Journal of Hip Preservation Surgery Vol. 3, No. 4, pp. 352–357
doi: 10.1093/jhps/hnw017
Advance Access Publication 17 June 2016
Research article

OXFORD

Defining the greater trochanter-ischial space: a potential source of extra-articular impingement in the posterior hip region

Benjamin R. Kivlan[1,2,*], RobRoy L. Martin[1,2] and Hal D. Martin[3]

[1]John G. Rangos Sr, School of Health Sciences, Duquesne University, Pittsburgh, PA 15282, USA,
[2]Department of Physical Therapy, Duquesne University, Pittsburgh, PA, USA and
[3]Hip Preservation Center, Baylor University Medical Center, Dallas, TX, USA
*Correspondence to: B. R. Kivlan. E-mail: kivlanb@duq.edu
Submitted 31 October 2015; revised version accepted 23 December 2015

ABSTRACT

The purpose of this study was to describe greater trochanteric-ischial impingement and the relative position of the hip joint where impingement occurs. Twenty-three hips from 13 embalmed cadavers (seven males and six females) with a lifespan ranging between 46 and 91 years were used for this study. The pelvic region of each cadaver was skeletonized leaving only the hip capsule and the sciatic nerve. From 90° of flexion, the hip was extended while maintaining a position of 30° abduction and 60° external rotation. The position of hip flexion was recorded when there was contact between the greater trochanter and the ischium. The procedure was repeated in 0° abduction. A Flexion-Abduction-External Rotation (FABER) test was then performed on all specimens with a positive finding defined as contact between the greater trochanter and the ischium. In 30° abduction, contact of the ischium and the greater trochanter occurred in 87% (20/23) of the hips at an average of 47° of flexion (SD 10; range 20–60°). In 0° abduction, a positive finding was noted in 39% (9/23) of hips at an average of 59° flexion (SD 6; range 52–70°). A positive finding in the FABER test position was noted in 96% (22/23) of hips. The greater trochanter can impinge on the ischium when the hip is extended from 90° flexion in a 60° externally rotated position. This impingement occurred more commonly when the hip was in 30° abduction compared with neutral abduction. The FABER test position consistently created greater trochanteric–ischial impingement.

INTRODUCTION

Retro-trochanteric hip pain occurs in approximately 23% of women and 9% of men [1], although the etiology is poorly understood [2, 3]. Several authors have postulated that these symptoms arise from ischio-femoral impingement involving the lesser trochanter and the lateral aspect of the ischium which has been shown to occur when the hip is placed in a combination of extension, adduction and external rotation [4–8]. It is hypothesized that repeated impingement episodes leads to damage to the quadratus femoris muscle and the sciatic nerve resulting in posterior hip pain that may also radiate into the posterior thigh [9, 10].

However, a recent case report has presented evidence suggesting that posterior or retro-trochanteric hip pain may also arise from impingement between the ischium and the *greater* trochanter. Singer *et al.* [11] described a case of 58-year-old woman with chronic left buttock pain that radiated into the posterior aspect of the thigh. The patient's magnetic resonance imaging (MRI) results, however, were not consistent with typical ischiofemoral impingement in which contact occurs between the ischium and the lesser trochanter when the hip joint is placed in extension, adduction and external rotation. Rather, the MRI indicated an apparent extra-articular impingement of the greater trochanter with the ischium as the hip joint was moved into external rotation [11]. This study [11] is the first to report impingement between the greater trochanter and the ischium as a potential cause of retro-trochanteric hip pain. Based on this discovery, further investigation is needed to understand how movement of the hip joint changes the space between the greater trochanter and ischium and its relationship to retro-trochanteric hip pain. Our preliminary observations of cadaveric specimens have suggested that the combined position of flexion, abduction, and external rotation approximates the greater trochanter to the ischium consistent to the case study presented by Singer *et al.* [11] as recreated in Fig. 1.

