26.6 kg/m² (SD=3.7)). The control group participants were
135 recruited from the University Hospital and also from the local community. All participants
136 were given information about the study and gave written informed consent, the study was
137 approved by the Universidade Estadual de Londrina Ethics Committee (#967/2014). The
138 sample size was calculated through G*Power 3.1.9.2 [25] using a two-tailed Student *t*-test to
139 find the mean difference between the two independent groups, an estimated effect size of
140 0.7, α error prob. of 0.05 and $1 - \beta$ error prob. of 0.85. Twenty-one subjects were necessary
141 for a power of 86%.

142 The inclusion criteria for the OA group were: women, aged between 60 and 85 years
143 a diagnosis of OA knee confirmed by the American College of Rheumatology (ACR)
144 criteria and independently mobile. A rheumatologist confirmed the diagnostic of knee OA
145 using the ACR – including the Kellgren-Lawrence radiographic criteria [26].

146 The exclusion criteria for both the OA and control groups were: surgical procedures
147 in the previous six months; chronic diseases such as coronary heart disease; rheumatic
148 disease; cancer; chronic obstructive pulmonary diseases; uncontrolled hypertension;
149 participating in physical activity programs in the previous two months (aerobic or resistance

150 activity more than once a week for at least two months); arthroplasty and severe obesity
151 (body mass index (BMI) $> 40 \text{ kg/m}^2$).

152 The participants from the OA group were evaluated using The Western Ontario and
153 McMaster Universities Osteoarthritis Index (WOMAC) [27] for function; a 10cm pain
154 Visual Analog Scale (VAS) [28], marked in 1cm increments, used to record average pain (at
155 rest); the Activities-Specific Balance Confidence Scale (ABC) [29], was used to measure
156 balance in activities of daily living and the Falls Self-Efficacy Scale (FES) [30], was used to
157 determine fear of falling.

158 Posturography was measured by kinetic data of the CoP, obtained through a portable
159 force platform (Bertec Corporation®, AM6500, USA), measuring 60x40x10 cm; and $F_z =$
160 5000 N, $F_x = F_y = 2500 \text{ N}$, with a frequency of data acquisition of 1000 Hz. Throughout
161 data collection participants remained in the upright position on the force platform; the legs
162 were positioned with the feet forming an angle of 30° with a distance of approximately five
163 cm between the heels and the arms at the sides of the body. Data were collected in both
164 visual conditions (eyes open and closed), in a random order, and each participant was
165 requested to maintain in an upright posture, as stable as possible, and keep their eyes fixed
166 on a spot marked on a wall three meters away. Three attempts of 30 seconds were allowed
167 for each participant on the force platform, with a one minute interval between attempts. The
168 CoP signals were analyzed ten seconds after data acquisition began to avoid the possible
169 effect of initial postural adjustments that could have altered the variables of CoP [8].

170 The variables analyzed were: total displacement of sway (TDS, length of the CoP on
171 the support base, in cm), anteroposterior amplitude displacement (APAD, distance between
172 the maximum and minimum displacement of the CoP for anteroposterior direction, in cm)
173 and medial-lateral amplitude displacement (MLAD, distance between the maximum and
174 minimum displacement of the CoP for medial-lateral direction, in cm), total mean velocity

175 (TMV, displacement of the total oscillation of the CoP in both directions divided by the total
176 time of the attempt, in cm/s) and dispersion of the center of pressure (AREA, estimates the
177 dispersion of the CoP data by calculating the stabilogram area, in cm^2), as demonstrated in
178 Figure 1. For analysis, the data recorded from the force plate were amplified using a digital
179 amplifier (Bertec® AM6800) and smoothed by a 4th order Butterworth filter and cutoff
180 frequency stipulated by spectral analysis; then exported and processed in a specific routine
181 developed in Matlab® software.

182 The Shapiro-Wilk test was used to verify normal distribution of the variables. When
183 the assumption of normality was met, variables were presented as mean (\bar{X}) and standard
184 deviation (SD), if not, in median (Md) and quartiles (25-75%). For group comparison the
185 Mann-Whitney test was used. The Spearman Correlation Coefficient (*rho*) was used to
186 correlate the posturography variables and questionnaires (ABC and FES). Discriminant
187 analysis was carried out using the Wilks' Lambda method to identify which of the variables
188 related to the CoP would be able to significantly discriminate between the OA and control
189 groups. The matrix of homogeneity was tested using the Box's M test of equality of
190 covariance. Statistical significance was set at 5% and SPSS version 22.0 (IBM SPSS®,
191 Armonk, NY, USA) was used in all analyses.

