Posterior Inferior Ilium Compensation Mechanism on the Longer Limb side, and the Resultant Kinetic Chain Pathway to Injury: A Case Study.

Clifton Bradeley Clinical MSK Podiatrist.

Understanding the effects of leg length inequality (LLI) on the kinetic chain is a challenge for many practitioners. This case study highlights one of the compensation mechanisms - posterior inferior ilium (PI ilium) at pelvic level on the longer limb side. The case study describes the knock-on effect from a PI ilium within the kinetic chain and proposes a **new** clinical protocol using a Digital Pelvic Inclinometer (DPI) to establish the difference between a bony and apparent LLI. An orthotic prescription was used to un-compensate the pelvis and reduce the pelvic torsion created by the PI ilium. Written consent was obtained from the patient to use his data for this paper.

Keywords: leg length inequality, PI ilium [31], pelvic torsion, Digital Pelvic Inclinometer, passenger unit, lower back pain, piriformis sciatica, vestibular balance.

Despite the well-documented effects of leg length inequality (LLI) on the musculoskeletal (MSK) system creating repetitive injury, many practitioners avoid using raise therapy as a form of correction. This may be because the effects of MSK compensation on the kinetic chain are complex, and the relationships between each segment are still poorly understood, especially at pelvic level.

LLI has been reported to cause a wide range of joint complex and soft tissue repetitive injuries including those in the lower limb, knee[15] hip[16] lower back[23,32] neck and shoulder etc.[1,2,3,5,7]

CASE PRESENTATION

A 31-year-old male amateur middle distance runner and factory worker (height: 175 cm, weight: 76 kg, body mass index 24.8 kg/m^2) presented with chronic lower back pain, left-side activity-induced piriformis sciatica, left Achilles tendinosis and right

1 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

musculotendinous junction calf strains. The injured runner presented to a sports injury clinic and underwent a biomechanical assessment.

Clinical history

During the history the patient reported feeling asymmetrical, suspecting he had a leg length difference. He exposed his shoes, which had heavy posterior wear at the rearfoot of the left shoe and excessive forefoot wear on the right shoe. He commented on preferring to cut into the right side during activities like hockey or football when he was younger and that he ‘edged’ better to the right side when skiing. One of his current concerns was that he felt unstable running the normal direction (anticlockwise) around the bends of an outdoor running track and developed right calf muscle cramping towards the end of a training session. The subject reported that his back pain had been present since he was a young man and was exacerbated by standing for long periods of time or flexing forwards to approximately a 30° angle e.g. gardening. His back pain had started to become a problem during running, along with left-sided piriformis sciatica and Achilles tendinosis, which had been diagnosed by his physiotherapist. He had been given calf stretches and gluteus medius strengthening exercises to stabilize his pelvis. Our subject reported that these had been unsuccessful, providing no benefit. To this end we carried out a common strength test for gluteus medius with the subject lying sideways on the couch, hip abducted with slight extension and external rotation. With the knee maintained in extension, pressure was applied against the leg, near the ankle in the direction of adduction and slight flexion. The subject could not resist the moderate pressure, although it should be noted that reliability for this test has been previously reported to be low.[34]

Clinical examination

In addition to the static and dynamic functional trials looking at pelvic mechanics, which are described fully below, the subject elicited the following clinical signs during the assessment:

- 15 mm difference between the right and left medial malleolus to sub-anterior superior iliac spines (ASIS) measurement – left longer (supine couch measurement), despite only a moderate LLI observed during quiet standing.
- Increased internal hip rotation on the left with patient lying flat supine on the couch.
- Standing left foot increased pronation and right lateral forefoot pressure reported by subject.
- Left limb increased knee flexion, heel-to-toe strike and delayed heel lift at 4km/hr on the treadmill.
- Right rapid knee extension, mid-foot strike and early heel lift on the treadmill.
- Left posterior innominate rotation i.e. PI ilium[31] at midstance using motion palpation on the treadmill.
- A consistently higher left posterior superior iliac spine

2 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

(PSIS) at left midstance, compared to the right PSIS during motion palpation of the sacral base on the treadmill.
- Lack of sinusoidal motion pattern[30] at head level when observed at 4 km/hr on the treadmill.

