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Postural balance in low back pain patients: Intra-session reliability of center of pressure on a portable force platform and of the one leg stand test

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ABSTRACT

Low back pain (LBP) patients have poorer postural control compared to healthy controls, and the importance of assessing and addressing balance is a matter of debate. In the clinic, balance is often tested by means of the one leg stand test (OLST) while research often employs center of pressure (CoP) on a force platform. Portable force platforms might be of clinical relevance, but their reliability for LBP patients in a clinical setting has not been demonstrated. As LBP patients are more dependent on vision compared to healthy controls, the ratio of tests performed with eyes open and eyes closed (Romberg Ratio) might be of clinical interest. This study aimed to assess postural balance in LBP patients by analyzing intra-session reliability of CoP parameters on a portable force platform, the Romberg Ratio, and the OLST. Furthermore, we aimed to determine whether CoP parameters and OLST measure identical aspects of postural stability. We examined 49 LBP patients and found acceptable reliability of the CoP parameters' trace length and velocity, whereas reliability regarding C90 area, the Romberg Ratio, and the OLST was poor. Correlations between the CoP parameters and OLST were insignificant. Reliability of trace length and velocity is acceptable and can be used as parameters when assessing CoP in LBP patients.

1. Introduction

Low back pain (LBP) is a common musculoskeletal complaint; recent years have seen an increase in the evaluation of functional capacity and physical parameters in patients with LBP [1,2]. Parameters such as muscle endurance, postural balance, and physical capacity are discussed with respect to diagnosis, prognosis, and outcome measures [1,3–6].

Postural balance involves a complex of dynamic interactions of vestibular, visual, and somatosensory information analyzed in a complex regulatory feedback system resulting in constantly changing outputs [2,7,8]. In order to maintain the wide range of activities that constitute normal daily life, a well-functioning balance is necessary [2,8,9]. Postural balance is often examined as the center of pressure (CoP) excursion measured on a force platform. LBP has been associated with altered CoP parameters, and balance may play a role in recurrence of LBP [2,5,7,8,10–15]. The mechanism that causes impaired balance in LBP patients is at present unknown, but a decrease in somatosensory input has been suggested [15].

A number of authors have reported that LBP patients are more dependent on vision compared to a healthy population [4,7,8,10,16]. For both LBP patients and healthy controls, balance is poorer in eyes closed (EC) tests compared to eyes open (EO) tests, but in EC tests the difference between LBP patients and healthy controls becomes more distinct [15,16]. In order to test this dependency the Romberg Ratio (RR) might be of interest for rehabilitation. The RR is the ratio of a given value measured using EO and EC, respectively. Usually greater than one, the ratio quantifies the visual contribution to balance [17]. The reliability of the RR has not yet been established.

Postural control has been assessed by applying various quantitative techniques to test LBP patients; the force platform technique is among the tools most frequently used [2,4,5,7,8,10,11,18]. In laboratory settings platforms are usually secured to the ground and tests are costly; such tests have not yet become part of daily routine [4,12]. As portable force platforms are becoming cheaper and time-efficient protocols have been developed, their usage would seem relevant in daily

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practice, but clinical use of these techniques has not been thoroughly investigated. Thus, both clinicians and researchers would benefit from an investigation of the reliability of the portable force platform.

A few studies have investigated the link between LBP and balance by observing patients standing on one leg. [19,20]. The one leg stand test (OLST), where the patient is observed and timed, is an easy, quick and low-cost test for evaluating postural stability [21–23]. In a previous study we found acceptable intra-observer and inter-observer reliability of the OLST [22].

For LBP patients, only a few studies have investigated whether the CoP parameters [4,24,25] or OLST [22] are reliable, which would be a precondition for their use as outcome parameters. Furthermore, possible correlations between CoP parameters and OLST have not been studied.

The main objective of this study was to assess postural balance in LBP patients by analyzing the intra-session reliability of CoP parameters on a portable force platform, the RR, and the OLST in daily clinical practice. Furthermore we aimed to test the association between CoP parameters and OLST in order to reveal whether they measure the same aspect.

