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Short communication

Test re-test reliability of centre of pressure measures during standing balance in individuals with knee osteoarthritis

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ABSTRACT

Assessment of changes in standing balance following an intervention requires accurate measurement of balance parameters. The reliability of centre of pressure measures of balance during single-leg standing has not been reported in individuals with knee osteoarthritis. The purpose of this study was to assess the test re-test reliability of force platform centre of pressure measures during single-leg standing in older adults with knee osteoarthritis. Twenty-five adults with radiographic evidence of knee osteoarthritis performed single-leg standing balance trials on a laboratory-grade force platform on two occasions, no more than 14 days apart. Participants were asked to stand on their more symptomatic limb for three, ten second trials. Centre of pressure measures collected included: standard deviation in the mediolateral and anteroposterior directions, mean path length, velocity, and area. The mean of the three trials was calculated. Intraclass correlation coefficients, standard error of measurement, Bland and Altman plots and the minimum detectable change were calculated. Intraclass correlation coefficients ranged from 0.54 to 0.87, suggesting mixed reliability of measures. Reliability was lowest for the centre of pressure area (intraclass correlation coefficient = 0.54), and highest for centre of pressure velocity and path length (intraclass correlation coefficient = 0.87 for both). Standard error of measurement values were low for standard deviation in the mediolateral direction and high for centre of pressure area. These results suggest that centre of pressure values, in particular path length and velocity, are appropriate for assessment of standing balance in people with medial knee osteoarthritis.

1. Introduction

Evidence suggests that those with knee osteoarthritis (OA) exhibit balance deficits such as increased centre of pressure (COP) variation during standing compared to age and sex-matched healthy controls [1–3]. Accordingly, those with knee OA may benefit from assessment and treatment of such balance deficits. One of the most common methods of measuring standing balance is using a force platform, with outcomes assessing the velocity, variation, and displacement changes of the COP. However, variability in measurements negatively affects the validity and reliability of such postural control outcomes, ultimately impacting the interpretation of findings. Thus, it is important to establish the reliability of COP measures before they can be used as a tool to monitor change, such as in balance training programmes.

Since falls are common in positions where only one leg is stable on the floor [41% of falls occur during weight shifting [4]], it is important to assess balance in positions that are challenging and reflective of functional ability, such as single-leg stance. Balance measures in healthy older adults are reliable in this position. For example, COP area and velocity during 30 s of single-leg stance exhibited intra-class correlation coefficient (ICC) values of 0.60–0.85 in one sample of 28 healthy older adults [5]. The reliability of COP measures during single-leg standing has not been reported in individuals with knee OA. Therefore, the purpose of this study was to assess the test re-test reliability of COP measures during single-leg stance in older adults with knee OA. It was hypothesized that COP measures would display adequate test re-test reliability with the highest reliability displayed by COP velocity.

2. Methods

Participants aged 50 years or older with radiographic evidence of medial compartment knee OA were recruited using local media

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and from a database of previous study participants. Severity of knee OA was determined using the Kellgren and Lawrence (KL) [6] rating scale. Ethics approval was obtained from the clinical research ethics board, and written informed consent was provided by all participants.

Each participant completed two test sessions, a maximum of 14 days apart. Testing consisted of three, ten second trials of single-limb stance on a floor-mounted force platform (Advanced Mechanical Technology Inc., Watertown, MA). During each trial, participants were instructed to stand on their study limb (the more symptomatic limb in bilateral OA) and to minimize overt movements. Trials ended after 10 s of collection, or if the participant produced excessive movement (for example, shuffling or arm waving). When the single-limb stance position was achieved and participants felt stable, data collection commenced. A maximum of six attempts were allowed. Participants who were unable to maintain single-limb stance for 10 s were excluded from the analysis. Kinetic data were collected at 50 Hz, and COP coordinates were calculated from the raw force platform data.

Dependent variables consisted of the following COP-based measures: (1) mediolateral (ML) standard deviation of the COP; (2) anteroposterior (AP) standard deviation of the COP; (3) COP path length; (4) COP velocity, and (5) COP area [area of the 95% confidence ellipse [7]]. Measures were specifically chosen based on their commonality in previous reports in the literature and the ability to be clinically interpretable (i.e. simple to calculate and easily understandable by clinicians). The mean of the three trials was computed.

$ICC_{(2,1)}$ was chosen to assess relative reliability using a two-way random effects model with absolute agreement. ICC values greater than 0.8 were considered acceptable. Standard error of measurement (SEM) was chosen to test absolute reliability, and was calculated as follows:

$$SEM = s_X\sqrt{1 - ICC}$$

where s_X = standard deviation of the measurement [8]. Bland and Altman plots were constructed by plotting the difference in COP measures between the two test sessions against the mean results [9]. Minimum detectable change (MDC) at the 95% confidence level was calculated for further clinical interpretation as follows:

$$MDC = SEM \times 1.96 \times \sqrt{2}$$

$P < 0.05$ was considered significant. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL) v21.0.