Pelvic assessment

As part of the biomechanical assessment the subject underwent static and dynamic functional trials on the pelvis using a Digital Pelvic Inclinometer (DPI).

There are other reliable methods of measuring pelvic position, however a mathematic formula is required.[17] The DPI method offers an instant reading for use in a busy clinical setting.

Before the trials, the subject was checked for normal sacroiliac (SI) joint function using the Gillett's test, standing forward flexion test, and sitting Piedallu's test. Although these tests are not considered to be conclusive[33], no lesions or limitations were noted at the SI joint.

DPI technique: The practitioner places the index finger and thumb of each hand on each finger grip at the end of the DPI arms. With each index finger slightly prominent ready for concurrent palpation of the PSIS and ASIS, the practitioner positions the DPI on the side of the innominate bone to be measured. The practitioner then reads off the degree of inclination from the liquid crystal display (LCD) on the DPI (Fig 1).

Fig 1. Measurement of the left innominate bone inclination from the PSIS to ASIS, using a digital pelvic inclinometer.

The difference in inclination between each innominate establishes the degree of pelvic torsion. When using this technique a measurement is considered to be +ve if the PSIS is higher than the ASIS using a flat horizontal reference plane, whilst a measurement is considered to be -ve if the ASIS is higher than the PSIS using the same flat horizontal reference plane. Although there are various references in the literature reporting mean innominate inclination and pelvic torsion, there is no information regarding what constitutes normal ranges.[12,18,21,24] In this study a range of 8 to 10° +ve was used as the target normal range, based on previous clinical out-comes achieved after orthotic interventions with a heel raise under the shorter limb following reduction of pelvic torsion.

It has also been noted previously that this measurement can increase in athletes with stronger musculature, suggesting that pelvic morphology may not be the only

3 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

influence on innominate orientation and pelvic torsion.[24]

In this case study the first measurement taken was a base measurement. This was the degree of inclination of both innominates on arrival to the clinic before any trials or tests took place. The second and third measurements were static and dynamic functional trials respectively, to establish how the pelvis behaves when the height is increased under the hip joint by using a 9 mm raise. The following clinical protocol was used to assess the subject's innominate behaviour. The patient was wearing shorts for easy access to the pelvis:

1. A static base measurement of the subject's innominate orientation was taken during quiet standing unshod on a flat reference surface with the feet at shoulder width apart. The patient was asked to stand relaxed looking forward, with the arms crossed over the chest. The practitioner recorded the right and left innominate inclination measurement between the PSIS and ASIS using a DPI.

Fig 2. A 9 mm depth EVA foot raise platform was used to raise each side of the pelvis during static functional trials.

2. The subject was then asked to walk on the treadmill set at 4km/hr for one-minute unshod before the next measurement was taken. This was done to allow the subjects pelvis to make adjustments necessary for gait efficiency. The subject was then again asked to stand unshod on the flat reference surface, with feet at shoulder width apart.

   On this occasion the subject was asked to stand with his right foot on a 9 mm high density ethylene vinyl acetate (EVA) board (Fig 2). Once settled the subject was asked to flex forward and touch his toes three times whilst maintaining straight legs. This allows the sacrum to move against the ilia. Then once upright again the practitioner recorded the right and left innominate inclination measurement between the PSIS and ASIS using a DPI.

   This protocol was then repeated with the subject standing with his left foot on the 9 mm EVA board. The practitioner recorded the right and left innominate inclination measurement between the PSIS and ASIS using a DPI.

3. The subject was again asked to walk on a treadmill set at 4km/hr unshod for one minute before the next

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

measurement was taken. The subject was then asked to put his training shoes on.

A full-length graduated foot raise (9 mm depth at the heel and 3 mm depth at the forefoot) was placed in the subject's right training shoe (Fig 3).

The subject was again asked to walk on a treadmill set at 4km/hr for one minute. After one minute the treadmill was stopped and the subject was asked to remain still whilst standing. The practitioner recorded the right and left innominate inclination measurement between the PSIS and ASIS using a DPI.

This protocol was then repeated but this time the graduated foot raise was placed in the left shoe. After one minute walking on the treadmill at the same speed, the practitioner recorded the right and left innominate inclination measurement between the PSIS and ASIS using a DPI.