2. Methods

2.1. Subjects

The 52 patients in this study comprised patients with LBP referred from general practitioners to one of two rheumatologic outpatient clinics. Patients in this study were enrolled in a large intervention study [26]. Inclusion criteria: persistent LBP, active on the labor market, age bracket 18–63, and Danish-speaking. Exclusion criteria: planned low back surgery, pregnancy, and serious other illnesses, e.g. vestibular diseases.

2.2. Procedures

Test conditions were standardized before the tests, and all trials were conducted by the same two experienced physiotherapists.

CoP excursion was tested using a four-channel portable force platform (HurLabs BT4). The platform was calibrated prior to testing, and the four channels were checked before test. Patients were instructed to look straight ahead and stand as still as possible in the center of the platform with arms hanging down.

The foot position was standardized: a 2 cm heel-to-heel distance and an angle of 30° between the feet. The test was carried out with EO, focusing at a point 2 m ahead, and with EC. The participants stood still for at least 5 s (pre-phase) before the measurement. After the pre-phase, CoP was measured during the next 60 s; signals were sampled at 200 Hz and filtered with a low-pass filter at 7.8 Hz cut-off frequency. The following measures were examined: *trace length*: the trajectory (mm) of the CoP; *velocity*: mean velocity (mm/s) of the CoP; and *C90 area*: area (mm^2) of the smallest ellipse containing 90% of the CoP points [1,27]. As velocity and trace length are connected it could be argued that one of these would be enough. In order to compare our results for relative reliability with others, we present both [4,24,25].

In order to quantify the visual contribution to posture we calculated the RR (EC/EO). The RR quantifies the dependency of vision, and an RR of 1.3 indicates that the sway is increased by 30% in EC compared to EO. RR was calculated using velocity (RRvel) and C90area (RRarea) as these results are comparable with other test protocols.

The OLST was carried out by having patients fold their arms across their chest, one foot lifted approximately 10 cm and placed behind the weight-bearing leg [22]. The test was carried out with EO, focusing at a point 2 m ahead, and with EC. The patients were timed while standing on the left and right leg, respectively. Timing was stopped after 60 s EO or 30 s EC, or when the position could no longer be maintained. When using the EO OLST we chose a cut point of 60 s, as testing beyond this timeframe might effectively constitute a test of muscle endurance or other parameters not relevant for balance. A pilot study showed that almost no LBP patients could stand on one leg for more than 30 s with EC, prompting our choice of cut point. Most patients in the pilot study were able to stand for between 5 and 20 s with EC, and this spectrum appears clinically relevant. Patients able to stand for more than 30 s with EC were excluded from further studies. Each OLST trial consisted of eight tests with the best of two EO results and best of two EC results recorded for each leg. In clinical practice, interventions will be based on patients having poor balance; therefore, results from the leg with the shortest stand time were used for analysis [22].

The patients were barefoot for both techniques. Tests were performed in the same order for every subject: CoP measurements first, then OLST after a 2-min break. There was a 10-min break between tests and retests. To familiarize patients with the task, a couple of preliminary trials were performed. Pictures of the test positions are available as supplementary data.

Mean pain during the last seven days was rated on an 11-point numerical pain rating scale (NPRS). Disability was assessed using the Roland Morris questionnaire.

2.3. Ethics

All patients gave written, informed consent. The study protocol was approved by the Danish Data Protection Agency, notified to the local ethic and scientific committee, and all procedures were in accordance with the Helsinki declaration.

2.4. Statistical analysis

The sample size of reliability studies should exceed 50; we included 52 patients [28].

Some test results showed non-normality, and some of the differences evinced heteroscedasticity; this was solved by log-transformation [29].