The purpose of this study is to use anatomic modeling to define the greater trochanteric-ischial space when moved in combined positions of flexion, abduction and external rotation of the hip joint. The information gained from this study will help to define a novel and poorly understood source of extra-articular impingement and provide biomechanical evidence through anatomical modeling that may aide in developing clinical tests and strategies of managing the condition.

METHODS

Thirteen formalin-embalmed, Caucasian cadavers (seven males and six females) with a lifespan between 46 and 91 years yielded 23 individual hip joints for evaluation for greater trochanteric-ischial impingement. Three hip joints were excluded from the study because of hardware from previous hip surgery (two total hip arthroplasties and one femoral neck fracture). Dissection of the pelvic region of each cadaver was performed to remove muscular attachments of the femur to the pelvis including the gluteus maximus, gluteus medius, gluteus minimus, iliopsoas and adductor muscles. The hip capsule was then vented using a scalpel to make several 5 mm incisions along the distal perimeter of the capsule to allow unobstructed hip motion for testing. The occurrence of impingement between the greater trochanter with the ischium was tested during three different kinematic maneuvers.

Impingement Test Position 1: Each cadaver was secured to a plinth in a supine position. The primary investigator (brk) placed the hip joint of the cadaver in a starting position of 90° of flexion, 30° abduction and 60° external rotation. A standard 12-in. goniometer (Baseline® Goniometer, Fabrication Enterprises Inc. White Plains, NY) was used by a second investigator (rlm) to confirm the starting position. From the start position, the primary investigator (brk) then moved the hip joint towards extension while maintaining a position of 30° abduction and 60° external rotation until the hip joint reached 0° flexion or when the greater trochanter came into contact with the ischium preventing further hip extension (Fig. 2). In cases of impingement, the position of hip flexion was recorded and the hip abduction and external rotation position was remeasured to confirm that the hip was maintained at 30°

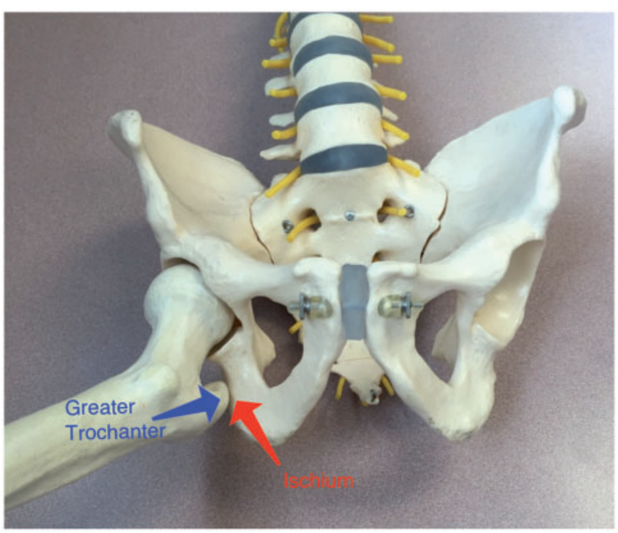

Fig. 1. An anatomic model showing contact of the greater trochanter (blue arrow) to the ischium (red arrow) in combined flexion, abduction, and external rotation of the hip joint.