Fig 3. A 9 mm depth EVA in-shoe raise (3mm at the forefoot, 9 mm at the rearfoot) was used to raise each side of the pelvis during dynamic functional trials.

The results of the base readings and functional trials are as follows:

1. **Base measurement:**

Left = 1° +ve, Right = 10° +ve

Pelvic torsion = 9°

2. **Static functional trial with 12mm high density EVA foot platform (subject unshod):**

With platform under the right foot:

Left = 9° +ve, Right = 11° +ve

Pelvic torsion = 2°

With platform under the left foot:
Left = 1° -ve, Right = 10° +ve

Pelvic torsion = 11°

3. **Dynamic functional trial with graduated in-shoe foot raise (9mm depth at the heel and 3mm depth at the forefoot):**

With graduated foot raise under the right foot:

Left = 10° +ve, Right = 12° +ve

Pelvic torsion = 2°

With graduated foot raise under the left foot:

Left = 2° -ve, Right = 10° +ve

Pelvic torsion = 12°

Therefore, the range of innominate inclination values on the right was:

Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

10° +ve, 11° +ve, 10° +ve, 12° +ve, 10° +ve

= a range of 2°

Therefore, the range of innominate inclination values on the left was:

1° +ve, 9° +ve, 1° -ve, 10° +ve,

2°-ve

= a range of 12°

This is a 10° > (L = 12° range minus R = 2° range) range of inclination at the left innominate compared to the right.

DISCUSSION

Without the use of sophisticated scanning or X-ray equipment, the MSK professions normally carry out a series of simple tests when assessing LLI. These include observation of the patient standing or in gait, iliac crest or sacral base palpation, supine couch measurement (tape measuring from the medial malleolus to ASIS) and sometimes muscle and sacroiliac (SI) joint function tests.[33] These techniques are often reported to be unreliable, which can lead to confusion.[4,7,13,15] Traditionally X-ray investigation for LLI is considered to be impractical and costly and is undesirable as it exposes the patient to the adverse effects of radiation. Moreover, the pelvis is a constantly adapting dynamic structure, which the static nature of X-ray cannot capture. Therefore, other methods are more often than not preferred clinically, despite their lesser accuracy.[8] Moreover, whilst such techniques may identify LLI, they do not discover its true origin i.e. whether the LLI is real bony (R-LLI), apparent (A-LLI) or functional (F-LLI). At present there is no reliable clinically accepted methodology for differentiating between the three and conclusions are therefore often purely speculative. However, the effects of LLI on the pelvis and multisegmental MSK system are numerous and potentially destructive and many clinicians believe such effects may be implicated in every stance and gait-related repetitive injury.[5,9,15]

In this case study, using traditional techniques including using a tape measure, the patient demonstrated the signs of a longer left leg. However, supine couch tape measurements can be unreliable and are not a true measure of leg length at all, but a measure from a fixed bony structure at the ankle to a constantly changing mobile structure at the pelvis.[6,7,8] Therefore, a DPI was used to quantify the behaviour of the pelvis in tandem with raises placed under each limb during the functional trials above. By increasing the height of the longer left limb with foot-raise platforms it was possible to increase pelvic tilt (in the frontal plane) up to the left whilst simultaneously increasing pelvic torsion (in the sagittal plane). When foot raise platform under the shorter limb was used it was possible to eliminate the pelvic tilt and pelvic torsion, thereby returning the pelvis back to symmetry in these planes. This test was also repeatable and eliciting the same results with each successful trial. These trials demonstrated that compensatory pelvic adaptions associated with R-LLI could be exaggerated and then

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

eliminated by using foot-raised platforms forms during a clinical setting. Previous studies have found similar results suggesting that measuring pelvic torsion may be a useful clinical tool for practitioners to differentiate between R-LLI and other types.[6,9,11,22] Therefore, if compensatory pelvic tilt and pelvic torsion can be eliminated during functional trials, thereby returning the pelvic back to normal symmetrical function, as demonstrated in gait, then the patient could potentially be sent away for a few days with a small raise under the shorter limb. Moreover, if this could be repeated at a later review date and the patient reports a cessation in symptoms with a simple foot-raise platform, then no further treatment on the pelvis or spine may be necessary. Alternatively, if the pelvic tilt, pelvic torsion and gait did not respond to a foot raise platform under the shorter leg during the clinical trials, and if this was repeatable then the patient should not be provided with a foot raise platform because the leg length and pelvic asymmetry observed by the practitioner could be caused by an A-LLI and pelvic subluxation, not compensatory adaption as with a R-LLI.