3. Results

Twenty-five participants volunteered. The mean (SD) difference between the first and second test sessions was 8.1 (2.6) days and the mean (SD) difference in the time of day for testing was 1.2 (1.5) h. Five participants (4 males, mean (SD) age 74.6 (12.7) years, BMI 29.1 (9.6) kg/m^2) were unable to maintain single-limb stance for ten seconds. The remaining twenty participants (13 males, mean (SD) age 64.1 (7.9) years, BMI 27.2 (4.9) kg/m^2) were considerably younger than those who could not maintain single-limb stance (mean difference of 10.5 years). Of these individuals, ten participants exhibited mild signs of OA (KL 2), nine participants exhibited moderate OA (KL 3), and one participant exhibited severe OA (KL 4). All further data analysis was conducted on these twenty individuals.

ICC values ranged from 0.54 to 0.87, with only two out of the five COP measures having ICC values above 0.8 (Table 1). Both COP path length (ICC = 0.87) and COP velocity (ICC = 0.87) displayed high reliability. SEM values can be found in Table 2. SEM values were low for ML COP standard deviation (SEM = 0.10, 95% CI 0.08–0.14) and COP path length (SEM = 7.28, 95% CI 5.73–9.98). Bland and Altman plots are shown in Fig. 1, and indicated no obvious relationship between the difference and the mean for COP measures. The 95% MDC values ranged from 0.27 to 23.22 (Table 2).

Table 1
Mean (SD) of each centre of pressure (COP) measure and intraclass correlation coefficients (ICC) with 95% confidence intervals. Two testing sessions were attended a maximum of 14 days apart. ML: mediolateral; AP: anteroposterior.

COP measure	Session 1 mean (SD)	Session 2 mean (SD)	$ICC_{(2,1)}$ (95% CI)
ML SD	0.79 (0.13)	0.75 (0.17)	0.60 (0.24–0.82)
AP SD	0.93 (0.20)	0.91 (0.33)	0.59 (0.20–0.81)
Path length (cm)	63.82 (18.3)	62.9 (20.6)	0.87 (0.70–0.95)
Velocity (m/s)	0.64 (0.18)	0.63 (0.21)	0.87 (0.70–0.95)
Area (cm^2)	14.20 (4.80)	14.20 (9.10)	0.54 (0.13–0.79)

4. Discussion

Reliability of COP measures varied, with the highest reliability seen for COP velocity and COP path length, while the lowest reliability exhibited by the AP COP standard deviation and COP area. These results suggest that reliable measures of standing balance such as COP velocity or COP path length can be used to assess changes over time in a population of older adults with knee OA.

The ICC values reported here are similar to previous studies of COP reliability during single-leg standing (ICC = 0.40–0.85) [5]. SEM values for COP velocity (SEM% = 12%) were lower than previous literature, ranging from 17 to 22% [5], perhaps owing to differences in age (64 years in our sample vs 69 years). The MDC values presented in Table 2 suggest, for instance, that for 95% of stable patients with similar characteristics to the current study, the COP path length would change by less than 20 cm upon reassessment. This is approximately equal to one standard deviation of COP path length and further supports the reliability and use of such a measure during testing of standing balance over time, such as in clinical interventions. Using clinically-available and validated devices such as the Nintendo Wii Balance Board [10], clinicians can use MDC values from these outcome measures, particularly COP velocity and COP path length, to evaluate standing balance when assessing patients. For example, if the change in standing balance is greater than the MDC, a clinician can be confident that the change is a true change in performance.

COP path length and velocity were more reliable than single-axis measures including ML COP standard deviation and AP COP standard deviation. The global (multi-axial) nature of these measures, and the smaller variability (lower SD) compared to COP area may make them more reliable choices when assessing changes in standing balance over time. COP path length is highly dependent on sampling time as well as sample rate. Thus, the current calculated values pertain only to the sampling time of ten seconds at 50 Hz. Calculations done with other parameters may result in different values and levels of reliability [11], and certainly different MDC values. For this reason, COP velocity, which can be compared across different sampling times at a given sample rate, may be more favourable as a measure when comparing across studies.

One limitation of this study was the requirement that participants stand on one leg for ten seconds. Five of the

Table 2
Point estimates of the standard error of measurement (SEM) and minimum detectable change (MDC) of centre of pressure (COP) measures. Absolute SEM, SEM as a percent of the mean scores, and the 95% MDC are provided. ML: mediolateral; AP: anteroposterior.

COP measure	SEM	SEM (%)	95% MDC
ML SD	0.10	0.09	0.27
AP SD	0.17	0.17	0.47
Path length (cm)	7.28	0.12	20.19
Velocity (m/s)	0.12	0.17	0.33
Area (cm^2)	8.38	0.34	23.22