Intratester and Intertester Reliability of the Palpation Meter (PALM) in Measuring Pelvic Position

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Abstract: This study determined the intra- and intertester reliability of the Palpation Meter (PALM) in measuring frontal and sagittal plane pelvic positions among asymptomatic adults during static standing. Four examiners measured 24 physical therapy students in two trials. The sagittal plane measurement was taken as the angle formed by a line connecting the ASIS and PSIS versus the horizontal. The frontal plane measurement was taken as the angle formed by a line connecting the superior border of the iliac crests versus the horizontal. Unlike previous studies, this study attempted to replicate the realities of clinical practice by using the PALM to perform measurements over clothing without applying adhesive markers for landmarks, and without controls for postural sway. Intraclass correlation coefficients suggest intratester reliability was high for both frontal (0.84) and sagittal plane measures (0.98), and intertester reliability was high for sagittal plane measures (0.89) but moderate for frontal plane measures (0.65). Standard error of the means for frontal and sagittal plane measures are presented, and clinicians are cautioned to observe the limitations of precision inherent in this device.

Key Words: Reliability, Posture, PALM

Frontal plane and sagittal plane measurements of pelvic symmetry are standard components of postural evaluations[1-9]. Frontal plane asymmetry, as measured by relative iliac crest height, is thought to generally reflect leg length discrepancy (LLD), which has been associated with hip[10-13] knee[13] and low back pain[10], and lower extremity stress fractures in runners[11]. Sagittal plane asymmetry, commonly referred to as anterior or posterior rotation of an innominate, is most often considered a sign of iliosacral dysfunction[14,15] or as a component of LLD [16-18].

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Currently, clinicians use palpation and visualization to measure frontal and sagittal plane asymmetry in the pelvis. Despite evidence that this method has poor reliability [19-24], findings of postural asymmetry in the pelvis are commonly used to identify dysfunctions and to direct treatment. As clinicians are increasingly challenged to validate their treatments using reliable measures and to provide quantification for interdisciplinary communication and third-party reimbursement, the need for a simple, quick and reliable clinical measurement tool is becoming more acute.

Several studies have examined various tools that have attempted to address the problems of reliability and quantification of pelvic asymmetries. Radiographic analysis typically has high reliability[25] but has been suggested as too expensive, as inaccessible, and as potentially harmful for routine clinical assessment[26]. Although the Iowa Anatomical Position System (IAPS), composed of an elec-

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tromechanical probe and precision potentiometers, has been shown to be highly reliable and non-invasive, it is not generally available[27]. A simple measuring stick was utilized in several studies that measured from floor to ASIS and PSIS and calculated differences utilizing trigonometry[26,28,29]; this method was highly reliable but required approximately 10 minutes to administer for a single side. Several studies have examined the use of a pelvic-leveling device that measures if the iliac crests are level[30-32]. If an unlevel posture exists, wooden shims are placed under one leg until a level reading is reached, and LLD is determined by the height of the shims. This tool is limited to use in the frontal plane and was found in one study to have unacceptable levels of reliability and validity[32]. Three studies, similar to the current study, have examined the use of caliper-inclinometer tools to measure sagittal plane pelvic positions[25,33,34]. High levels of reliability were reported, but the tools used in these studies were either handmade or modified.

A commercially produced caliper-inclinometer instrument, the Palpation Meter, referred to as the PALM*, has recently been introduced for clinical postural evaluation. The potential advantages of this instrument include uniform construction, general availability, direct palpation of bony landmarks during testing, short time period required for measurement, and direct measurement output in degrees. Reliability of this instrument has not previously been reported.

The purpose of this study was to examine the reliability of the PALM in measuring frontal and sagittal plane position of the pelvis in asymptomatic subjects. An attempt was made to design the methodology so as to mirror the realities of current clinical practice by avoiding constraints that may increase reliability but decrease generalizability such as (1) requiring subjects to disrobe adequately to palpate bony landmarks directly [25-29,31-33,35], (2) applying adhesive markers to bony landmarks [25,26,28,33,34], (3) restricting postural sway[25,33,34].

None of the previous studies examined asymmetry between innominates, considered by many orthopedic and manual therapists to be a critical measure[3-6,9]. This study measured both sides of the pelvis in the sagittal plane and examined relative innominate tilt.

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Methods

Subjects

24 subjects were selected as a sample of convenience from the Physical Therapy Program at Long Island University. Exclusion criteria included a self-reported inability to stand for 20 minutes. See Table 1 for demographic data.

