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

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ABSTRACT

Background: Osteoarthritis (OA) is a chronic degenerative disease that commonly affects the knee joints. Individuals over 65 years with knee OA have a greater risk of falls. However, there has be limited examination of the parameters of postural sway (increased time, speed and postural sway area (center of pressure area (CoP)), and OA of the knee.

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

Design: Cross-sectional study.

Setting: University Biomechanics Laboratory.

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

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

Main outcome measure: Variables the CoP: total displacement of sway (TDS, in cm), anteroposterior amplitude displacement (APAD, in cm), medial-lateral amplitude displacement (MLAD, in cm), total mean velocity (TMV, in cm/s) and dispersion of the center of pressure (AREA, in cm^2).

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

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

Keywords: Osteoarthritis; Aged; Postural Balance; Knee.

INTRODUCTION

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

Postural or balance disturbance normally prompts an equilibrium reaction that may involve adjustments at the ankle, hip or stepping, depending on the muscle activation and the degree of postural disturbance. Postural sway can be assessed by questionnaires, physical/functional tests and computer software or directly from a force platform [5-8]. Although the relationship between knee OA and reduced balance is not fully understood, studies have shown that reduced quadriceps function and diminished proprioception are associated with a deterioration in balance (that is the ability to maintain the center of gravity within base of support with minimal sway or maximal steadiness) and can take the knee OA patient to an increased risk of falls [9-12].

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

The relationship between balance and knee OA was explored by Khalaj et al. [6] who compared asymptomatic individuals with patients with knee OA. These authors found that there was a decrease in static and dynamic balance and greater impairment and higher risk of falls in individuals with moderate knee OA, when assessed by Overall Stability Index. This Index assesses subject’s balance control using the Biodex Stability System on either static or unstable surface. Stability is determined from the center of mass excursion about the anterior- posterior and medial- lateral axes from the center point [17]. Hurley et al [13] also reported that people with OA (n=103) had weaker quadriceps, poorer voluntary muscle activation and impaired acuity of knee joint position sense. These authors reported that of the 103 individuals with OA, only seventy six were able to complete the balance test, indicating poor stability and decreased balance control when compared to the control group, with a consequent increased risk of falls [13,18]. Wegener et al. [7] reported significant differences in postural sway between the OA and control group in the bipedal and unipodal conditions, with eyes closed. Similarly, Masui et al. [19] reported greater displacement in the center of pressure (CoP) in those with OA, with eyes closed and Hassan et al. [20] found that individuals with OA demonstrated increases in CoP displacement in the medial-lateral and anteroposterior direction.

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

A number of authors have reported differences in CoP variables between those with OA and healthy controls, however, there are no studies to date that clearly demonstrate which CoP variables are able to discriminate between patients with knee OA and healthy individuals. Additionally further work is required to explore the relationship between direct measures of balance (force platform) and subjective measures of confidence in balance and risk of falls in those with knee OA. Thus, the primary aims of this study were: to determine whether the CoP variables discriminate between patients with knee OA and healthy individuals and to correlate the CoP variables with the Activities-Specific Balance Confidence Scale (ABC) and Falls Self-Efficacy Scale (FES). The secondary aim of this study was to compare the CoP of the older women with knee OA and a control group in bipedal support condition with eyes opened and closed.

METHOD

Twenty-two participants in this cross-sectional study were equally divided into two groups: OA group ($\bar{x}$=68 years (SD=7.4) and $\bar{x}$=30.2 kg/m^2 (SD=6.3)) and a control group ($\bar{x}$=66 years (SD=4.4) and $\bar{x}$=26.6 kg/m^2 (SD=3.7)). The control group participants were recruited from the University Hospital and also from the local community. All participants were given information about the study and gave written informed consent, the study was approved by the Universidade Estadual de Londrina Ethics Committee (#967/2014).The sample size was calculated through G*Power 3.1.9.2 [25] using a two-tailed Student *t*-test to find the mean difference between the two independent groups, an estimated effect size of 0.7, α error prob. of 0.05 and 1 – β error prob. of 0.85. Twenty-one subjects were necessary for a power of 86%.

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

The exclusion criteria for both the OA and control groups were: surgical procedures in the previous six months; chronic diseases such as coronary heart disease; rheumatic disease; cancer; chronic obstructive pulmonary diseases; uncontrolled hypertension; participating in physical activity programs in the previous two months (aerobic or resistance activity more than once a week for at least two months); arthroplasty and severe obesity (body mass index (BMI) > 40 kg/m^2).

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

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

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

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

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

RESULTS

Twenty-two individuals participated in this study and data from the clinical examination (VAS, WOMAC, ABC and FES) of the OA group are shown in table 1. The Kellgren-Lawrence radiographic criteria indicated that most patients (58 %) had mild OA (grade 1 and 2); while the others (42 %) had severe stage of radiographic abnormalities (grade 3 and 4). Regarding the postural sway analysis, when the comparison between the groups was performed, statistically significant differences were found between all variables (TDS (*p*=.020), APAD (*p*=.042), TMV (*p*=.010), and AREA (*p*=.045)) when evaluated in eyes open condition, except for MLAD (*p*=.061). The control group demonstrated better results (i.e. greater stability) when compared to patients with knee OA. However, when comparing the eyes closed condition, no statistically significant differences were found in any of the variables, as shown in table 2.

