Static innominate asymmetry and leg length discrepancy in asymptomatic collegiate athletes

C.J. Krawiec, C.R. Denegar, J. Hertel, G.F. Salvaterra, W.E. Buckley

Athletic Training Research Laboratory, Department of Kinesiology, Pennsylvania State University, USA

SUMMARY. The objectives of the study were to assess: (1) static innominate asymmetry in the sagittal plane, (2) leg length discrepancy (LLD), and (3) the relationship between static innominate rotation and LLD in asymptomatic collegiate athletes. The study was an observational study by design which took place in a University athletic training research laboratory. The participants were twenty-four male and 20 female asymptomatic intercollegiate athletes who volunteered to take part in the study. Static innominate asymmetry was assessed with a caliper/inclinometer tool and LLD was measured with a tape measure using standard clinical methods. Results showed that forty-two subjects (95%) demonstrated some degree of static innominate asymmetry. In 32 subjects (73%), the right innominate was more anteriorly rotated than the left. Nearly all subjects were determined to have unequal leg lengths with a majority, 30 subjects (68%), showing a slightly longer left leg. Weak correlations (r = 0.33 – 0.44) were identified between static innominate asymmetry and LLD. In conclusion static innominate asymmetry and LLD are common among asymptomatic collegiate athletes. This information provides clinicians with normative data of common clinical measures in a physically active population.

INTRODUCTION

Physical medicine and rehabilitation clinicians regularly examine the pelvic girdle when evaluating patients with lumbosacral and lower extremity pain and dysfunction. Faulty biomechanics of the lower extremity, pelvis, and spine are thought to contribute to musculoskeletal pathology in these regions. Alignment and motion in the pelvic region is particularly complex making clinical assessment difficult. The bony pelvis is comprised of the right and left innominate bones, which are each composed of the fused segments of the ilium, ischium and pubis. The motion between the sacrum and the innominate bones exists such that motion ipsilaterally is dependent on and relative to motion and position contralaterally (Bemis & Daniel 1995). Clinical assessment of innominate position and motion is subsequently made by describing motion or position of one side in relation to the other (Beal 1982; Erhard & Bowling 1977; Cibulka et al. 1988; Crowell et al. 1994; Bemis & Daniel 1995).

The literature contains very little documentation of the incidence of specific innominate asymmetries as determined under controlled investigation. This is in large part due to the difficulty in assessing pelvic asymmetry, arising from the low reliability of common clinical tests and the lack of a gold standard objective measure (Potter & Rothstein 1985; Cummings & Crowell 1988; Dreyfuss et al. 1994). The most common pelvic asymmetry that has been studied is that of innominate rotation in the sagittal plane (Beal 1982; Cibulka et al. 1988; Crowell et al. 1994; Bemis & Daniel 1995). However, research related to the symmetry between the innominates in healthy and symptomatic populations is limited.
Leg length discrepancy (LLD) has long been implicated as an etiological factor of pain and dysfunction throughout the lower quarter (Beal 1977; 1982; Woerman & Binder 1984; Gogia & Braatz 1986; Aspargren et al. 1987; Danbert 1988; Schuit et al. 1989; Beattie et al. 1990; Don Tigny 1990; Hoyle et al. 1991; Mannello 1992; Cummings et al. 1993; Gross et al. 1998). Pelvic asymmetry and LLD are interrelated because the innominates will typically adapt in either an anteriorly or posteriorly rotated position in order to lengthen or shorten the extremity relative to the contralateral side (Kuchera & Kuchera 1997). The extent of the relationship between LLD and pelvic asymmetry has been investigated and described in the literature (Pitkin & Pheasant 1936; Cummings et al. 1993), however, the natural occurrence of this relationship has not been previously documented in a healthy athletic population.

The purposes of our study were to assess: (1) static innominate asymmetry in the sagittal plane, (2) leg length discrepancy (LLD), and (3) the relationship between static innominate rotation and LLD in asymptomatic collegiate athletes. Innominate position asymmetry differences between males and females were also examined.

METHODS

Subjects

Twenty-four male (age = 19.7 ± 1.2 years, $h = 185.1 ± 7.3$ cm, mass = 81.4 ± 9.9 kg) and 20 female (age = 19.4 ± 1.2 years, $h = 168.6 ± 6.9$ cm, mass = 64.2 ± 6.2 kg) healthy intercollegiate athletes volunteered to participate. All subjects read and signed an informed consent form approved by the Institutional Review Board at the Pennsylvania State University. All subjects were free of self-reported pain in the lumbosacral spine, hip, groin, thigh, or buttocks that caused the subject to seek medical attention or caused interruption or significant limitation of normal physical activity or athletic participation for a period of 1 week or more during the 6 months prior to the study.

