The Accuracy of the Palpation Meter (PALM) for Measuring Pelvic Crest Height Difference and Leg Length Discrepancy

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Study Design: Test-retest reliability and validity.
Objective: To determine the validity and reliability of the Palpation Meter (PALM).
Background: Leg length discrepancy (LLD) has been associated with a variety of musculoskeletal disorders. Therefore, the clinical measurement of LLD has become a routine and important part of the physical examination. The PALM is an instrument that was recently developed to indirectly measure LLD, but little is known about its measurement properties.
Methods and Measures: Fifteen healthy and 15 symptomatic subjects with suspected LLD participated in this study. Measurements of pelvic crest height difference (PD) were obtained by 2 examiners using the PALM. A standing antero-posterior (AP) radiograph of each subject's pelvis was taken, and PD and LLD (femoral head height difference) were determined from the radiograph for comparison with the PALM values. Intraclass correlation coefficients (ICCs) were calculated to determine the validity and reliability estimates of the PALM.
Results: For all subjects, the validity estimates ($ICC_{2,3}$) of the PALM for PD were excellent (0.90 for rater 1 and 0.92 for rater 2) when compared with the standing AP radiograph of the pelvis. The PALM was less accurate ($ICC_{2,3}$ of 0.76 and 0.78 for rater 1 and 2, respectively) as an indirect estimate of LLD. Intrarater reliability for each rater was excellent ($ICC_{3,3}$ = 0.97 and 0.98) and interrater reliability was very good ($ICC_{2,3}$ = 0.88).
Conclusion: The PALM is a reliable and valid instrument for measuring PD. Clinicians should consider this convenient, cost-effective clinical tool as an alternative to radiographic measurement of pelvic crest height difference. *J Orthop Sports Phys Ther 2003;33:319–325.*

Key Words: *leg length inequality, measurement, pelvic obliquity, reliability, validity*

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Leg length discrepancies (LLDs) have been associated with a variety of musculoskeletal disorders. Previous reports suggest that LLDs are linked to low back pain (LBP),[4,8,11,16,26–28] hip pain,[8] knee pain,[4,17–19,22,27] and stress fractures.[9] The association of LLDs with a number of clinical disorders has made their determination a significant part of the physical examination.[3] Numerous techniques have been described for measuring LLDs.[1,3,6,7,13,14,16,20,29] The standing antero-posterior (AP) radiograph of the pelvis is considered to be the most accurate and reliable procedure for measuring true leg length inequality.[20,21] However, radiographs are not always practical in the clinical setting. They can be expensive and they may place the patient at risk for radiation exposure.[23]

A number of clinical measurements of LLD were developed as alternatives to radiographs. Woerman et al[29] investigated the accuracy of 5 clinical techniques for assessing LLD. The authors found that the measurement from the anterior superior iliac spine (ASIS)

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to the lateral malleolus was the most accurate and precise clinical technique when compared with mini scanograms (radiographs of leg length in the supine position). Beattie and colleagues[3] reported that the supine measurement from the ASIS to the medial malleolus was valid (intraclass correlation coefficient [ICC] = 0.68) when compared with mini-scanograms in healthy subjects and patients with back pain. De Boer et al[7] investigated the intrarater reliability of a prone leg length discrepancy test in an asymptomatic population and reported a range of ICCs from 0.52 to 0.77.[7]

Each of the clinical estimates of LLD described in these studies was obtained with the patient in a non–weight-bearing position. The accuracy of non–weight-bearing methods may be limited as they fail to account for mechanical changes that occur between the foot and the pelvis in the weight-bearing position. For that reason, it has been suggested that any measurement of LLD be obtained with the subject in a standing posture.[12] Various commercially produced instruments are available for measuring LLD in weight bearing. Gross and colleagues[13] determined the reliability and validity of a weight-bearing measurement of leg length inequality using a pelvic leveling device. Rigid lifts were placed under the foot of the subject's shorter extremity until levelness of the iliac crests was achieved. The authors reported $ICC_{2,1}$ values of 0.84 for intratester reliability and 0.77 for intertester reliability. Recently, the Palpation Meter (PALM) (Performance Attainment Associates, St. Paul, MN) was developed to measure LLD in the standing position (Figure 1). The PALM is a pelvic leveling device that combines the features of a caliper and an inclinometer. Hagins and colleagues[14] investigated the reliability of the PALM for measuring iliac crest height differences in 24 asymptomatic subjects. The authors reported ICCs for interrater reliability of 0.65 in the frontal plane and 0.89 in the sagittal plane, and intrarater reliability coefficients of 0.84 (frontal plane) and 0.98 (sagittal plane).[14]