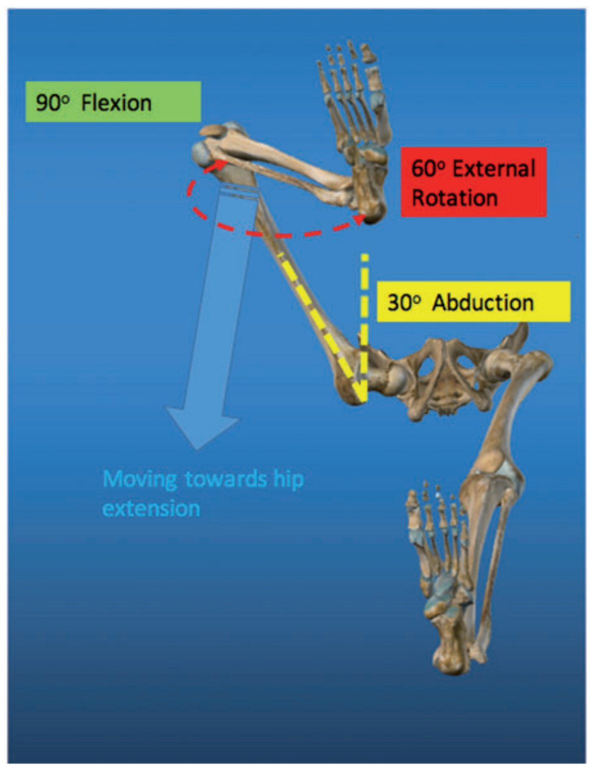

Fig. 2. Impingement test position 1. From a start position of 90° of flexion, 30° abduction and 60° external rotation, the hip joint is moved toward hip extension until the greater trochanter contacts the ischium. Image courtesy of Cyber Anatomy 3D created by Cyber Science Inc. Coralville, IA <www.cyberscience3d.com>.

and 60°, respectively, by the secondary investigator (rlm). Each measurement procedure was repeated three times with 60 s in between trials.

Impingement Test Position 2: The testing procedures described above were repeated with the hip placed in a starting position of 90° of flexion, 0° abduction and 60° external rotation. The hip was extended until contact occurred between the greater trochanter and the ischium or the hip reached 0° flexion (Fig. 3). Each measure was repeated three times with 60 s in between trials. The average of the three trials was utilized for data analysis

Impingement Test Position 3*:* The hip specimens were also tested for bony impingement when placed in the FABER test position, which combines Flexion-Abduction-External Rotation of the hip. To perform this test, the lateral malleolus of the tested limb was placed in contact with the lateral aspect of the knee joint, as shown in Fig. 4. The primary investigator (bkr) assessed each specimen to determine if the FABER position caused greater trochanteric-ischial impingement, as indicated by contact between the greater trochanter and the ischium preventing further hip extension.

In each of the three positions, the testing procedure was repeated after the primary and secondary investigators exchanged places. The secondary investigator was blinded to the measurements recorded in the first round of testing.

Data analysis

Data analysis was performed using a commercially available statistical software package (SPSS 17.0; Chicago, IL). Mean, standard deviation (SD) and range of the values measured by the primary investigator for hip flexion in impingement test position 1 and impingement test position 2. A Pearson Correlation Coefficient comparing the first and third trials of the primary (bkr) and secondary (rlm) investigators was used to determine intra-rater reliability of the hip flexion measure. Inter-rater reliability was determined by a Pearson Correlation Coefficient that compared the average of the first three trials by the primary