Levine and Whittle showed that there is a potentially large range of anterior to posterior and vice versa range of pelvic inclinations.[18] This case study simply demonstrates that using a DPI can be useful in assessing the behaviour of the pelvis and how the body can adapt this range to compensate for LLI. Other studies have reported that using external pelvic measuring apparatus over the use of X-ray may perhaps be more reliable in reporting changes in pelvic angle.[19]

In this case study the range of innominate inclination on the right between the ASIS and PSIS was 2° and on the left 12°. The 10° difference on the left demonstrates the range and adaptability of one side of the pelvis to compensate for LLI. Other studies have found similar ranges and compensatory motion patterns. Levine and Whittle[18] found a mean of 11.3° and a standard deviation of 4.3° across their study of female subjects, Kroll et al reported between 3-22° in his study of 54 normal subjects[25,] and Gilliam et al reported a range of 4-21° in a cohort of 15 back pain sufferers.[26] In a cadaver study Preece et al[24] found a range of values of 0-23° with a mean of 13° and a standard deviation of 5° but could not conclude whether these ranges were determined by muscular and ligamentous forces or pelvic morphology.

It is the experience of our clinic, that unlike in this R-LLI case study, in a purely A-LLI the data revealed by the DPI is totally random, and follows no pattern. The pelvic behaviour is less predictable and would change as a chiropractor or osteopath carried out corrective work. The associated pelvic torsion therefore, would be a subluxation in origin and not compensatory, and would be eliminated if the treatment sessions were successful. On the other hand, in R-LLI, with a more significantly dose related correction i.e. 2 mm incremental foot raise

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

platforms (increasing the height until compensatory pelvic torsion was eliminated) the sacral base and iliac crests would be returned to level in the frontal plane, once the desired height correction had been achieved. Hanada et al concluded that the "iliac crest palpation and book correction (ICPBC)" method was highly reliable and moderately valid.[9] This technique using a DPI could be used to establish the real bony difference without the need for expensive CT scanning or X-ray, which carries associated risks.

Compensatory pelvic torsion can create a 'domino effect' of injuries as adaptions and dysfunctional motion patterns develop, as seen in this case study. Walsh et al. demonstrated that the pelvic obliquity was a common compensation mechanism in stance up to 2.2 cm, however increased hip, knee and ankle dorsiflexion and pelvic compensation occurred with larger induced LLI during gait.[15] This study also describes increased knee extension and ankle plantarflexion on the shorter limb side, suggesting a wide range of MSK adaptations in the presence of LLI. Each adaption potentially increases the risk of repetitive injury.[35]

This patient history can give vital clues regarding the presence of LLI and its origin. The symptoms of edging better to the right during skiing, difficulty running anticlockwise around a running track and a sense of cutting away better to the right during sports like hockey and football seen in this patient are all signs of a longer left leg. The patients shoe wear patterns were indicative of asymmetry in the cantilever ability of the lower limb to adapt in an attempt to maintain sinusoidal motion patterns at pelvic, centre of mass (CoM) and head level.

In this case study the patient in this study arrived at the clinic with a PI ilium compensation pattern. The left innominate went further into a PI ilium orientation during both the static and dynamic functional trials when a raise was placed under the left foot increasing pelvic torsion. Moreover, the left sided PI ilium and pelvic torsion significantly reduced during the static and dynamic trials when the right foot was raised revealing a R-LLI.[6,9,11]