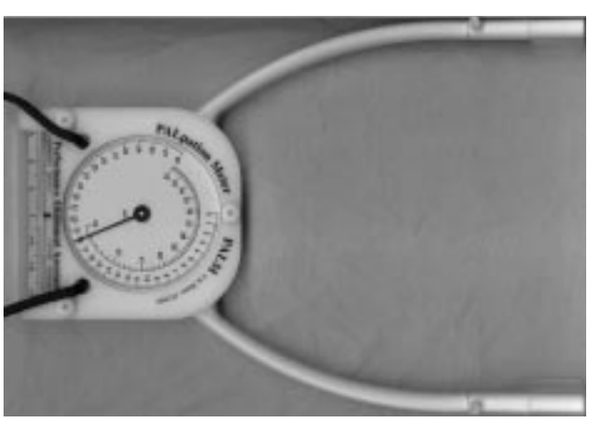

FIGURE 1. Palpation meter (PALM) device.

To our knowledge, no previous study has investigated the validity of the PALM for the measurement of pelvic crest height and leg length differences. Therefore, the primary purpose of this study was to assess the validity of the PALM for these measurements compared with the standing AP pelvis radiograph reference standard. Additionally, we wanted to determine the intrarater reliability and interrater reliability of the instrument in a patient population.

METHODS

Subjects

Thirty subjects (9 males, 21 females) ranging from 23 to 73 years of age participated in the study. Fifteen healthy subjects were recruited from the active-duty military population in San Antonio, Texas and participated in this study as the asymptomatic group. None of these subjects had a history of known lower extremity or spinal dysfunction that required medical care. A description of the asymptomatic group is shown in Table 1. A second group of 15 subjects with a clinical presentation of a LLD (identified by palpation and visualization of iliac crests in standing) and a recent history of lower extremity or spinal dysfunction were recruited by physical therapists working at Brooke Army Medical Center (BAMC). These subjects participated in the study as the patient group. A description of the patient group is shown in Table 2. Subjects were excluded from the study if they were pregnant, had lower extremity joint contractures, or had a self-reported inability to stand for longer than 20 minutes. The study was approved by the Institutional Review Board and Radiation Risk Committee at BAMC and written informed consent was obtained for all subjects prior to enrollment in the study.

TABLE 1. Characteristics of the subjects in the asymptomatic group (n = 15).

Subject	Age (y)	Sex	Height (cm)	Weight (kg)
1	38	M	191	96
2	23	M	173	72
3	28	F	144	45
4	28	F	156	58
6	24	F	161	75
8	31	M	196	104
9	32	M	180	98
10	34	M	183	91
11	29	F	155	54
13	41	F	166	69
16	57	F	162	70
17	39	F	168	57
22	55	F	162	54
24	28	F	180	92
25	28	F	163	66

TABLE 2. Characteristics of the subjects in the patient group (n = 15).

Subject	Age (y)	Sex	Height (cm)	Weight (kg)	Diagnosis
5	39	F	173	63	Low back pain
7	67	F	160	108	Low back pain
12	26	F	164	57	Low back pain
14	44	F	170	75	Low back pain
15	50	F	175	72	Trochanteric bursitis
18	53	M	169	66	Low back pain
19	56	F	152	55	Medial meniscus tear
20	31	M	163	68	Low back pain
21	57	F	152	51	Hip and knee pain
23	29	M	180	92	Low back pain
26	73	F	168	82	Hip osteoarthritis
27	57	F	163	55	Low back pain
28	42	F	163	62	Hip and knee pain
29	55	M	178	107	Hip pain
30	66	F	159	82	Low back pain

FIGURE 2. Measurement of pelvic crest height difference (PD) with the palpation meter (PALM).

PROCEDURES

All subjects were measured with the PALM and radiographed on the same portion of floor in a radiology examination room. Levelness of the floor was established with a carpenter's level. Prior to the subject's arrival, 2 pieces of tape spaced 15 cm apart were placed on the floor.[6,11,26] The tape strips marked the location on the floor where subjects would position their feet for measurements with the PALM. Each subject was first measured with the PALM, which combines the features of a caliper and an inclinometer (Figure 1). A carpenter's level was used to calibrate the PALM prior to the first data collection session. The subjects were instructed to march in place for 10 steps and then align the medial borders of their feet with the outsides of the tape strips on the floor.[14] Raters instructed the subjects to stand in a fully erect posture with no bending of the ankles, knees, hips, or spine, and to fold their arms across their chest. Standing behind the subject, the rater palpated the most superior aspect of the iliac crests with the PALM calipers and instructed the subject to take a deep breath in, exhale, and to wait to inhale again until after the measurement was taken (Figure 2).