To test for significant differences between test and retest, paired *t*-tests were performed. The agreement between test and retest (log scale) was examined by a Bland–Altman plot for each parameter. A marking of the mean, 95% CI, and limits of agreement (LOA) were included in the plots [29,30]. LOA represents a measure of random error and thereby variability in the measurements of individual patients [29,30]. The standard error of the measurement (SEM), which represents the typical error in a single measurement, was calculated [28,31]. The SEM provides a measure of variation on the original scale, meaning it can be used to distinguish between measurement noise and genuine change in intervention studies [31]. The log-transformed means were back-transformed to the geometric means. As data are log-transformed SD of the mean, difference, LOA and SEM are presented in percent. Using SEM to determine reliability, a result of <7% is considered to indicate a high reliability, while over 12.5% indicates poor reliability [32]. The intra-class correlation coefficient (ICC), which is a ratio of the variance between subjects over the total variance model 2.1, was calculated for the CoP and OLST [30]. The ICC is not relevant when analyzing reliability of a ratio. When calculating the ratio the variation between subjects will be reduced, and furthermore the ratio is calculated by two measures, each of these presenting their own variation; this would tamper with the ICC. Correlations were calculated using Spearman's rho.

3. Results

3.1. Fifty-two patients were included in the study

All patients completed tests and retests with both techniques. Forty-six patients (88%) were able to maintain the EO OLST for the maximum time. When this ceiling level was reached, no further analysis was carried out for the EO OLST. Three patients were able to maintain the EC OLST for 30 s and were thus excluded from further analysis. The calculations were based on the remaining 49 patients. The three excluded patients did not differ from the 49 patients included in the study with respect to baseline parameters. All patients had LBP for more than 8 weeks, ranging from 9 weeks to 30 years, and 73.5% experienced daily LBP during the last three months. Patients with radiating pain accounted for 87.6%, of these, 12.2% had bilateral pain. Demographics and clinical characteristic are presented in Table 1.

Table 1
Demographics and clinical characteristics.

Age (yr), mean (SD)	46.6 (9.49)
Sex, m/f (%)	24/25 (49/51)
Weight (kg), mean (SD)	78.7 (15.5)
Height (cm), mean (SD)	174.1 (9.4)
Body mass index, mean (SD)	25.9 (4.0)
Mean pain during the last 7 days, mean (SD)	4.91 (2.66)
Sørensen test (s), median (IQR)	86 (54–145)
Roland Morris questionnaire, median (IQR)	12 (8–15)
Maximal oxygen uptake, median (IQR)	30.0 (24.0–36.0)
Quebec task force classification	
1: Without radiating pain (%)	22.5
2: With radiating pain, not below knee level (%)	18.4
3: With radiating pain below knee level (%)	59.2
4: Neurologic deficit (%)	38.8
Patients with daily low back pain during the last three month (%)	73.5

Table 2
Reliability parameters for CoP parameters, one leg stand test, and Romberg Ratio.

		Mean (SD) test Mean (SD) retest	Difference (95% CI)*	p	Standard error of measurement (95% CI)*	ICC
CoP parameters	Trace length mm; eyes open	724 (20.9%) 721 (23.3%)	0.4% (−3.2%; 4.1%)	0.83	9.0% (7.5%; 11.2%)	0.84
	Trace length mm; eyes closed	945 (27.9%) 964 (30.9%)	−2.0% (−6.2%; 2.4%)	0.34	10.9% (9.1%; 13.6%)	0.86
	Velocity mm/s; eyes open	12 (20.9%) 12 (23.3%)	0.4% (−3.2%; 4.1%)	0.83	9.0% (7.5%; 11.2%)	0.84
	Velocity mm/s; eyes closed	16 (27.9%) 16 (30.9%)	−2.0% (−6.2%; 2.4%)	0.34	10.9% (9.1%; 13.6%)	0.85
	C90 area EO mm^2; eyes open	238 (51.0%) 234 (56.3%)	−1.6% (−12.0%; 15.2%)	0.81	34.4% (28.5%; 43.7%)	0.56
	C90 area mm^2; eyes closed	285 (55.0%) 309 (55.6%)	−8.0% (−18.8%; 2.7%)	0.14	26.9% (22.3%; 33.9%)	0.73
	Romberg Ratio, velocity	1.31 (15.2%) 1.34 (18.7%)	−2.4% (−7.8%; 3.0%)	0.37	13.3% (11.1%; 16.9%)	
	Romberg Ratio, C90 area	1.20 (37.9%) 1.32 (45.7%)	−9.6% (−26.2%; 6.7%)	0.25	40.8% (34.0%; 51.0%)	
OLST	Stand time s; eyes closed	7 (71.2%) 8 (66.4%)	−13.0% (−24.2%; −1.7%)	0.03	28.3% (23.5%; 35.8%)	0.79