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

DISCUSSION

The results of this study demonstrate that older women with knee OA presented greater postural sway with the eyes open when compared with healthy volunteers, in the closed eyes condition this difference was not observed. The results of the present study support previous work that reported increased postural sway in individuals with knee OA, with eyes open. Wegener et al. [7], Hinman et al. [5] and Masui et al. [19] found that participants with knee OA displayed higher postural sway than age matched controls under both the eyes open and closed conditions. In addition, Hurley et al. [13] reported increased postural sway only under the eyes open condition.

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

The mean score of the questionnaires for this sample was 33 points for the FES (indicating risk of recurrent falls [30]) and 50% for ABC (predictive of increased risk of falls [29]). Regarding the results of the correlations, there were no tenable relationships between questionnaires scores and CoP variables evaluated by force platform. An interesting inverse relationship between the ABC and CoP AREA was found: the better the ABC score, the worse was the performance in the CoP. This inverse correlation does not correspond to the clinical practice and this result does not have clinical relevance as an individual with high ABC scores should have better results in CoP variables. Many factors may have contributed to this finding, for example there may be a problem with the ABC questionnaire in terms of its validity (evaluation internal consistency and construct validity), or the presence of other conditions that may affect some components of the questionnaire such as self-efficacy, anxiety or depression, which were not controlled in this study.

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

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

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

No CoP variable was able to discriminate between individuals with OA and healthy volunteers. Due to the sensitivity of the proportion of the sample in relation to the predictors variables presented in this study, type II error may have occurred even with the sample size calculation [36].

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

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

CONCLUSION

Patients with knee OA presented greater postural sway when compared to healthy volunteers in the eyes open condition. No CoP variables were able to discriminate between patients with knee OA and those without OA. The correlations between the CoP variables and the ABC/ FES questionnaires ranged from weak to strong, however, these relationships are not meaningful.

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Table 1. Baseline scores in pain, function, balance and self-efficacy in participants with knee osteoarthritis

	OAG (n=11) $\bar{x}$ (SD)
VAS (cm)	5 (2)
WOMAC	32 (18.75)
ABC (%)	50 (24.56)
FES	33 (11.01)

Osteoarthritis group (OAG); Visual analog scale (VAS); Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC); Activities-Specific Balance Confidence Scale (ABC) and Falls Self-Efficacy Scale (FES).

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%)**	***p***	**OAG Md (25-75%)**	**CONTROL Md (25-75%)**	***p***
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

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

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

CoP Variables	ABC *rho* (95% CI)	FES *rho* (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)

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

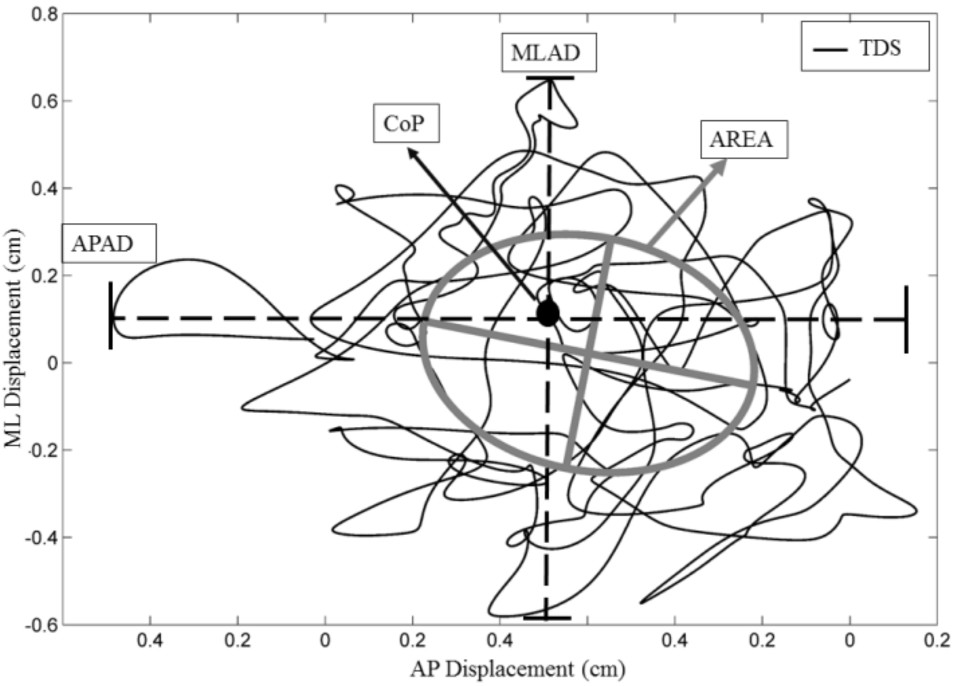

Figure 1. Posturography data of the different variables included in the analyses. AP: anteroposterior; ML: medial-lateral; TDS: total displacement of sway; APAD: anteroposterior amplitude displacement; MLAD: medial-lateral amplitude displacement; CoP: center of pressure and AREA: dispersion of the center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