Measurement tools

Sagittal plane innominate position was measured using the Palpation Meter (PALM), a commercially available caliper—inclinometer instrument (Performance Attainment Associates, St. Paul, MN). The PALM, shown in Fig. 1, consists of an inclinometer and two caliper arms. The bubble inclinometer is a semi-circular arc with one-degree gradations that range from $0^\circ$ to $30^\circ$ on either side of the midline. The caliper tips allow for direct palpation of bony landmarks, namely the anterior superior (ASIS) and posterior superior (PSIS) iliac spines, and measurement of the sagittal plane rotation of the innominate bone.

A standard clinical tape measure with 1 mm units was utilized to measure leg length. A large paper clip was fixed to the tape in a manner that allowed the tape to slide through the paper clip and the tip of the free arm of the paper clip was bent over the edge of the tape, creating a pointer in line with the increments on the tape (see Fig. 2). The proximal end of the tape was placed at the ASIS. The distal measurement was made utilizing the paper clip. The clip was slid up the tape until the bent tip butted up beneath the distal end of the medial or lateral malleoli, and the measurement was read where the adjacent arm crossed the tape.

Procedures

One investigator (CJK) made all palpations for measurement placements of leg length and innominate

![Fig. 1—Measurement of static innominate rotation using the PALM. Caliper ends are place on the ipsilateral ASIS and PSIS.](image1)

![Fig. 2—A large paper clip was fixed to the tape measure in a manner that allowed the tape to slide through the paper clip and the tip of the free arm of the paper clip was bent over the edge of the tape, creating a pointer in line with the increments on the tape.](image2)
position, while an assistant recorded the numerical measurements, thus blinding the palpating investigator from the results. Measurement of static innominate asymmetry was made in standing, with the subject’s anterior thigh snug against a treatment table and looking at a fixed point on the wall to reduce postural sway. Initial palpation of the ASIS was made by bringing the thumbs from inferior to superior, coming underneath the solid ledge created by the inferior slope of the ASIS and then to the most prominent protrusion of the ASIS, where an adhesive marker was placed. The tester then palpated the PSIS by tracing the iliac crest posteriorly to the most posterior part and moving the thumbs superiority and laterally from the sacrum to the ledge created by the PSIS. After butting the thumbs underneath the PSIS, the tester moved his thumb superiority to the most prominent protrusion of the PSIS, and placed an adhesive marker over it. To derive a kinesthetic sense of the location of the landmarks, the tester then palpated the ipsilateral ASIS and PSIS prominences as before, except this time with the index fingers. Using the caliper tips of the PALM, the investigator repeated the initial palpation, established the position on the ipsilateral ASIS and PSIS, and stabilized the PALM (see Fig. 1). An assistant then read the inclinometer and recorded the measurement in degrees. The investigator positioning the PALM was not informed of the measurement recordings. Positive angular measurements indicated anterior innominate rotation, while negative values indicated posterior rotation. Three measurements were made on both the right and left innominates.

Leg length difference was measured with subjects lying supine on a plinth. Leg length was measured by two methods; by measuring from the ASIS to the medial malleolus (MM) and from the ASIS to the lateral malleolus (LM) (Hoppenfeld 1976). The tip of the tape measure was held at the ASIS. The tape coursed across the lower extremity to the respective malleolus where the measurement was made by butting the paper clip tip against the distal edge of the malleolus. The assistant lifted the tape, read, and recorded the measurement without informing the tester who laid the tape of the results. Three measurements of each measurement were made on both the right and left limbs.

Statistical analysis

Intraclass correlation coefficients (ICC) and standard errors of measurement (SEM) were calculated to estimate the intratester reliability and precision of measurement for the static innominate rotation and LLD measurements.

Means of the three innominate rotation measurements were calculated for the right and left sides. Positive angular measurements indicated anterior innominate rotation, while negative values indicated posterior rotation. The difference in innominate rotation between the right and left sides was calculated by subtracting the left side mean from the right side mean. Descriptive statistics and frequency distributions were calculated.

Means were calculated for the left and right leg length measurements. LLD was calculated from the means of the three repeated measures by subtracting the value for the left leg from the value for the right leg. A positive value indicated that the right leg was longer, and a negative value indicated that the left leg was shorter. Descriptive statistics and frequency distributions were calculated for the LLD measures.

Pearson product moment correlations were calculated between: (1) MM and LM LLD measures, (2) MM LLD and innominate rotation measures, and (3) LM LLD and innominate rotation measures. Independent t-test were conducted to assess gender differences in each measure. The alpha level was set at $P < 0.05$ for the statistical comparisons. All data were analysed using the SPSS 8.0 statistical package (SPSS Inc., Chicago, IL).

RESULTS

ICCs for the innominate rotation measures were 0.99 and SEMs ranged from 0.44° to 0.47°. ICCs for the LLD measures were 0.99 and SEMs ranged from 0.14 to 0.22cm.