192

193 RESULTS

194

195 Twenty-two individuals participated in this study and data from the clinical
196 examination (VAS, WOMAC, ABC and FES) of the OA group are shown in table 1. The
197 Kellgren-Lawrence radiographic criteria indicated that most patients (58 %) had mild OA
198 (grade 1 and 2); while the others (42 %) had severe stage of radiographic abnormalities
199 (grade 3 and 4). Regarding the postural sway analysis, when the comparison between the

200 groups was performed, statistically significant differences were found between all variables
201 (TDS ($p=.020$), APAD ($p=.042$), TMV ($p=.010$), and AREA ($p=.045$)) when evaluated in
202 eyes open condition, except for MLAD ($p=.061$). The control group demonstrated better
203 results (i.e. greater stability) when compared to patients with knee OA. However, when
204 comparing the eyes closed condition, no statistically significant differences were found in
205 any of the variables, as shown in table 2.

206 The correlations between CoP variables and ABC questionnaire ranged from weak to
207 strong. The strongest correlations were found in the eyes open condition, although this
208 relationship was inversely proportional, that is, the better the ABC score, the worse was the
209 performance in the CoP. Except for the TMV variable, where there was a better performance
210 in the CoP for those patients with higher ABC scores ($\rho = .70$). For the eyes closed
211 condition, the performance was as expected, that is, the better ABC score, the better the
212 performance in the CoP, but the correlations were weak. The FES questionnaire does not
213 correlate with the CoP variables (table 3). When performing the multivariate analysis none
214 of the variables were able to discriminate between groups (Wilks' Lambda = .42; $p= .15$).

215

216 DISCUSSION

217

218 The results of this study demonstrate that older women with knee OA presented
219 greater postural sway with the eyes open when compared with healthy volunteers, in the
220 closed eyes condition this difference was not observed. The results of the present study
221 support previous work that reported increased postural sway in individuals with knee OA,
222 with eyes open. Wegener et al. [7], Hinman et al. [5] and Masui et al. [19] found that
223 participants with knee OA displayed higher postural sway than age matched controls under

224 both the eyes open and closed conditions. In addition, Hurley et al. [13] reported increased
225 postural sway only under the eyes open condition.

226 A possible explanation for these results may be that the tasks required different
227 skills; with the eyes open the test evaluated the external-orientation perception, while with
228 closed eyes there is greater reliance upon self-orientation perception. It has been shown that
229 external-orientation perception is remarkably dependent on visual inputs associated with
230 complete somatosensory input [31]. This may explain some of the differences between
231 groups in the current study since both possessed intact visual inputs while the muscle and
232 joint afferent input were changed. For self-orientation perception it could be expected that
233 vestibular mechanisms compensate for the lack of visual input, however, vestibular
234 disorders in patients were not controlled; this may account for the lack of observed
235 differences between the groups in the eyes closed condition [32]. Another possibility is that
236 patients with somatosensory disorders may increase “prior for upright” reference during
237 self-orientation perception tasks [31]. On the other hand, no differences in posture variables
238 in the eyes closed condition were observed although this has previously been reported. A
239 possible explanation may be due to a lack of the standardization in CoP analysis methods
240 such as differences in duration, number of repetitions and frequency acquisition.

241 The mean score of the questionnaires for this sample was 33 points for the FES
242 (indicating risk of recurrent falls [30]) and 50% for ABC (predictive of increased risk of
243 falls [29]). Regarding the results of the correlations, there were no tenable relationships
244 between questionnaires scores and CoP variables evaluated by force platform. An interesting
245 inverse relationship between the ABC and CoP AREA was found: the better the ABC score,
246 the worse was the performance in the CoP. This inverse correlation does not correspond to
247 the clinical practice and this result does not have clinical relevance as an individual with
248 high ABC scores should have better results in CoP variables. Many factors may have

249 contributed to this finding, for example there may be a problem with the ABC
250 questionnaire in terms of its validity (evaluation internal consistency and construct validity),
251 or the presence of other conditions that may affect some components of the questionnaire
252 such as self-efficacy, anxiety or depression, which were not controlled in this study.

253 Both questionnaires assess self-efficacy, defined as a sense of confidence to perform
254 a specific activity [33]. However, self-efficacy is highly modulated by self-regulation
255 because the individual reacts not only to external stimuli, but also interprets and imposes
256 self-direction, thereby modulating the behavior [34, 35].