Both raters were students in an entry-level physical therapy program. The raters practiced taking measurements with the PALM for approximately 3 weeks and collected pilot data on 20 subjects prior to initiating the study. Measurements from the PALM were read aloud by each rater to the recorder (MRP). The distance between caliper heads was read to the nearest mm, while the angle of inclination was read to the nearest half degree. The inclinometer ball is designed to move towards the side of the shorter limb. All data were recorded on a spreadsheet and the amount of pelvic crest height difference (PD) was then calculated using the PALM calculator (Figure 3). The PALM calculator is a slide ruler that converts the inclinometer and caliper values to a corresponding pelvic obliquity value (mm). All measurements taken with the PALM calculator were rounded to the nearest mm and the side of the higher pelvic crest was recorded. The first rater took 3 measurements of the subject and was immediately followed by the second rater, who repeated the procedure and took 3 additional measurements. Both raters used the standardized procedure described above and were masked to each other's results.

Radiographs were taken immediately after the 2 raters completed the measurements with the PALM. The standing AP pelvic radiograph was the reference standard used to determine the validity of the PALM.[2,6,10,11] Radiographic images were taken using the Fuji computer radiography model CR-AC 352 (FUJIFILM Medical Systems USA, Inc., Stamford, CT). A plumb line consisting of a 45-lb (20-kg) test Surflon fishing wire and an 8-oz (224-g) professional carpenter steel plumb bob was used to establish a true vertical reference for all radiographs. Subjects were instructed to wear shorts without a metal zipper to prevent obstruction of the vertical line. The standard procedure for obtaining a standing AP radiograph of the pelvis was followed.[6] A 15-cm block was placed between the subject's feet during the radiographic procedure to standardize foot placement.[6,11,26] Once subjects were positioned for the radiograph (Figure 4), they were instructed to place their arms across their chest, take a deep breath in, exhale, and to wait to inhale until after the radiograph was completed.

FIGURE 3. Palpation Meter (PALM) calculator.

A single staff radiologist performed all measurements of pelvic crest height difference as well as femoral head height differences. The plumb line was used as a pure vertical line and horizontal right angle lines were drawn from the vertical line to the superior border of the iliac crests (Figure 5).[10] The PD (defined as the difference between the iliac crest heights) and the LLD (defined as the difference between the superior aspects of the femoral heads) were measured and recorded. The side of the longer leg was also documented. A positive number was recorded for subjects with a higher left side, while a negative number was recorded for a higher right side.

Statistical Analysis

All data were analyzed using SPSS Version 10.1 statistical software (SPSS, Inc., Chicago, Illinois). Descriptive statistics were calculated for the subject characteristics, PALM, and radiographic measurements. Absolute values of PD and LLD were computed to determine the mean values of those measures, regardless of which side was higher. Unpaired *t* tests were used to determine if any differences existed between the asymptomatic group and patient group for the mean values of age, height,

FIGURE 4. Standing position for the anterior-posterior radiograph of the pelvis.

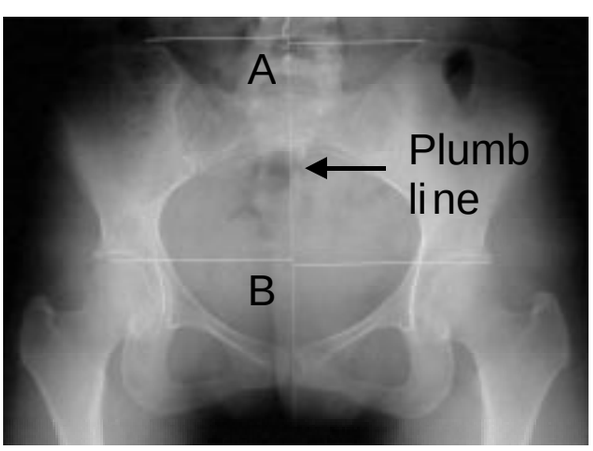

FIGURE 5. Standing anterior-posterior radiograph of the pelvis. The plumb line is the true vertical while horizontal lines are drawn at right angles to the superior aspect of the iliac crests and femoral heads. The vertical distance between the 2 lines represents the amount of pelvic crest height difference (A) or leg length (femoral head height) difference (B).

weight, PD, and LLD. Validity and reliability coefficients were determined for all subjects and also for each subject group. Validity estimates of the PALM measurements in comparison to the radiographic measurements were performed using $ICC_{2,3}$ values. Interrater reliability was analyzed using an $ICC_{2,3,}$ while intrarater reliability was calculated using $ICC_{3,3}$. The mean and standard error of measurement (SEM) was also determined for the PALM measurements.