Understanding the origin and behaviour of a pelvic torsion can often be very difficult to achieve clinically with or without radiographic equipment.[23] This is primarily because pelvic torsion is often present in both R-LLI and A-LLI, one being due to compensation and the other a subluxation at SI joint level respectively. To further complicate what the clinician observes these two types of LLI create some degree of F-LLI (increased knee flexion and delayed heel lift on the longer limb side etc.), all three often coexisting during gait. In this situation the majority factor would need to be addressed i.e. if the R-LLI created the greatest risk of injury, then use a heel and forefoot raise. If the A-LLI created the greatest risk of injury, then the subluxation would need to be dealt with and a foot raise would not be

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appropriate. It seems clear that the main difficulty is that practitioners traditionally do not have the clinical protocols to differentiate between the two different types of pelvic torsion and studies have revealed a low level of inter-rater reliability in assessment of the SI joint.[13]

Pelvic torsion can present as either an anterior superior innominate (AS ilium) or posterior inferior innominate (PI ilium), which can artificially raise or lower the pelvis respectively.[21,22] An AS ilium occurs > 10° +ve and a PI ilium occurs < 8° +ve (assuming normal innominate inclination of 8 to 10° +ve).[12]

An AS ilium orientation often occurs on the shorter limb side. Whilst a PI ilium orientation often occurs on the longer limb side [6,9,11,21,22.] There are variations to this pattern however depending on the position of the CoM to the body's sagittal midline, suggesting that increased forces in the acetabulum may influence innominate motion.

This author has previously observed that pelvic torsion is often determined by body type: a PI ilium is more likely to occur with an ectomorphic body type, whilst an AS ilium is more likely to occur in mesomorphs. It is rare to find both an AS ilium and PI ilium in co-existence because body types do not co-exist.

This means that the truly (real bony) shorter limb can present clinically as being the longer when observed in stance and gait because an AS ilium raises and externally rotates the acetabulum on the ipsilateral side. This situation highlights the importance of using a DPI to identify the AS ilium orientation avoiding the incorrect placement of a heel raise.

Likewise the truly (real bony) longer limb can present clinically as being the shorter when observed in stance and gait because a PI ilium lowers and internally rotates the acetabulum on ipsilateral side. Hence the subject in this study demonstrated increased internal leg rotation and increased foot pronation on the longer left side. The patient also had piriformis sciatica on the longer limb side because gluteus medius became dysfunctal in the PI ilium orientation. Piriformis becomes hypertonic in the presence of a weakened gluteus medius. This was contrary to Rothbart's study looking at the relationship between functional LLI and abnormal pronation. However, Rothbart made no reference to other types of LLI in his subject group, had no radiographic evidence of what he claimed and did not measured sagittal plane innominate inclination.[14]

The 15 mm of LLI measured supine on the couch from the medial malleolus to sub-ASIS was a misnomer because of the PI ilium orientation, which non-weight bearing artificially increases the height of the ASIS due to the backwards rotation of the whole innominate.

Note: It is worth mentioning at this point that a PI ilium will artificially increase leg length with a patient

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

lying supine on a couch, but lower the whole innominate in stance and gait. Moreover, an AS ilium will artificially decrease leg length with a patient supine on a couch, but raise the whole innominate in stance and gait.[13] This highlights the confusion amongst practitioners and explains why R-LLI and A-LLI are misunderstood and why an alternative LLI assessment protocol is required.

Studies have also shown that increasing anterior pelvic tilt can increase lumbar lordosis, whilst increased posterior pelvic tilt can decrease lumbar lordosis thereby contributing to the complexity of pelvic mechanics.[18, 21]

Clinical presentation of a PI ilium

A PI ilium mechanism occurs in order to lower the pelvis on the longer limb side. It can only occur if there is sufficient motion available at the SI joint and there is no resistance from surrounding muscles and ligaments. As very few individuals have sufficient strength to resist a PI ilium compensation, it is one of the most common and effective mechanisms used within the kinetic chain to stabilise the CoM.

Although the PI ilium mechanism is effective in lowering the longer limb side pelvis, we hypothesise that it may also create a *'domino effect'* of MSK changes and therefore lead to repetitive injury, which can become chronic until the mechanism is identified and reversed.

In reference terms, an innominate is considered to be in a PI ilium orientation if the angle is recorded to be < 8° +ve (therefore a PI ilium can be both +ve and –ve, e.g. 3° +ve, 2° -ve), whilst an innominate is considered to be in an AS ilium orientation if the angle is recorded to be > 10° +ve (therefore an AS ilium can only be +ve, e.g. 17° +ve).

