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FULL PAPER

Anatomical analysis of the pelvis to identify any predisposing anatomical factors for ischiofemoral space pathology: a retrospective study

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Objective: Anatomical analysis of the hips and pelvis was performed using MRI to evaluate morphological characteristics and associations between them. We identified correlations between the ischiofemoral space (IFS), quadratus femoris space (QFS), femoral version angle (FVA) and cervicodiaphyseal angle (CDA).

Methods: This study involved a retrospective search of a database of consecutive reports of adult hip MRI examinations carried out between January and September 2016. Patients with a medical history likely to affect pelvic and hip morphometry were excluded.

Results: A total of 137 adult patients were enrolled in the study (45.3% males and 54.7% females), with a mean age of 50.16 ± 13.87 years. The mean IFS was 20.88 ± 5.96 mm, mean QFS was 15.2 ± 6.18 mm, mean FVA was 12.43 ± 6.98, and mean CDA was 121.27 ± 4.6°. The IFS measurements were significantly correlated with femoral measurements (p = 0.025). These visible differences showed a slight negative relationship (−0.191), and females had a smaller distance between these anatomical structures than males (p < 0.001). Females had a significantly smaller QFS than males (12.42 ± 5.94 *vs* 18.73 ± 4.48 mm, p = 0.000). There was a small but significant positive relationship between CDA and FVA (p = 0.022), with a correlation coefficient of 0.195.

Conclusion: A higher FVA was correlated with a smaller IFS. Furthermore, an increase in the CDA appeared in tandem with an increase in the FVA.

Advances in knowledge: A single conventional MRI sequence can alert us to how anatomical factors could predispose individuals to a decrease in IFS.

INTRODUCTION

Although the exact mechanisms of painful pathologies of the pelvis are not fully understood, they are likely to appear due to anatomical changes. Many syndromes or entities are encompassed under the term "posterior hip pain" (PHP), which are interrelated to one another and sometimes simultaneously present.[1] The symptoms for these syndromes, the origins of which can be difficult to determine, are often very similar. Detailed information on the anatomical structures surrounding the coxofemoral joint and their femoropelvical relationship can be used by clinicians to help determine the origin of such pain, and the availability of such information has facilitated more precise diagnosis and suitable treatments for the various symptoms that can arise.[1,2]

The grouping of PHP syndromes is greatly dependent on the anatomy of the pelvis and femur. Within this grouping, one can find ischiofemoral impingement (IFI), deep gluteal syndrome (DGS) and medium and minor gluteus tendinosis (GT).

Within DGS, the most important entity is piriformis muscle syndrome, which results from compression of the sciatic nerve in the greater sciatic foramen.[3] The main cause of this syndrome has been confirmed to involve space-occupying lesions in the piriformis region.[4] For many years, it was thought that there was a relationship between the anatomy of the pelvis, more precisely the path of the sciatic nerve, and piriformis syndrome. However, a study published last year concluded that there is no such relationship, nor is there an association with buttock pain.[5] In our study, we evaluated certain aspects of the pelvis in order to better understand IFI.

Ischiofemoral impingement is a pathology resulting from a narrowing of the space between the lesser trochanter and the ischial tuberosity, and between the hamstring tendons and the lesser trochanter. It is characterised by pain and quadratus femoris (QF) muscle abnormalities. On multiple occasions in the literature, IFI has been confirmed to be one of the leading causes of posterior hip pain.[1,6–8]

To obtain an accurate diagnosis, different imaging tests are available, one of which is MRI. The configuration and diameters of the ischiofemoral and pelvic anatomical spaces, as well as alterations in the morphology and signal of the muscular and tendinous bone elements, can all be evaluated by MRI.

The ischiofemoral space (IFS) should exceed 20 mm.[6] In such instances, impingement is uncommon, although several studies[1,6,9–11] have shown that patients with spaces less than 15 mm are more likely to suffer IFI.