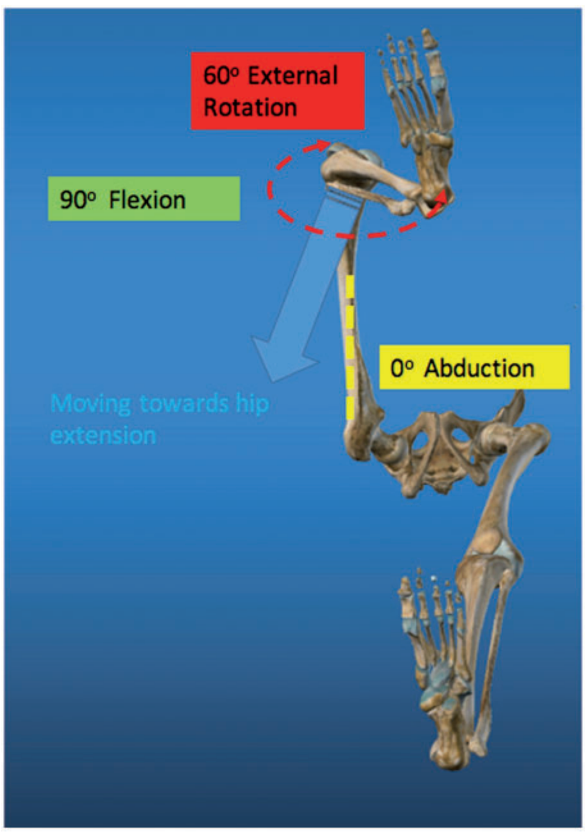

Fig. 3. Impingement Test Position 2. From a start position of 90° of flexion, 0° abduction and 60° external rotation, the hip joint is moved toward hip extension until the greater trochanter contacts the ischium. Image courtesy of Cyber Anatomy 3D created by Cyber Science Inc. Coralville, IA <www.cyberscience3d.com>.

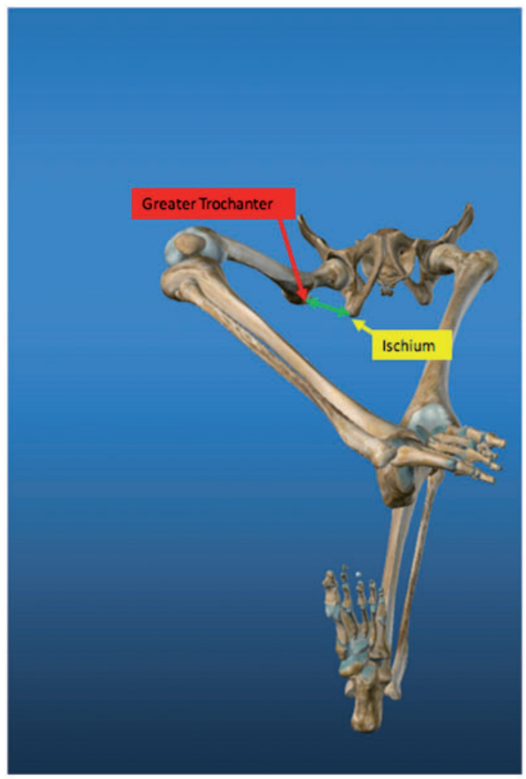

Fig. 4. Impingement Test Position 3. The FABER test position that combines flexion, abduction and external rotation of the hip joint noting the approximation of the greater trochanter to the ischium. Image courtesy of Cyber Anatomy 3D created by Cyber Science Inc. Coralville, IA <www.cyberscience3d.com>.

Table I. Angle of hip flexion at contact between the Greater Trochanter and Ischium

Specimen	***Rater 1***				***Rater 2***			
	Position 1		*Position 2*		*Position 1*		*Position 2*	
	Left	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*
1	55°	55°	Neg	Neg	54°	48°	Neg	Neg
2	46°	54°	52°	Neg	43°	52°	51°	Neg
3	54°	55°	65°	Neg	51°	51°	60°	Neg
4	47°	NA	Neg	NA	45°	NA	Neg	NA
5	59°	32°	58°	56°	53°	38°	60°	58°
6	NA	45°	NA	55°	NA	41°	NA	55°
7	44°	39°	Neg	Neg	38°	41°	Neg	Neg
8	20°	39°	Neg	Neg	24°	43°	Neg	Neg
9	46°	34°	Neg	Neg	39°	38°	Neg	Neg
10	Neg	60°	Neg	70°	Neg	54°	Neg	72°
11	NA	58°	NA	58°	NA	44°	NA	61°
12	Neg	Neg	Neg	61°	Neg	Neg	Neg	61°
13	46°	48°	Neg	Neg	45°	47°	Neg	Neg

Position 1: 30° abduction and 60° external rotation. *Position* **2:** 0° abduction and 60° externall rotation. *Neg*, Impingement not observed between the greater trochanter and the ischium; NA, not available for assessment.

investigator (brk) to the average of the three trials of the secondary investigator (rlm). A percentage of agreement of positive findings of greater trochanteric-ischial impingement during the FABER test was computed for the primary (brk) and secondary (rlm) investigators.