RESULTS

The mean age, height, and weight for all subjects and the 2 groups is shown in Table 3. The mean age of the patient group was significantly greater than the mean age of the asymptomatic group ($P<.002$). The mean values for height and weight did not differ significantly between the 2 groups.

The means for the absolute values of the PALM and radiographic measurements are shown in Table 3. The mean PD measurement on all subjects was 7 mm (range, 0-21 mm) and the SEM was 1.4 mm. The mean values for the measurements of PALM PD, radiograph PD, and radiograph LLD did not differ significantly between the 2 groups ($P = .48$, .57, and .51, respectively). Sixteen of the 30 subjects in the study had a higher left pelvic crest and the number of subjects with a higher left side was equal in the 2 groups (n = 8). The ICC values for the validity, intrarater, and interrater reliability measurements are shown in Tables 4 and 5.

TABLE 3. Mean (±SD) values for subject characteristics and mean absolute values for the PALM and radiographic measurements. There was no statistically significant difference between the 2 groups except for age ($P<.002$).

	All subjects	Asymptomatic	Patients
Age (y)	42 ± 14	34 ± 10	50 ± 14
Height (cm)	167 ± 11	169 ± 14	166 ± 9
Weight (kg)	74 ± 19	73 ± 19	75 ± 20
PALM PD (mm)	7 ± 4	8 ± 5	6 ± 4
Radiograph PD (mm)	7 ± 5	8 ± 5	7 ± 4
Radiograph LLD (mm)	6 ± 4	5 ± 4	6 ± 4

Abbreviations: PALM, Palpation Meter; PD, pelvic crest height difference; LLD, leg length discrepancy (as measured by the height of the femoral heads).

TABLE 4. Reliability estimates of the Palpation Meter (PALM) using intraclass correlation coefficients (ICC) and their 95% confidence intervals.

	Rater 1	Rater 2
Intrarater reliability ($ICC_{3,3}$)		
All subjects (n = 30)	0.97 (0.93–0.99)	0.98 (0.94–0.99)
Asymptomatic (n = 15)	0.94 (0.87–0.98)	0.98 (0.96–0.99)
Patients (n = 15)	0.99 (0.97–0.99)	0.99 (0.97–0.99)
Interrater reliability ($ICC_{2,3}$)		
All subjects (n = 30)	0.88 (0.75–0.94)	
Asymptomatic (n = 15)	0.97 (0.90–0.99)	
Patients (n = 15)	0.70 (0.31–0.89)	

TABLE 5. Validity estimates (using intraclass correlation coefficients [ICC] and their 95% confidence intervals) of the Palpation Meter (PALM) compared to radiographs as the reference criterion.

	Rater 1	Rater 2
Validity of PALM for measuring PD ($ICC_{2,3}$)		
All subjects (n = 30)	0.90 (0.80–0.95)	0.92 (0.84–0.96)
Asymptomatic (n = 15)	0.94 (0.81–0.98)	0.94 (0.82–0.98)
Patients (n = 15)	0.87 (0.62–0.96)	0.90 (0.72–0.97)
Validity of PALM for measuring LLD ($ICC_{2,3}$)		
All subjects (n = 30)	0.76 (0.50–0.88)	0.78 (0.54–0.89)
Asymptomatic (n = 15)	0.89 (0.67–0.96)	0.90 (0.69–0.97)
Patients (n = 15)	0.64 (0.00–0.88)	0.64 (0.00–0.87)

Abbreviations: PD, pelvic crest height difference; LLD, leg length discrepancy (as measured by the height of the femoral heads).