The presence of altered IFS will affect the QF muscle, and can sometimes be responsible for sciatic nerve pathology. Indeed, altered IFS can result in changes to both the femoral version angle (FVA) and cervicodiaphyseal angle (CDA) of the femur. Modifying these spaces can also lead to the development of alterations in the pelvic rotator cuff.[6,8,11]

We believe an important constitutional component predisposes some patients to the development of these pathologies or other secondary conditions when not properly diagnosed or prevented in time.

For the aforementioned reasons, the objective of the current study was to conduct an anatomical substrate analysis of the hips and pelvis using MRI. We sought to assess their morphological characteristics and any associations between them. We also investigated whether any correlations exist between the IFS, quadratus femoris space (QFS), FVA and CDA.

METHODS AND MATERIALS

Study design

A retrospective search was performed using a database of consecutive reports of adult hip MRI examinations carried out between January and September 2016. This article has been written in compliance with the STROBE checklist (Appendix A) and has been registered on clinicaltrial.gov under the number NCT03768895.

Hips were evaluated at an MRI centre and the images were selected from Kodak Carestream PACS (online storage server diagnostic workstation, v. 10.0). All MRI examinations were performed using the same MRI machine. DICOM images were analysed by one radiologist specialised in musculoskeletal resonance with more than 30 years of experience.

All patients included in this study provided informed consent for the collection and use of information relevant to their MRI, and all aspects of the study were performed in accordance with the Helsinki declaration of 1963 (revised October 2013).

Inclusion and exclusion criteria

We designed a retrospective review study with the objective of analysing all the recorded MRI findings in the time period between January and September 2016. Patients who underwent a pelvis MRI for any cause at the MRI centre were included in the study. The inclusion and exclusion criteria are listed in Table 1.

Table 1. Inclusion and exclusion criteria

INCLUSION CRITERIA	Age > 18 years old
	To had realised a pelvis MRI for any cause at MRI centre
EXCLUSION CRITERIA	Age < 18 years old
	Inadequate imaging quality
	To have a medical history likely to affect pelvic and hip morphometry:pelvic oncological disease, infection or inflammatory arthritis, post-surgicalchange disruptions, soft tissue abnormality, avascular necrosis, or pelvic and hip fracture.

After selecting the MRI tests and the complementary clinical data for every consecutively performed MRI, a database was created. The included data comprised only general demographic information, and no clinical manifestations were included.

Imaging studies

All hip MRIs were performed using a Hitachi AIRIS II, Open MRI, with a permanent vertical magnetic field (0.3T), in accordance with the MR Department protocol. Patients were placed in a supine position, with their hips in an internal rotation and feet similarly secured. Coronal and axial SE T_1, T_2 weighted imaging sequences were included in our study, in addition to the rest of the hip protocol sequences.

When measuring the IFS, the position of the hips is very important, as measurements can vary depending on the degree of rotation.[12] Finnof et al sonographically evaluated 10 asymptomatic adults in various positions with different degrees of abduction/adduction and rotation of the hips. The authors demonstrated that if the measurement was performed with abduction and internal rotation of the hips, the space will appear larger than for measurements performed with adduction and external rotation. In the current study, MRIs were performed with all participants positioned with internal hip rotation, therefore, we can be certain that our measurements of the IFS correspond to the space of the opening.

Analysis of MRI findings

We analysed different studies of MRI and selected the appropriate images to measure the IFS, QFS, CDA and FVA using a Kodak Carestream PACS (v. 10.0) on coronal and axial SE T_1 WE.

The IFS was measured as the smallest distance between the lateral cortex of the ischial tuberosity and the medial cortex of the lesser trochanter.[6,8] Normally, the IFS should exceed 20 mm (Figure 1).[6]

The QFS was measured as the smallest space for passage of the quadratus femoris muscle, delimited by the superolateral surface

Figure 1. Axial hip MRI with SE T_1WI sequence. The IFS is the smallest distance between the lateral cortex of the ischial tuberosity and the medial cortex of the lesser trochanter (it is indicated with a continuous line). The QFS is the smallest space for passage of the quadratus femoris muscle, delimited by the superolateral surface of the hamstring tendons and the posteromedial surface of the iliopsoas tendon or lesser trochanter (it is indicated with a dotted line). IFS, ischiofemoral space; QFS, quadratus femoris space; T_1WI, T_1 weighted imaging.