257 Several studies have shown a relationship between self-efficacy and functionality,
258 however, the CoP variables may not reflect function; it would be inappropriate therefore to
259 relate the results of CoP variables to the confidence that the patient has to perform activities
260 of daily living. Other factors have been demonstrated to correlate with knee OA and postural
261 sway, pain, for example, was tested in previous studies with differing results. Hassan et al.
262 [20] reported knee pain to be a significant predictor of increased postural sway in those with
263 symptomatic OA compared to healthy individuals. However, Hinman et al. [5], Bennell [1]
264 and Masui et al. [19] found no correlation between the degree of pain and balance deficit.

265 Hassan et al. [20] showed that the presence of knee OA, obesity, and weak maximum
266 voluntary contraction were the most significant independent predictors of increased postural
267 sway – the model accounted for 47% of variation in lateral postural sway. Hinman et al. [5]
268 tested correlations between the step test and postural sway and showed significant inverse
269 relationships between the step test and seven of the twelve postural sway variables; however,
270 the relationships were weak, indicating that the step test cannot accurately predict results
271 obtained using the sway meter.

272 No CoP variable was able to discriminate between individuals with OA and healthy
273 volunteers. Due to the sensitivity of the proportion of the sample in relation to the predictors

274 variables presented in this study, type II error may have occurred even with the sample size
275 calculation [36].

276 This study has some limitations that may compromise the results: vestibular and
277 psychological disorders were not controlled in this sample and the ABC questionnaire was
278 translated into Portuguese and tested only for reliability, not for its validity.

279 Further research that analyzes the relationship between functional tests in those with
280 OA and questionnaires assessing self-efficacy should be conducted, however, with greater
281 control of covariates that may influence the results. The findings of this study have some
282 implications for clinical practice. The assessment of dynamic pain and the use of
283 multidimensional, qualitative tools and health-related quality of life instruments are essential
284 to better evaluate its impact on physical, emotional and social functions in those with OA. It
285 is known that patients with somatosensory disorders show adaptations in motor control,
286 therefore when treating patients with knee OA, tasks that require external-orientation
287 perception are recommended, since afferent input from the muscles and joints take place
288 under this condition and this reflects everyday life. Self-efficacy is influenced by: the results
289 of previous performances, the experience of watching others, verbal feedback and the
290 physiological state, however, this outcome does not reflect the performance of CoP
291 variables. Postural control (evaluated by the force platform) does not seem to discriminate
292 between individuals with knee OA and those without OA, indicating that factors other than
293 the OA are responsible for the balance disorders.

294

295 CONCLUSION

296

297 Patients with knee OA presented greater postural sway when compared to healthy
298 volunteers in the eyes open condition. No CoP variables were able to discriminate between

299 patients with knee OA and those without OA. The correlations between the CoP variables
300 and the ABC/ FES questionnaires ranged from weak to strong, however, these relationships
301 are not meaningful.

302

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405 **Table 1.** Baseline scores in pain, function, balance and self-efficacy in participants with
 406 knee osteoarthritis
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	OAG (n=11)
	\bar{x} (SD)
VAS (cm)	5 (2)
WOMAC	32 (18.75)
ABC (%)	50 (24.56)
FES	33 (11.01)

408 Osteoarthritis group (OAG); Visual analog scale (VAS); Western Ontario and McMaster Universities
 409 Osteoarthritis Index (WOMAC); Activities-Specific Balance Confidence Scale (ABC) and Falls Self-
 410 Efficacy Scale (FES).
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427 **Table 2.** Comparison of CoP variables between the knee osteoarthritis group and the control group.

	EO (n=11)			EC (n=11)		
	OAG Md (25-75%)	CONTROL Md (25-75%)	<i>p</i>	OAG Md (25-75%)	CONTROL Md (25-75%)	<i>p</i>
TDS (cm)	36.70 (30.27-56.43)	26.93 (18.03-33.36)	.020	46.62 (35.23-63.93)	44.80 (24.92-56.32)	.62
APAD (cm)	1.98 (1.79-4.22)	1.77 (1.27-2.63)	.042	3.15 (2.55-4.60)	2.68 (1.86-3.37)	.08
MLAD (cm)	1.98 (1.62-3.26)	1.42 (1.22-1.99)	.061	2.63 (1.74-3.91)	1.91 (1.30-2.41)	.12
TMV (cm/s)	1.73 (0.70-2.07)	0.89 (0.60-1.11)	.010	1.55 (1.17-2.13)	1.49 (0.83-1.87)	.62
AREA (cm ²)	4.22 (2.39-12.65)	1.83 (1.22-3.70)	.045	5.27 (3.07-6.89)	3.44 (1.68-6.06)	.17

428 Median (Md) and quartile (25-75%); Eyes opened (EO); Eyes closed (EC); Osteoarthritis group (OAG); Total displacement of sway (TDS); Antero-posterior amplitude
 429 displacement (APAD); Medial-lateral amplitude displacement (MLAD), Total mean velocity (TMV) and Dispersion of the center of pressure (AREA).