PI ilium mechanics

When an innominate bone has the range to move in relation to the sacrum a PI ilium orientation can be created if the forces acting on the femoral axis (A^1) and sacral-2 axis (A^2) are sufficient enough to move the innominate bone posteriorly relative to the sacrum (Fig 4.). Generally the PI ilium occurs on the side of the pelvis under the influence of the greatest force.

The Orendurff study[30] it describes a hypothesis that the movement of the CoM during human walking moves on a sinusoidal motion pattern and that excursions of the CoM increases vertically and decrease mediolaterally with increased velocity. The Orendurff study demonstrated increased mediolateral displacement of the CoM at slower walking speed but did not report any asymmetry in excursion in the same plane due to LLI, which was not mentioned. It proved difficult to find any studies that reported the effects of CoM displacement mediolaterally as a consequence of LLI.

There are very few in vivo studies that have recorded the actual forces taking place at the hip joint using specialist implants e.g. strain gauges, and these studies are rather old because of modern day ethics restraints.[20] In this case study the PI ilium occurred on the

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

longer limb side because the subject was ectomorphic in body type and had developed a functional scoliosis to maintain a central CoM. In this situation the greater force is elicited to the longer limb side because as ground reaction forces (GRF) push up under the longer limb side, the passenger unit resists and pushes back down.

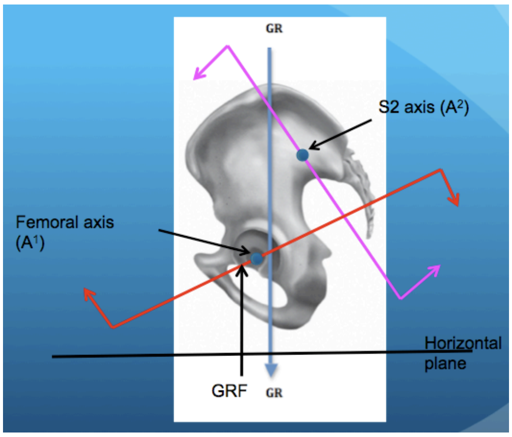

Fig. 4 This image shows the relationship between hip joint and sacral-2 axes to a descending gravity and ascending ground reaction force.

In Lee et al study[27] the CoM trajectory has been demonstrated to behave differently between walking and running, raising upwards to its high point by midstance walking and downwards to its lowest point by midstance running. The difference being that the inverted pendulum model[29] in walking raises the CoM whilst the spring mass model[28] lowers the CoM in running. Both these models however create kinetic energy, which is converted to gravitational potential energy. Therefore a PI ilium may be created by displaced gravitational potential energy influencing hip joint and sacral axes.

CONCLUSION

MSK compensation for R-LLI including a PI ilium orientation, is extremely common, potentially causing repetitive injury. However there is little evidence to support the corresponding use of heel raise therapy to reduce these pathomechanical adaptions. It is possible that some LLI's are assumed to be apparent in origin with no heel raises used at all. Rather the compensatory origin of the pelvic torsion from R-LLI is often ignored, left to create further repetitive injury in a 'domino effect' over many years. Clearly, further work is required to establish more detailed assessment techniques of LLI.

In this case study a DPI was used to identify compensatory pelvic torsion associated with a R-LLI. This device demonstrates a repeatable and reliable clinical technique to reduce this pelvic torsion improving the abnormal motion patterns that create injury.

The DPI can therefore be used to identify the random innominate behaviour associated with A-LLI and that pelvic manipulation should only be used in certain cases of pelvic torsion. Following identification of R-LLI by using the DPI, the patient was dispensed bespoke orthotics with a 5 mm rearfoot heel raise and 3 mm graduated forefoot raise on the right side. At the three-month review stage the patient reported a sense of feeling more symmetrical and presented with a reduction in all symptoms. More importantly the compensatory pelvic torsion

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

created by the R-LLI was still absent.