Mean are the back transformed geometric mean; ICC = intra class correlation; trace length = CoP trajectory in mm; velocity = average velocity in mm/s of the CoP; C90 area = area of the smallest ellipse containing 90% of the CoP points; OLST = one leg stand test; *based on log transformed data.

As seen in Table 2 there was no significant difference between test and retest in the CoP parameters, but for the OLST there was a significant difference of 13% ($p = 0.03$) between test and retest; difference, SEM, and ICC are showed for both techniques.

Fig. 1A–D shows the differences between tests and retests plotted against the mean of the EC tests for the CoP parameters and OLST; mean, 95% CI, and LOA are marked in the plots.

The results for RRvel and RRarea are presented in Table 2. We found no significant difference between test and retest; means for test and retest, difference, and SEM are presented. Fig. 1E–F shows plots illustrating the differences between test and retest against the mean of the RRvel and RRarea.

We found insignificant correlations of <0.15 between OLST and the CoP parameters, as shown in Fig. 2.

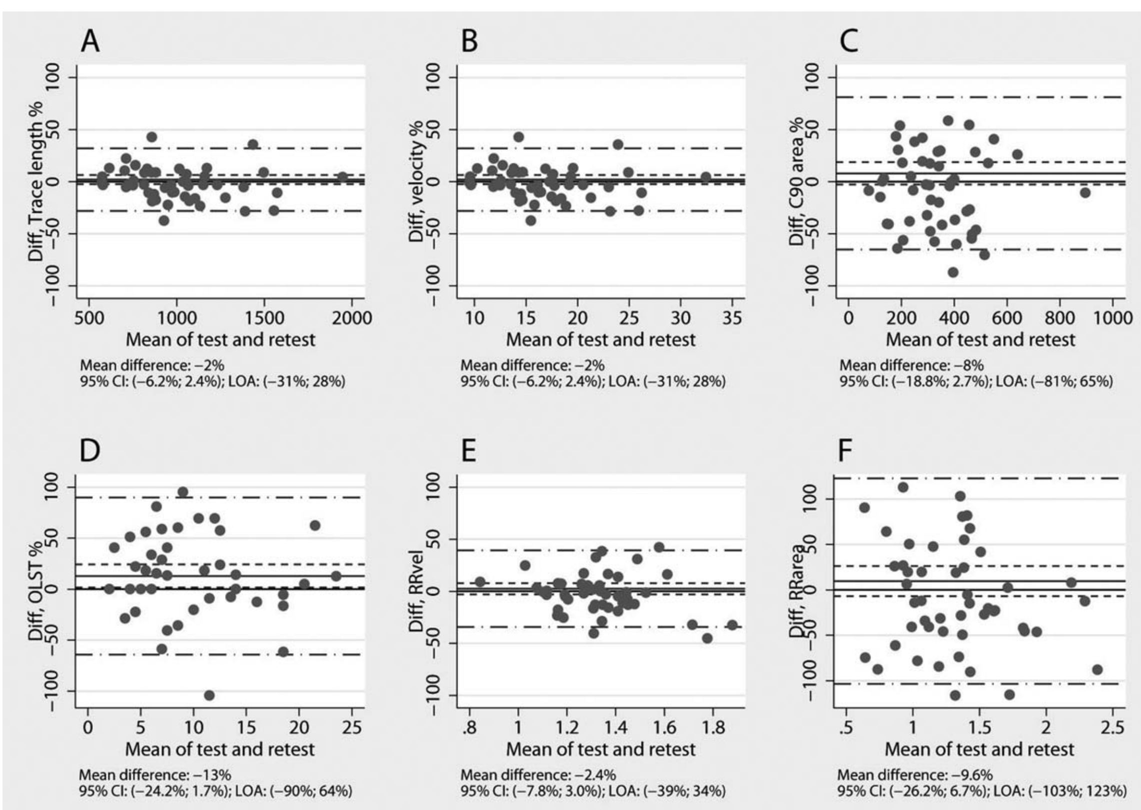

Fig. 1. Differences between test and retest plotted against the mean. The eyes closed tests for trace length (A); velocity (B); C90 area (C); OLST (D); 'Eyes Open/Eyes Closed difference' velocity (E); and 'Eyes Open/Eyes Closed difference' area (F). Diff = difference; OLST = one leg stand test; RRvel = Romberg Ratio, velocity; RRarea = Romberg Ratio, C90 area.

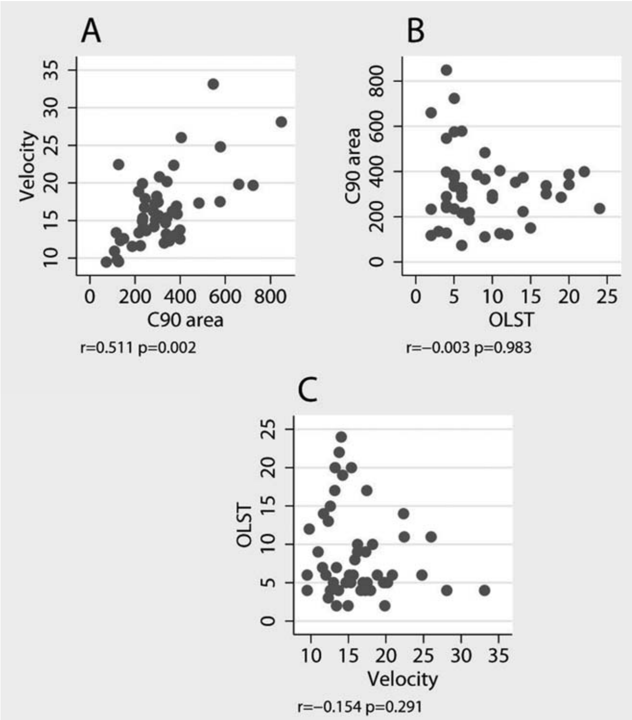