RESULTS

Reliability tests

The data describing the flexion angle of the hip joint when contact was made between the greater trochanter and the ischium for each specimen in each respective impingement position is presented in Table I according to the tester. Intra-tester reliability ($r = 0.98$) and inter-tester reliability ($r = 0.90$) were excellent for measures of hip flexion in impingement test (position 1) and impingement test (position 2). The average difference between angles recorded by the two observers was 1.6°, with a standard deviation of 4.4° (range: −6° to 14°). There was 100% agreement between investigators for positive findings of greater trochanteric-ischial impingement in the FABER test position.

Impingement testing

The individual results of the impingement test positions 1 and 2 are listed in Table I, while the incidence of impingement between the greater trochanter and the ischium observed in each test position is reported in Table II. In 30° abduction, greater trochanteric-ischial impingement was noted in 87% (20/23) of the hips examined at an average of 47° flexion (SD 10; range 20°–60°). In 0° abduction, impingement was noted in only 39% (9/23) of hips at an average of 59° flexion (SD 6; range 52°–70°). A positive FABER test was noted in 96% (22/23) of hips.

DISCUSSION

The primary purpose of the current study was to define the position of the hip joint when greater trochanteric-ischial impingement occurs. Our data showed that in a majority of specimens (20/23), the greater trochanter contacted the ischium when the angle of hip flexion was between 20° and 60° (mean = 47°) with the hip joint in 30° abduction and 60° external rotation. In neutral abduction/adduction and 60° external rotation, only nine out of 23 specimens demonstrated contact of the greater trochanter to the ischium. Based on this data, it would appear that in the flexed and externally rotated hip, impingement of the greater trochanter on the ischium is more likely to occur with the hip positioned in abduction and is less likely when the hip joint is positioned in a neutral abduction/adduction.

Impingement of the greater trochanter to the pelvis has been previously described in patients with Legg–Calve–Perthes disease, although with a different contact pattern than in the present study [12]. In Legg–Calve–Perthes disease, extra-articular impingement commonly occurs as the superior margin of the greater trochanter contacts the lateral surface of the ilium in positions of hip abduction and extension [12]. This type of impingement occurs as a result of dramatic deterioration and malformation of the articular surfaces of the hip joint which effectively shortens the distance between the greater trochanter and the ilium [12]. Surgical procedures to lengthen the femoral neck have successfully restored sufficient clearance between the greater trochanter and ilium to eliminate this form of impingement [12, 13]. Our current study describes impingement between the greater trochanter and the ischium in a position of flexion, abduction, and external rotation in the absence of gross intra-articular hip disease.

Table II. The occurrence of greater trochanteric-ischial impingement according to Impingement Test Position

Impingement test position	*Positive finding*	*Mean flexion angle*	*Standard deviation*	*Range*
Position 1 (30° abduction, 60° external rotation)	87% (20/23)	47°	10°	20°–60°
Position 2 (0° abduction, 60° external rotation)	39% (9/23)	59°	6°	52°–70°
Position 3 (FABER Test position)	96% (22/23)	—	—	—

Singer *et al.* [11] recently published a case study describing approximation of the greater trochanter to the ischium during passive external rotation of the hip. Concurrent MRI findings included edema and a high density signal at the femoral attachment of the quadratus femoris, consistent with injury arising from repetitive episodes of impingement. The presence of quadratus femoris pathology has been previously documented in cases of ischiofemoral impingement in which the lesser trochanter approximates the ischium [10, 14, 15]. In these cases, impingement is commonly associated with a narrowing of the ischiofemoral space, as defined by the distance between the lesser trochanter and the ischium [16, 17]. However, in Singer's case study, the injury to the quadratus femoris was attributed to impingement between the ischium and the greater trochanter as the hip moved to 60° of external rotation, a conclusion that is consistent with the results of the present study.