Note: In this case study the subject was found to have short right leg (or longer left leg). As an interesting side note, this author has found a greater incidence of shorter right legs amongst the patients that have visited our sports injury centres over the last twenty-five years. Other studies have also noted a higher incidence of shorter right legs.[6,10]

Disclosures

The digital pelvic inclinometer used in this case study was manufactured by Sub-4 Technologies.

REFERENCES

1. *Defrin R P, Ben Benyamin SM, et al: Conservative Correction of Leg-Length Discrepancies of 10mm or Less for the Relief of Chronic Low Back Pain. Arch Phys Med Rehabil, Nov (86): 2075-2080, 2005.*

2. *Knutson G A: Incidence of Foot Rotation, Pelvic Crest Unleveling, and Supine Leg Length Alignment Asymmetry and Their Relationship to Self-Reported Back Pain. Journal of Manipulative and Physiological Therapeutics. 25(2): 1 - , 2001.*

3. *McCaw S. and Bates B: Biomechanical Implications of Mild Leg Length Inequality. Br J Sp Med 25(1): 10 - 13, 1991.*

4. *Nichols PJR, Bailey NTJ: The Accuracy of Measuring Leg-Length Differences. British Medical Journal, Nov. 19, 1247-1248, 1955.*

5. *Rothenberg RJ: Rhematoid Disease Aspects of Leg Length Inequality. Semin Arthritis Rheum 17 (3): 196-205, 1988.*

6. *Krawiec CJ, Denegar CR, Hertel J, Salvaterra GF, Buckley WE: Static Innominate Asymmetry and Leg Length Discrepancy in Asymptomatic Collegiate Athletes. Manual Therapy 8(4), 207-213, 2003.*

7. *Clarke GR: Unequal Leg Length: An Accurate Method of Detection and Some Clinical Results. Rheum. phys. Med., 11,385-389, 1972.*

8. *Beattie p, Isaacson k, Riddle DL, Rothstein JM: Validity of Derived Measurements of Leg Length Differences Obtained by Use of tape Measure. Physical Therapy, Vol 70, No 3, 150-157, 1990.*

9. *Hanada E, Kirby RL, Mitchell M, Swuste JM: Measuring Leg-Length Discrepancy by the "Iliac Crest palapation and Book Correction" Method: Reliability and Validity. Arch. Phys.Med. Rehabil, Vol 82, 938-942, July 2001.*

10. *Holt KR, Russell DG, Hoffmann NJ, Bruce BI, Bushell PM, Taylor HH: Interexaminer Reliability of a Leg length Analysis Procedure Among Novice and Experienced Practitioners. Journal of Manipulative and Physiological Therapeutics Vol 32, Number 3, 216-221, 2009.*

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

11. *Zabjek KF, Leroux MA, Coillard C, Martinez X, Griffet J, Simard G: Acute Postural Adaptions Induced by a Shoe Lift in Idiopathic Scoliosis Patients. Eur. Spine J, 10 (2), 107-113, 2001.*

12. *Hagins M, Brown M, Cook C, Gstalder K, Kam M, Kominer G, Strimbeck K: Intratester and Intertester Reliability of the Palpation Meter (PALM) in Measuring Pelvic Position. The Journal of Manual & Manipulative Therapy, Vol 6, number 3, 130-136, 1998.*

13. *Potter NA, Rothstein JM: Intertester Reliability for Selected Clinical Tests of the Sacroiliac Joint. Physical Therapy, Volume 65, Number 11, 1671-1675, 1985.*

14. *Rothbart BA: Relationship of Functional Leg-Length Discrepancy to Abnormal Pronation. Journal of The American Medical Association, Vol 96, Number 6, 499-504, 2006.*

15. *Walsh M, Connolly P, Jenkinson A, O'Brien T: Leg Length Discrepancy - An Experimental Study of Compensatory Changes in Three Dimensions Using gait Analysis. Gait and Posture, 12, 156-161, 2000.*

16. *Gofton JP, TruemanGE: Studies in Osteoarthritis of the Hip: Part II. osteoarthritis of the Hip and Leg-Length Disparity. CMA Journal Vol 104, 791-799, 1971.*

17. *Gajdosil R, Simpson R, Smith R, DonTigny RL: Intratester Reliability of Measuring the Standing Position and Range of Motion. Physical Therapy, Vol 65, Number 2, 169-174, 1985.*