Fig. 2. Correlation between parameters of postural stability, eyes closed condition: velocity vs C90 area (A); C90 area vs OLST (B); OLST vs velocity (C). Velocity = average velocity in mm/s of the center of pressure (COP); C90 area = area in mm^2 of the smallest ellipse containing 90% of the COP points; OLST = One leg stand test.

4. Discussion

This study evaluated assessments of postural balance in LBP patients by analyzing the intra-session reliability of CoP parameters, the RR, and OLST, as well as the correlation between CoP parameters and OLST. The reliability of trace length and velocity was acceptable, whereas the reliability of C90 area, RRvel, and RRarea was poor. The reliability of OLST was not acceptable as we found a significant difference of 1 s between test and retest. There were no correlation between OLST and the CoP measurement.

Random variability can be subject to inaccuracy in the measurement itself or variations in the performance of the patient. In this study it is not possible to distinguish between these types of variation, but as assessments will be influenced by both, the total variability is of clinical interest.

In LBP patients there is no agreement as to which parameter is best suited to explain postural stability [5,7,8], and no other study has used a portable force platform [4,24]; the difference in technique hampers comparison to other studies.

Three studies have investigated reliability of CoP measurements in LBP patients; presenting ICC as a statistical parameter with values from 0.44 to 0.91 [4,24,25]. In one study the test population was young female gymnasts [24], while another had LBP patients mixed with other patients [25], making the results difficult to compare. This left one study with a comparable population [4]. Using COP information that accords with our results from trace length, Leitner presented an ICC of 0.77 [4].