The discovery of a novel source of extra-articular impingement between the greater trochanter and the ischium may have clinical significance as a source of retro-trochanteric hip pain, which is very common, especially in middle-aged female patients [18]. There may be several sources of retro-trochanteric pain that may cause symptoms in the buttock region or pain to radiate into the lower extremity. Martin *et al.* [1] described entrapment of the sciatic nerve by fibrovascular bands extending from the greater trochanter to various structures in the deep gluteal region. Abnormal magnetic resonance imaging of the quadratus femoris is also a common finding, even in asymptomatic individuals [16]. Extra-articular impingement of the greater trochanter and the ischium is a possible genesis of these abnormal findings, especially when the hip is repetitively loaded in positions combining flexion, abduction and external rotation as occurs during squatting, sitting with the legs crossed, or in positions adopted for sexual intercourse.

Previously, the FABER test has been described as a test for eliciting posterior hip pain [19, 20]. To our knowledge, no previous publication has described the FABER test as a test for provoking impingement between the ischium and the greater trochanter. Our findings suggest that the FABER position consistently approximates the greater trochanter to the ischium, which may generate posterior or retro-trochanteric hip pain in addition to that referred from the sacroiliac joint. Our cadaveric study can neither confirm nor negate this hypothesis. However, our findings support anecdotal observations from clinical practice that provocation of posterior hip pain with the FABER test may accompany abnormal findings on imaging of the deep gluteal region.

There are limitations to the current study that deserve consideration when interpreting the results. First, our experiments were performed on the hips of embalmed cadavers, which generally have greater stiffness than living tissues or fresh frozen cadaver tissues [21]. In order to freely move the hip joint for data collection, the gluteus maximus, gluteus medius, gluteus minimus, iliopsoas and adductor muscles were resected and the joint capsule was vented. Therefore, the data obtained in the current study does not account for the influence of these structures in their native forms. Without the presence of the soft tissue structures we do not know the extent to which impingement between the greater trochanter and the ischium occurs clinically. The lack of soft tissue structures may also change the absolute values of the tri-planar joint position in which the impingement was observed. In addition, we are unable to determine whether the impingement is a legitimate source of pain. The use of fresh frozen cadavers with intact soft-tissue structures as well as dynamic magnetic resonance imaging and computerized models may be other means to more closely explore the pathomechanics associated with greater trochanteric-ischial impingement *in vivo*. Second, hip joint position was measured with a hand-held goniometer, which, no doubt introduces some inherent error in quantifying joint position [22, 23]. Nonetheless, the intra- and the inter-rater reliability of the measurements of joint position were excellent overall, although the angles measured by each of the two observers differed by up to 14°, with a standard deviation of 4.4°. Future studies may consider utilizing three-dimensional motion analysis equipment for greater accuracy in determining joint position. Finally, other factors such as size and version angle of the acetabular or femoral components of the hip region could have influence the presence of impingement [6, 24]. These factors may explain the wide range of flexion angles at which the greater trochanter contacted the ischium while the hip joint was abducted and externally rotated.