Forty-two subjects (95%) had some degree of innominate position asymmetry and in 32 subjects (73%) the right innominate was in a more anteriorly rotated position (1.9° ± 2.6°). The distribution of innominate rotation asymmetry is illustrated in Fig. 3. A majority ($n = 24$, 54.5%) of subjects...
presented with innominate position differences greater than 2°, irrespective of direction. Across our sample, the right innominate was in a more anteriorly rotated position than the left by a mean of 1.91°. Only two subjects were measured as having no difference between the sagittal plane rotation of the right and left innominates.

Forty-two subjects (95%) exhibited a LLD with 30 subjects (68%) demonstrating a longer left leg. The mean MMLLD assessment was 0.22 ± 0.73 cm. The mean LM LLD was –0.14 ± 0.62 cm. The frequency distribution of the LLD measurements are illustrated in Figs. 4 and 5. There was a high frequency of measurable LLD across our sample with only two subjects showing equal leg lengths by the LM method and no subjects showing equal leg lengths by the MM method. The measured differences were small as most subjects had less than 1 cm difference. Only six subjects (13.7%) displayed a LLD greater than 1 cm by the MM method, and only five subjects (11.3%) displayed a LLD greater than 1 cm by the LM method.

A relatively strong correlation was found between the MM and LM LLD measures (r = 0.75, P < 0.01). Weak negative correlations were found between the measures of innominate rotation and MM LLD (r = 0.33, P = 0.026) and LM LLD (r = 0.44, P = 0.003). A non-significant (t = 1.09, P = 0.28) difference in innominate rotation was found between males and females with females demonstrating a slightly greater (0.9°) right anterior innominate rotation.

DISCUSSION

The primary findings of this investigation were: (1) asymmetry of the innominate bones was demonstrated frequently with the majority of subjects demonstrating a more anteriorly rotated right innominate, (2) LLD was also frequently observed with a longer left leg being more common, and (3) there were relatively weak correlations between the magnitude of LLD and innominate rotation asymmetry.

Innominate rotation asymmetry

The ICCs for our measures of innominate position are higher than other studies utilizing a caliper and inclinometer measurement tool (Walker et al. 1987; Cibulka et al. 1988; Crowell et al. 1994; Gilliam et al. 1994; Hagins et al. 1998). Hagins et al. (1998) previously investigated the measurement properties of the PALM and reported an ICC of 0.98 and an SEM of 3.66 cm, which was much higher than our mean SEM of 0.45 cm. Our estimates of reliability and precision of measurement lend credibility to our findings. Using a 95% confidence interval, measures of innominate position would be ±0.91° from the true measurement. With confidence that measurement could repeatedly be made within 1° of precision, the 24 subjects (54.5%) showing an innominate rotation difference of greater than 2° and the 32 subjects (73%) showing a difference of at least 1° can be considered to be recorded with great accuracy. Thus we conclude that a substantial proportion of our sample of healthy intercollegiate athletes presented with a quantifiable sagittal plane innominate rotation asymmetry.

Barakatt et al. (1996) previously reported a mean innominate rotation difference of –2.3° ± 1.7° in their study of gymnasts. Their results indicated the right
innominate to be in a more posteriorly rotated position than the left. This finding is similar to our results in magnitude but not direction. The unique physical characteristics of gymnasts, who may tend to possess greater overall range of motion than other athletes, may affect the comparisons that can be made between these two studies. Hagins et al. (1998) reported that 43% of their subjects showed a difference in innominate position of greater than 2°, irrespective of direction. They also reported that 52% of their subjects were in a more anteriorly rotated position on the right and 43% were in a more anteriorly rotated position on the left. (Hagins et al. 1998) Variations in palpation methods or control of subject postural sway may account for the differences in the results between their study and our current study.

The ranges of innominate rotation measurements we identified were quite small. The largest innominate rotation asymmetry we recorded was 7°. The clinical relevance of asymmetries of these magnitudes remains unknown. Currently, the significance of magnitude of asymmetry is left to the discretion of clinicians and must be placed in the context of the entire presentation of signs and symptoms of individual patients.

**Leg length discrepancy**

A tape measure was used to detect LLD in this study because of the common use in clinical settings as well as previous reports of validity and reliability for these methods (Woerman & Binder 1984; Gogia & Braatz 1986; Beattie et al. 1990; Hoyle et al. 1991; Mannello 1992). The high intratester reliability (ICC = 0.99) found in our study was consistent with or higher than previous studies. Using a 95% confidence interval, measures would be ±0.36 cm for the MM method and ±0.31 cm for the LM method. Even though the SEMs we reported were small, error was still an issue. In 11 out of 44 subjects (25%), the estimated long leg was different between the MM and LM methods. Potential sources of error for both methods include palpation variations, tissue contour and deformation, and body positioning.