18. *Levine D, Whittle MW: The Effects of Pelvic Movement on Lumbar Lordosis in the Standing Position. Journal of Orthopaedic & Physical Therapy, Vol 24, Number 3, 130-135, 1996.*

19. *Gilliam J, Brunt D, MacMillan M, Kinard RE, Montgomery WJ: Relationship of the Pelvic Angle to the Sacral Angle: Measurement of Clinical Reliability and Validity. Journal of Orthopaedic & Sports Physical Therapy, Volume 20, Number 4, 193-199, 1994.*

20. *English TA, Kilvington M: In Vivo Records of Hip Loads Using a Femoral Implant with Telemetrric Output (A Prelimary Report). J.Biomed.Eng. Volume 1, Number 2, 111-115, 1979.*

21. *Pitkin HC, Pheasant HC: Sacrrarthrogenetic Telalgia II. A Study of Sacral Mobility. The Journal of Bone and Joint Surger. Vol XVIII, Number 2, 365-374, 1936.*

22. *Cooperstein R, Lew M: The Relationship Between Pelvic Torsion and Anatomical Leg Length Inequality: A Review of The Literature. Journal of Chiropractic Medicine, 8, 107-118, 2009.*

23. *Hoikka V, Ylikoski M, Tallroth K: Leg-Length Inequality has Poor Correlation with Lumbar Scoliosis. A Radiological Study of 100 Patients with Chronic Low-Back Pain. Arch Orthop. Trauma Surg,108, 173-175, 1989.*

24. *Preece SJ, Willan P, Nester CJ, Graham-Smith P, Herrington L, Bowker P: Variation in Pelvic Morphology May Prevent The Identification of Anterior Pelvic Tilt. J Man Manip. Ther. 16 (2), 113-117,2008.*

25. *Kroll PG, Arnofsky SL, Peckham S, Rabinowitz A:The Relationship Between Lumbar Lordosis and Pelvic Tilt Angle. J.Back Musculoskeletal Rehabil. 14, 21-25, 2000.*

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).

26. *Gilliam J, Brunt D, MacMillan M, Kinard RE, Montgomery WJ: Relationship of The Pelvic Angle to The Sacral Angle: Measurement of Clinical Reliability and Validity. J. Orthop. Sports Phys Ther. 20, 193-199, 1994.*

27. *Lee CR, Farley CT: Determinants of The Centre of Mass Trajectory in Human Walking and Running. The Journal of Experimental Biology, 201, 2935-2944,1998.*

28. *Blickhan R: The Spring Mass Model for Running and Hopping. J. Biomech. 22,1217-1227,1989.*

29. *Alexander R: Simple Models of Human Movement. Appl. Mech. Rev., 48, 461-470,1995.*

30. *Orendurff MS, Segal DS, Klute GK, Berge JS, Rohr ES: The Effect of Walking Speed on Centre of Mass Displacement. Journal of Rehabilitation Research & Development, Volume 41, Number 6A, 829-834, 2004.*

31. *Herbst RW: Gonstead Chiropractic Science & Art: The Chiropractic Methodology of Clarence S. Gonstead, D.C. Sci-Chi Publications, 1-11.*

32. *Giles LGF, Taylor JR: Low-Back Pain Associated With Leg Length Inequality. Spine, Volume 6, Number 5, 510-521,1981.*

33. *Levangie PK: Four Clinical Tests of Sacroiliac Joint Dysfunction: The Association of Test Results with Innominate Torsion Among Patients With and Without Lower Back Pain. Physical Therapay, 79, 1043-1057, 1999.*

34. *Frese E, Brown M, Norton BJ: Clinical Reliability of Manual Muscle Testing. Physical Therapy, 67, 1072-1076, 1987.*

35. *Powers CM: The Influence of Abnornal Hip Mechanics on Knee Injury: A Biomechanical Perspective. Journal of Orthopaedic & Sports Physical Therapy, Vol 40, Number 2, 42-51, 2010.*

 Address correspondence to C. Bradeley, Sub-4 Health, Leek Road, Cellarhead, Staffordshire Moorlands ST9 0JQ (e-mail: Clifton@sub-4.co.uk).