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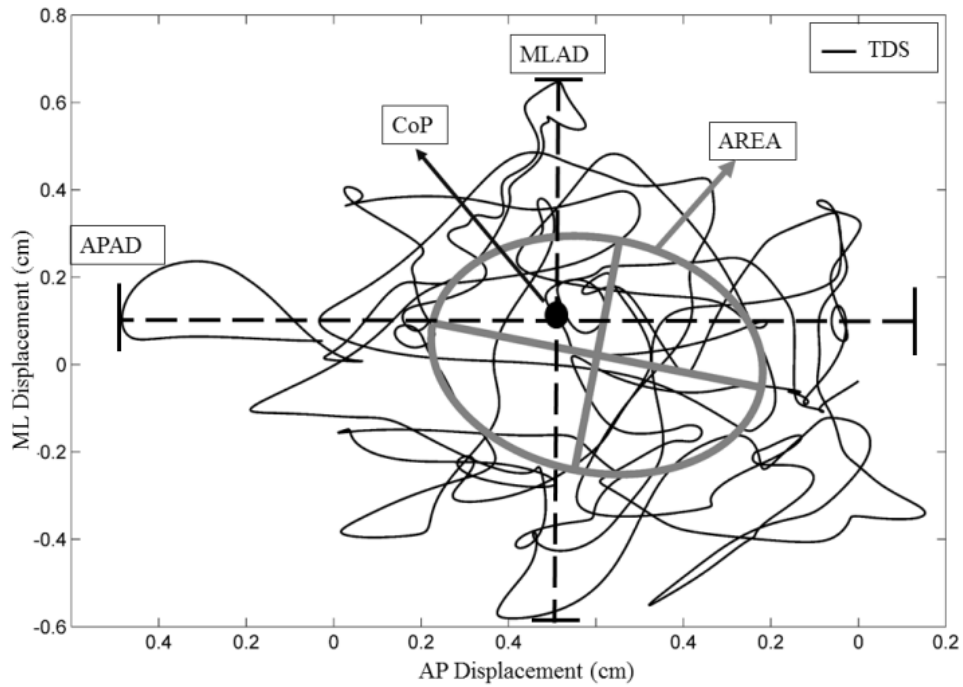
431 **Table 3.** Correlations between CoP variables and ABC and FES questionnaires.

CoP Variables	ABC	FES
	<i>rho</i> (95% CI)	<i>rho</i> (95% CI)
EO		
TDS (cm)	.56 (.31; .80)	.09 (-.15; .33)
APAD (cm)	.29 (.04; .53)	.17 (-.07; .41)
MLAD (cm)	.55 (.30; .79)	.04 (-.20; .28)
TMV (cm/s)	.70 (.45; .94)	.08 (-.16; .32)
AREA (cm ²)	.40 (.15; .64)	.18 (-.06; .42)
EC		
TDS (cm)	-.24 (-.48; .005)	-.06 (-.30; .18)
APAD (cm)	-.07 (-.31; .17)	-.33 (-.57; -.08)
MLAD (cm)	-.28 (-.52; -.03)	-.11 (-.35; .13)
TMV (cm/s)	-.26 (-.50; -.01)	-.10 (-.34; .14)
AREA (cm ²)	-.41 (-.63; -.16)	-.07 (-.31; .17)

432 Center of pressure (CoP); Activities-specific balance confidence scale (ABC); Falls self-efficacy scale (FES);
433 Confidence interval of 95% (95% CI); Eyes opened (EO); Eyes closed (EC); Total displacement of sway (TDS);
434 Antero-posterior amplitude displacement (APAD); Medial-lateral amplitude displacement (MLAD) and Total
435 mean velocity (TMV).

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440 Figure 1. Posturography data of the different variables included in the analyses. AP:
 441 anteroposterior; ML: medial-lateral; TDS: total displacement of sway; APAD:
 442 anteroposterior amplitude displacement; MLAD: medial-lateral amplitude displacement;
 443 CoP: center of pressure and AREA: dispersion of the center of pressure.

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