Instrumentation

The PALM combines the features of a caliper and an inclinometer (Figure 1). The analog caliper dial used to determine distance between the caliper arms was not used in this study and will not be described further. The body of the PALM contains a bubble level in a semi-circular arc with one degree gradations that range from zero degrees to thirty degrees on either side of the midline. The PALM is suspended from around the examiner's neck by an adjustable cord and held with both hands directly in front of the body. The caliper arms are placed on bony landmarks, and the degree of deviation from horizontal is read from the inclinometer. Three types of removable tips are available for the ends of the caliper arms. The "O" tips, used in this study, were designed for palpation concurrent with measurement by allowing the fingertips to protrude through a flexible rubber circle and come into direct contact with the landmark.

Procedure

All subjects read and signed an informed consent. Subjects were required to wear gym shorts, T-shirts, and no shoes. Subjects were asked to march in place ten times and stand in a normal, static position with equal weight bearing on both lower extremities. The width of their stance was self-selected but the distal tip of their hallux was adjusted to be touching a floor tile border lying in the frontal plane. To prevent their arms from being in the examiner's path, subjects were asked to fold their arms across their chest. The subjects were instructed to not let the examiner push them forward or backward during the measurement procedure.

Four examiners measured all subjects in two trials in one day. Two subjects were measured in the same time

Table 1 Mean and range for subjects age (years), height (feet/inches), weight (lbs).

	Number	Age	Height	Weight
male	9	28.6 (21-43)	5'10" (5'6"-6'3")	174 (155-210)
female	15	27 (21-40)	5'5" (5'2"-5'9.5")	131 (112-174)

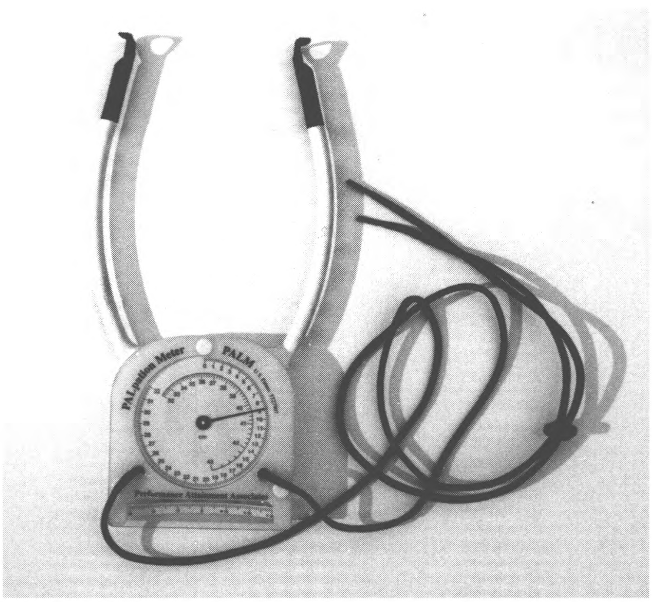

Fig. 1: Palpation Meter

period utilizing two PALMs to speed data collection. The order of examiners for each pair of subjects was randomly selected. As examiners completed a measurement, they reported the value to an assistant who documented the value. After the initial pair of examiners completed Trial 1, the second pair of examiners completed Trial 1. This process was repeated for Trial 2 immediately following the completion of Trial 1.

The same procedure for measurement was used by all examiners and was discussed in detail prior to data collection. Palpation occurred over clothing. Palpation was first performed without the PALM in order to derive an initial kinesthetic sense of the location of the landmarks and to determine how much adipose tissue existed and how much force would be needed to find a firm end feel. The examiners then placed their index or middle finger into the "O-tips" and repeated the initial palpation and determined the value from the inclinometer. The examiners then released the PALM and repeated the exact process again, providing two independent values to the recorder for averaging prior to analysis.

The order of measurement was arbitrarily chosen and standardized: frontal plane, left sagittal plane, right sagittal plane. Examiners first stood behind each subject and palpated bilaterally, moving from the lateral aspects of the abdomen to the superior border of the iliac crests. Attempts were made to move adipose tissue as necessary and to apply "firm" pressure to determine the superior border of the iliac crest. For sagittal plane measures, examiners moved to a lateral position relative to the subject and were instructed to "scoop" under the ASIS and PSIS and to move superiorly to the most outwardly projecting point for location of the landmark. In order to reduce error, attempts were made to maintain a parallel position of the PALM to the horizontal line connecting the examiner to the subject. This often required examiners to adjust their height by bending their knees, or to adjust the length of string supporting the PALM. By convention, an inferior position of the left caliper arm was assigned a negative value and an inferior position of the right caliper arm was assigned a positive value. This convention was taken into account during analysis.