The LM method may be considered the better of the two methods based on its slightly greater precision of measurement although firm conclusions are difficult to draw. Differences between the two measures support previous research that shows the LM method to be more accurate and precise than the MM method (Woerman & Binder 1984). This may be due factors such as having a more direct line of measurement with less torsion to the tape measure, and the lateral malleolus landmark being more prominent.

The high frequency of occurrence of LLD we found was consistent with previous findings (Beal 1977; Mannello 1992). By the MM method, 30 subjects (68%) demonstrated a longer left leg. The LM measurements were more centrally distributed than the MM measurements with 24 subjects (54.5%) exhibiting a longer left leg. Our findings agree with Beal’s report of the more frequent left long leg (Beal, 1977). The more frequent finding of a long left leg is interesting because of the possible link to innominate position asymmetry. It has been theorized and demonstrated in research that the innominates will typically adapt to an anteriorly or posteriorly rotated position in order to lengthen or shorten one extremity relative to the other (Cummings et al. 1993; Kuchera & Kuchera 1997).

**Leg length discrepancy and innominate rotation asymmetry**

Our results demonstrate a frequent occurrence of both anterior innominate rotation asymmetry and LLD, but failed to demonstrate a strong correlation between these two measures. There is evidence of a weak association between the findings of a longer left leg and an anteriorly rotated innominate on the right side, however, the variation in LLD measures accounts for less than 19% of the variation seen in innominate rotation asymmetry ($r = -0.33$ to $-0.44$).

The bivariate correlations between MM LLD and innominate rotation, and LM LLD and innominate rotation were negative correlations. At first glance, this might be interpreted to mean that as LLD increases innominate position asymmetry decreases. This would not seem sensible because it is theorized that as LLD increases the amount of asymmetry between innominates also increases. However when interpreting our results, the negative sign in the correlation coefficient can be attributed to our subtracting the measurements of the left side from the measurements of the right side. If the equation were changed to subtracting the right side measures from the left side, the correlation would then be positive.

As the amount of LLD increases, one would expect that innominate position asymmetry would also increase due to the antagonistic mechanical movement of the two innominates. The innominate on the side opposite to the longer leg would anteriorly rotate in order to lengthen the short leg, and the long leg innominate would rotate posteriorly to shorten the long leg. The findings across our sample support this association. There was a greater frequency of a more anteriorly rotated right innominate and a majority of subjects were estimated to have a longer left leg. These findings are consistent with those of Pitkin and Pheasant (1936) and Cummings et al. (1993).

Previously it was mentioned that the innominate on the contralateral side to the longer leg would tend...
to be found in a more anteriorly rotated position in order to lengthen the short leg. This seems to be mechanically reasonable, however, this is a phenomenon best seen in standing, weight-bearing positions. Dispute arises when, as in our study, leg length is measured in a supine, non-weight bearing position. In supine positions, an anteriorly rotated innominate is associated with the longer leg, and a posterior rotated innominate is associated with the shorter leg (Bemis & Daniel 1987). Any correlation between supine measures of leg length, particularly clinical measures utilizing pelvic landmarks, and standing measures of innominate position may be called into question. The supine measure of leg length was used in our study, despite this inevitable conflict, because we felt that this method provided the most commonly used clinical method of measuring leg length without expensive radiographic imaging techniques. It is difficult to make an accurate assessment of leg length while standing, because any weight bearing measure could be considered a measure of functional leg length. The muscular action, joint compression, and overall compensation that occur in standing are factors that are troublesome when trying to uncover the impact of true LLD on innominate asymmetry.

The presence of LLD and innominate asymmetry may also be a compensatory result of repetitive motor patterns related to limb dominance. Our subjects were predominantly right hand dominant and the right side innominate was most often in an anteriorly rotated position along with a higher frequency of a longer left leg. LLD may also be related to side dominance and motor control as a result of developmental patterns. Further research is needed to investigate this possibility.

CONCLUSIONS

Our results demonstrated the frequent incidence of innominate rotation and LLD in asymptomatic intercollegiate athletes, however there were weak statistical correlations between measures of LLD and innominate rotation. Subjects most frequently demonstrated greater anterior innominate rotation of the right side and a longer left leg. Innominate rotations and LLD appear to occur normally in asymptomatic athletes without history of lumbar-sacral symptoms. Thus, a physical examination finding of static asymmetry must be put in context of a complete examination including a thorough history and tests of joint mobility and stability. Further research is needed to explore objective methods of quantifying pelvic asymmetries among healthy and symptomatic populations and the relationships between LLD, innominate rotation, and lower quarter dysfunction.

References


© 2003 Elsevier Science Ltd. All rights reserved. Manual Therapy (2003) 8(4), 207–213