Others have found better reliability from trace length and velocity than from area [24,33]; which is in agreement with our findings. This might be due to the fact that some of the area in the ellipse is ‘dead space’ whereas trace length and velocity reflects exact measurements. ‘Dead space’ is the part of the area not covered by the COP trajectory. The C90 area is the smallest ellipse, containing 90% of the COP points, meaning that outliers are excluded, but the dead space of the C90 area will still not be covered by the COP points. The area in the ‘dead space’ might vary more than other parameters when test and retest is compared (see Fig. in supplementary data).

We used SEM as our primary indicator of reliability. One study with a similar population reports variability comparable to our findings as regards trace length and velocity [24].

In the C90 area the SEM was found to be poor and therefore considered inadequate for tracking changes in individual patients.

No other studies have reported the reliability of RR in LBP patients. The ratio reflects dependence on vision and possibly the loss of somatosensory information. As in the CoP parameters, reliability of RRarea is unacceptable. The result from RRvel is just 1% from acceptable reliability (13.3%). From a clinical perspective RRvel could be of interest because LBP patients are more dependent on vision and in addition the inter-personal variability in CoP parameters is high [2,5,7,8,10–13]. If dependency on vision is to be explored in LBP patients the RRvel is an interesting outcome measure.

In accordance with our results, previous studies have shown that the EO OLST is not challenging enough for healthy persons, nor for LBP patients [22,23].

We found a significant difference between test and retest in the EC OLST: this contrasts with a former study on LBP patients where we found acceptable variability [22]. The difference might be due to a type one error, as we found no difference in the previous study, or in a smaller pilot test of 20 patients. As the SEM shows poor reliability, the OLST is not recommendable as an outcome measure in clinical practice. Better reliability means that the CoP parameters are preferable to the OLST.

Three previous studies have tested reliability in LBP patients standing on one leg [19,20,22]. Two studies observed the quality of the position and are not comparable to our findings [19,20]. When comparing EC OLST with normative data we found significantly poorer performance [21,23]. The difference is most likely due to the fact that our study featured LBP patients whereas the studies of normative data included healthy persons; furthermore the test positions were different.

In this first study analyzing the association of CoP parameters and OLST we found no significant correlation, which indicates that the two techniques measure different aspects of postural control. As both techniques test the ability to maintain a specific posture, and thereby aspects of postural stability [9], this was a surprising result that needs further investigation.

Patients were referred from general practitioners to a rheumatologist for diagnostic evaluation of LBP. Almost all patients could be included and only a few patients refused to participate.

The result of the ICC is highly dependent on the variability in the population observed; a higher ICC may occur if some patients perform poorly and others perform very well. Thus, the ICC must be interpreted with caution [28].

We emphasized clinical relevance, e.g. by taking best of two trials in the OLST and just one trial using the portable force platform. For better reliability a mean of two or three tests would be preferable [4]. However, this would lower the clinical relevance as procedures become more time-consuming and complicated. It has furthermore been suggested that a number of test trials are needed in order to reduce learning effect [4]. In this study only the OLST showed systematic differences between test and retest, and thereby a possible learning effect. As exercises to improve balance will differ from the test situation, and as we always have months between tests in daily practice, the role of learning effect seems insignificant.

5. Conclusion

We found an acceptable intra-session reliability of some of the CoP parameters, i.e. velocity and trace length, but poor reliability of the C90 area. The reliability of RRarea was poor. Reliability of RRvel was close to acceptable, and the RRvel may be an interesting outcome measure in LBP patients if dependency on vision is to be explored.

The reliability of the OLST was unacceptable.

Our expectations – that we would find a relevant correlation of CoP parameters and OLST in LBP patients – were not met.

We used a clinically feasible and time-efficient protocol for both techniques.

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Conflict of interest statement

There were no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gaitpost.2011.04.014.

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