Data Analysis

Measurements obtained from each subject were summarized using descriptive statistics.
Intraclass Correlation Coefficients (2,1) were computed to indicate the agreement within testers and between testers. Sagittal plane measures within individuals for Trial 1 were examined for relative differences in innominate rotation and described.

Results

A summary of descriptive statistics is presented in Table 2. Although men and women had similar mean frontal plane values, the mean values for sagittal plane were quite different, with women having approximately twice as much deviation from the horizontal as men. Mean sagittal plane values for left and right sides were 7.34 degrees and 6.93 degrees respectively. Table 3 presents information on a subset of the data (Trial 1, examiners 1 and 2), relating degree of innominate tilt (1°-7°) to percentage of subjects. A separate analysis using the same subset of data, but not shown in Table 3, determined that the left innominate was anterior 43% of the time, the right innominate was anterior 52% of the time, and 4% (1 person) had level innominates.

Intraclass Correlation Coefficients and their corresponding lower confidence intervals are presented in Table 4. Intratester reliability was high for both frontal (0.84) and sagittal (0.98) plane measures [36]. Intertester reliability was high for sagittal (0.89) plane measures but moderate for frontal (0.65) plane measures[36].

Discussion

Frontal Plane

No studies were found that utilized an inclinometer with a direct output in degrees to measure relative iliac crest heights. Studies have been performed using a pelvic leveling device that indicates the presence or absence of a horizontal position[30,31]. In these studies examiners placed shims with known values ranging from 3.2-5 mm thick under the low iliac crest until a level position is reached

Table 2 Descriptive statistics. All values in degrees. Standard Deviation (SD). Standard Error of the Mean (SEM).

Plane of Measurement	Mean	Gender Related Mean	SD	SEM	Range
Frontal	-.077†	male -0.75 female -0.8	1.45	.755	2 - (-6.5)†
Sagittal Left	7.34	male -4.8 female -8.7	5.2*	3.658*	1.5 - (-19)†
Sagittal Right	6.93	male 4.6 female 8.3			(-4)† - 22

† Negative values represent inferior position of left arm of caliper in relation to examiner
* Combined left and right sagittal values

Table 3 Degree of difference in sagittal plane measures computed by averaging values of examiner 1 and 2 during Trial 1 and comparing right and left innominates.

Difference right vs left innominate	1°	2°	3°	4°	5°	6°	7°
Percentage of subjects	56%	17%	9%	13%	4%	0%	0%

Table 4 ICC and lower confidence limits (CI) for Intra- and Intertester reliability.

Plane of Measurement	Intratester ICC	Intratester lower 95% CI	Intertester ICC	Intertester lower 95% CI
Frontal	0.84	0.70	0.65	0.47
Combined right and left sagittal	0.98	0.95	0.89	0.70

and then count the shims to determine height differences. If the average distance between femoral heads, as suggested by the literature, is 20 cm[37], approximate comparisons to these studies can be performed using trigonometry (Table 5). Each degree of relative tilt read from the PALM is equal to approximately 3.5 mm of iliac crest height difference. Consequently, from Table 2, the mean difference found in this study in iliac crest height was 2.7 mm and the SD was 5.1 mm. The mean values were almost identical to those found by Jonson and Gross[31] and Woerman et al[30] at 2.2 mm and 3.2 mm respectively. Jonson and Gross[31] found a SD of 2.6 mm and Woerman et al[30] found a SD of 3.9 mm. The variability in this study was higher than previous studies and may be explained by the methodology, which avoided constraints not normally encountered in clinical practice.

Sagittal Plane

Other studies[25,26,33,38] examining the angle formed between a line connecting the ASIS to PSIS and the horizontal have found mean values ranging from 8.35 degrees[26] to 11.3 degrees[38]. This relatively narrow range was found despite various measurement methods and the use of both men and women as subjects. These mean values correspond well to those found in this study for women but differ markedly from those found in men. It is unclear why this distinction between men and women occured.

Table 5 Translation of PALM measures in frontal plane to trigonometrically derived height difference in the iliac crests based on average of approximately 8 inches[37] between femoral heads.