The findings of our study provide an anatomic and biomechanical model that describes greater trochanter-ischial impingement in a way that has not been previously reported. Our cadaveric observations provide a foundation from which clinical studies may investigate the relationship of the FABER test to imaging findings suggestive of ischiofemoral impingement in symptomatic patients.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Martin HD, Shears SA, Johnson JC *et al*. The endoscopic treatment of sciatic nerve entrapment/deep gluteal syndrome. *Arthroscopy* 2011; **27**:172–81.
2. Martin HD, Kivlan BR, Palmer IJ *et al*. Diagnostic accuracy of clinical tests for sciatic nerve entrapment in the gluteal region. *Knee Surg Sport Tr a* 2014; **22**:882–8.
3. Meknas K, Johansen O, Kartus J. Retro-trochanteric sciatica-like pain: Current concept. *Knee Surg Sport Tr a* 2011; **19**:1971–85.
4. Hatem MA, Palmer IJ, Martin HD. Diagnosis and 2-year outcomes of endoscopic treatment for ischiofemoral impingement. *Arthroscopy* 2015; **31**:239–46.
5. Tosun O, Cay N, Bozkurt M *et al*. Ischiofemoral impingement in an 11-year-old girl. *Diagn Interv Radiol* 2012; **18**:571–3.
6. Johnson KA. Impingement of the lesser trochanter on the ischial ramus after total hip arthroplasty. Report of three cases. *J Bone Joint Surg Am* 1977; **59**:268–9.
7. Kivlan BR, Martin RL, Martin HD. Ischiofemoral impingement: Defining the lesser trochanter-ischial space. *Knee Surg Sports Traumatol Arthrosc* 2016.
8. Safran M, Ryu J. Ischiofemoral impingement of the hip: A novel approach to treatment. *Knee Surg Sports Traumatol Arthrosc* 2014; **22**:781–5.
9. Patti JW, Ouellette H, Bredella MA *et al*. Impingement of lesser trochanter on ischium as a potential cause for hip pain. *Skeletal Radiol* 2008; **37**:939–41.
10. Torriani M, Souto SC, Thomas BJ *et al*. Ischiofemoral impingement syndrome: An entity with hip pain and abnormalities of the quadratus femoris muscle. *Am J Roentgenol* 2009; **193**:186–90.
11. Singer A, Clifford P, Tresley J *et al*. Ischiofemoral impingement and the utility of full-range-of-motion magnetic resonance imaging in its detection. *Am J Ortho* 2014; **43**:548–51.
12. Macnicol MF, Makris D. Distal transfer of the greater trochanter. *J Bone Joint Surg Br* 1991; **73**:838–41.
13. Leunig M, Ganz R. Relative neck lengthening and intracapital osteotomy for severe perthes and perthes-like deformities. *Bull NYU Hospital for Joint Dis* 2011; **69 Suppl 1**:S62–7.
14. Kassarjian A. Signal abnormalities in the quadratus femoris muscle: Tear or impingement? *Am J Roentgenol* 2008; **190**:W379–author reply W80. 1.
15. O'Brien SD, Bui-Mansfield LT. Mri of quadratus femoris muscle tear: Another cause of hip pain. *Am J Roentgenol* 2007; **189**:1185–9.
16. Maras Ozdemir Z, Aydingoz U, Gormeli CA *et al*. Ischiofemoral space on mri in an asymptomatic population: normative width measurements and soft tissue signal variations. *Eur Radiol* 2015;
17. Sussman WI, Han E, Schuenke MD. Quantitative assessment of the ischiofemoral space and evidence of degenerative changes in the quadratus femoris muscle. *Surg Radiol Anat* 2013; **35**:273–81.
18. Segal NA, Felson DT, Torner JC *et al*. Greater trochanteric pain syndrome: epidemiology and associated factors. *Arch Phys Med Rehabil* 2007; **88**:988–92.
19. Arab AM, Abdollahi I, Joghataei MT *et al*. Inter- and intra-examiner reliability of single and composites of selected motion palpation and pain provocation tests for sacroiliac joint. *Man Ther* 2009; **14**:213–21.
20. Laslett M. Evidence-based diagnosis and treatment of the painful sacroiliac joint. *J Man Manip Ther* 2008; **16**:142–52.
21. Jaung R, Cook P, Blyth P. A comparison of embalming fluids for use in surgical workshops. *Clin Anat* 2011; **24**:155–61.
22. Boone DC, Azen SP, Lin CM *et al*. Reliability of goniometric measurements. *Phys Ther* 1978; **58**:1355–60.
23. Bovens AM, van Baak MA, Vrencken JG *et al*. Variability and reliability of joint measurements. *Am J Sports Med* 1990; **18**:58–63.
24. Bredella MA, Azevedo DC, Oliveira AL *et al*. Pelvic morphology in ischiofemoral impingement. *Skeletal Radiol* 2015; **44**:249–53.