DISCUSSION

Validity

Portney and Watkins[24] recommend that a standard of greater than 0.90 is perhaps needed to ensure reasonable validity for clinical measurements, but provide no data to support this recommendation. Nevertheless, given these guidelines, the findings of this study suggest that the PALM is an excellent tool for measuring differences in pelvic crest height in the clinical setting (ICC = 0.90 and 0.92). The PALM measurements of PD were less accurate (ICC = 0.76 and 0.78) when compared with the radiographic measurements of LLD. The observed discrepancy between the clinical measurement of PD using the pelvic crests as landmarks and the radiographic determination of LLD using the femoral heads as landmarks is similar to the findings of an earlier study.[13] Gross and colleagues[13] compared clinical measurements using a pelvic leveling device with radiographic analysis at the femoral heads and reported validity coefficients of 0.64 and 0.76. A simple explanation for these results is the fact that the measurements with the PALM and pelvic leveling device were a direct assessment of the amount of pelvic crest height discrepancy, but an indirect estimate of femoral head height discrepancy. Differences between iliac crest and femoral head heights in standing may be attributed to side-to-side asymmetry of the innominates, muscle imbalances, or dysfunctions of the lumbopelvic complex (eg, anterior or posterior tilts of 1 innominate).[5,16] The data suggest that pelvic tilt or innominate dysfunction may have occurred in the patient population. In particular, the correlation coefficient of the PALM PD measure to

radiographic LLD was substantially lower in the patient population than in the asymptomatic group (Table 5).

In summary, the PALM measurement of PD is excellent for determining the amount of pelvic crest height difference in the clinic, but it may be less accurate for the measurement of a true LLD, particularly in the presence of lumbopelvic dysfunction. Therefore, clinicians should consider treatment of sources of functional LLDs prior to measurement with the PALM. In the future, PALM measurements taken at the level of the greater trochanters may provide a more accurate assessment of LLDs. Further research is needed to validate the PALM measurement at the trochanters as an estimate of a true LLD.

Reliability

Portney and Watkins[24] proposed that correlation coefficients with a value of less than 0.50 indicate a poor correlation, those with a value between 0.50 and 0.75 suggest a moderate relationship, and those with values above 0.75 are indicative of good to excellent correlation. However, the authors point out that these recommendations must be based on the precision of the measured variable and how the results will be applied. The most clinically useful measurement property was the SEM. In our study, the SEM was 1.4 mm, suggesting that clinicians can be quite confident in the accuracy of the PALM for measuring PD. The intrarater reliability values for the PALM were excellent (ICC = 0.97 and 0.98) and the interrater reliability was classified as very good (ICC = 0.88).[24] These findings compare favorably with the results of Hagins and colleagues,[14] who reported ICC values of 0.84 and 0.65 for intratester and intertester reliability, respectively. The procedures used in our study were identical to those described by Hagins et al[14] with 1 significant difference: in the current study, 3 measurements were taken on each subject, while the testers in the earlier study performed just 2 trials with the PALM. It is possible that the additional trial in the current study led to higher intrarater and interrater reliability values.[24] Intrarater reliability was excellent for both subject groups, but the interrater reliability was lower in the patient population (Table 4). This finding provides further support that measurements in patient populations between clinicians may be less precise.

Clinical Implications

It is important to recognize that the PALM measurement of PD used in this study was an indirect estimate of a true LLD. The mean (±SD) amount of PD for subjects in the patient group was 6 ± 4 mm. This value falls within the 3-to-20-mm range of LLDs considered to be clinically significant for patients with back pain and lower extremity injuries (see summary in Beattie et al[3]). In contrast, mean values for LLDs in healthy populations range from 3 to 5 mm.[15,25] In the present study, there was no statistically significant difference for the mean PD between the asymptomatic and patient groups (P = .48). It is important that clinicians recognize the prevalence of LLDs and that the determination of a LLD is just 1 element of the physical examination. The decision to treat the LLD with a corrective lift should be based on findings from a comprehensive history and physical examination and from monitoring the patient's response to treatment. Based on the results of this study, it appears that the PALM can be used to determine a change in PD and provides the clinician with a tool that is useful in making decisions on modifying footwear to minimize discrepancies. However, we encourage clinicians to treat lumbopelvic dysfunctions or muscles imbalances prior to PALM measurement.

CONCLUSION

To our knowledge, this was the first study to investigate the validity of the PALM for the measurement of pelvic crest height and leg length differences. The findings of our study provide evidence that the PALM is a reliable, valid, and precise instrument for measuring differences in pelvic crest height in both healthy and patient populations. The PALM measurement of pelvic crest height difference was less accurate as an indirect estimate of true leg length discrepancy in patients. Clinicians should consider this convenient, cost-effective clinical tool as an alternative to radiographic measurement of pelvic crest inequalities.

ACKNOWLEDGMENTS

The authors are grateful to Richard A. Redd, MD and Manuel Natera for their generous help with the radiographic portion of the study.

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