Frontal Plane measure	= in cm.	= in mm.	= in inches
1°	.349	3.49	.137
2°	.698	6.98	.2748
3°	1.048	10.48	.4125
4°	1.398	13.98	.5504
5°	1.749	17.49	.6889
6°	2.102	21.02	.8268
7°	2.455	24.55	.9645

The standard deviations reported in three of the previously mentioned studies[26,33,38] for sagittal plane measurement varied between 3.4 degrees and 4.3 degrees; these values agree reasonably well with the value in this study of 5.2 degrees. The deliberate approach in this study to avoid constraints on the measurement process beyond what is likely to occur in the clinic (placing adhesive markers on landmarks, etc.) may be responsible for the greater degree of variability.

The apparent symmetry in the sagittal plane between right and left innominates in Table 2 appears to be a characteristic of summary statistics rather than a typical finding on an individual. Approximately half of the subjects were anterior on the right; the other half were anterior on the left. Importantly, the degree of asymmetry was relatively small between innominates with 96% of the subjects having less than or equal to 4 degrees of asymmetry (Table 3).

Although it is possible in clinical practice to ask patients to disrobe sufficiently to expose the ASIS and PSIS and to mark landmarks with adhesive markers, and to have them brace themselves against a thoracic or femoral support, the authors felt that constraints were both impractical and improbable in a busy clinic. Consequently, the decision was made to utilize the PALM in a manner thought to replicate probable clinical practice with this new instrument, so that the observed reliability could be authentically generalizable. The high reliability found in the sagittal plane for both intra- and intertester measures and in the frontal plane for intratester measures is remarkable given such a lack of controls.

The ICC is based on an analysis of variance that partitions variance into categories for comparison. The moderate intertester frontal plane ICC value (0.65) possibly reflects the lack of variance in the true values of frontal plane position in this asymptomatic population. It is probable that including a number of subjects with genuine leg length discrepancies would have increased the variance of the true values and provided higher ICC values for reliability. This can be appreciated by comparing the SD values between frontal (SD = 1.45) and sagittal (SD = 5.2) plane measures. Future studies should address reliability in symptomatic populations.

Although the ICC values found in this study generally suggest that measured values are consistent, the clinical use of the PALM must also be evaluated in terms of the precision of the instrument. The SEM for sagittal plane measures was approximately 3.7 degrees. Clinically, this value indicates that the examiner cannot be certain that one measurement in the sagittal plane is different from another unless that difference is more than two times the SEM or 7.4 degrees. A necessary change of 7.4 degrees is relatively large when one considers that some authors suggest that the sacro-iliac joint has a range of motion of 1-11 degrees[17,39]. We found that 96% of all right versus left innominate differences were 4 degrees or less. If a clinician measures an anterior innominate of 14 degrees prior to an intervention and measures a value of 9 degrees after an intervention, he or she cannot be certain that a change has occurred. However, if initial measurements determine that the right innominate is tilted 8 degrees and the left is tilted 0 degrees and an intervention succeeds in creating an 8 degree tilt on the left, then the clinician can state that a real change has occurred.

Similar reasoning can be followed for frontal plane measurements, but in this case the SEM is .755 degrees indicating a necessary difference of 1.5 degrees before the clinician can be certain a difference exists. A 1.5 degree difference translates to 5.2 mm height difference between iliac crests. The amount of LLD necessary for symptom generation is controversial, but a recent survey of the literature suggests that 10 mm is r equired[40]. The PALM, therefore, appears to have sufficient precision to determine, through the indirect method of iliac crest height measurement, if a significant LLD exists.

A few points regarding methodology should be mentioned. Examiners were not blinded to their own measurements as it was felt that the instrument required a direct vertical view for accurate reading of the inclinometer. At worst, this may have inflated the intratester reliability, despite attempts to direct the examiners to perform each measure as an isolated event. The intertester reliability values were not subject to this source of error and tended to fall as expected, slightly lower than the intratester values, suggesting little effect from the lack of blinding on the intratester values. Another source of error was the potential differences between the two PALMs used in this study. Again, the authors felt the value of this study was in creating a clinically realistic methodology using an instrument that is commercially produced and readily available. It was decided that any error created by multiple versions of the instrument, although potentially useful to know, should not be separated out in this study.

Conclusions

In summary, this study examined standing static pelvic posture in asymptomatic subjects using the PALM and found that intratester reliability was high for both frontal and sagittal plane measures and that intertester reliability was high for sagittal plane measures but moderate for frontal plane measures. Mean values agreed reasonably well with other studies while variability was slightly higher potentially due to a methodology that attempted to replicate the lack of constraints typically found in clinical practice. The clinical use of the PALM should always be performed with consideration given to the limitations inherent in the precision of the instrument.

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