Figure 2. Coronal hip MRI with SE T_1WI sequence. The CDA is formed by the axis of the femoral neck, which joins the femoral head, with the axis of the femoral shaft. CDA, cervicodiaphyseal angle; T_1WI, T_1 weighted imaging.

of the hamstring tendons and the posteromedial surface of the iliopsoas tendon or lesser trochanter.[6,8] The normal distance for this space is approximately 12 mm in control subjects with an internal rotation (Figure 1).[3]

The CDA is the angle formed at the axis of where the femoral neck joins the femoral head with the axis of the femoral shaft. As previously reported in the literature, the CDA is usually around 135° in adults, with variations of 115–140° according to Kapanji. The measurement protocol was standardised in 1980 by Hoaglund and Low (Figure 2).[13]

The FVA is the projection on the transverse plane of the longitudinal axis of the femoral neck at the centre of the femoral head. The angle changes with age, although in adults it ranges between 10 and 30° (Figure 3).[13]

In all images, we evaluated the IFS, QFS, CDA and FVA. These measurements are shown in Figures 1–3.Figure 4

Statistical analyses

Variables are presented as the average and standard deviation in keeping with their distribution. Descriptive statistics were used to present data from the series at the beginning of the study.

The percentage of male and female subjects and the participants' age (mean and standard deviation), IFS, QFS, CDA and FVA were analysed to describe the sample.

Kolmogrov–Smirnov test was used to check the normality of the distribution of these quantitative variables (IFS, QFS, FVA and CDA). The relationship between normally distributed variables was analysed with a Pearson test, and a Spearman test was used for non-normally distributed variables.

We also analysed the correlations between all measurements for both genders with a Student's *t*-test to determine whether there was any difference between them.

All data were analysed using SPSS (v. 21.0) software, and the significance level for all analyses was $p \leq 0.05$.

RESULTS

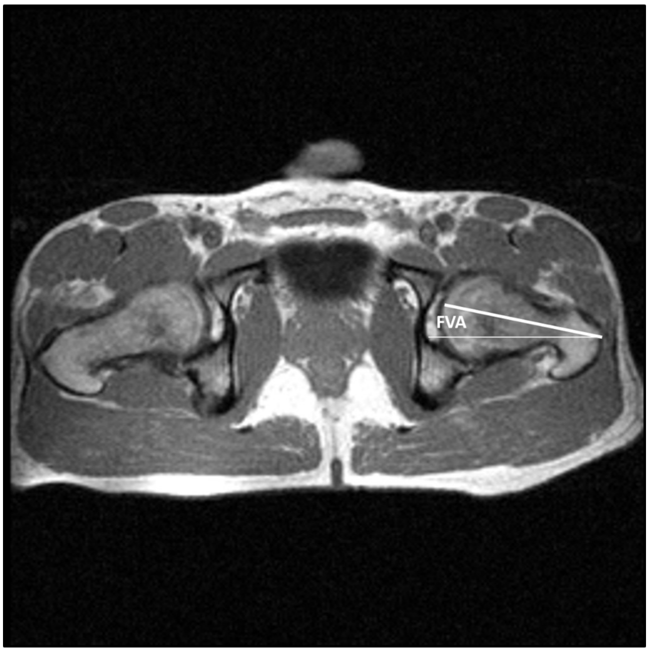
A total of 137 adults were enrolled in the study (45.3% males and 54.7% females), with a mean age of 50.16 ± 13.87 years. All met the inclusion and exclusion criteria and were willing participants. Before the start of this study, all patients signed an informed consent form. The subjects' age, sex, date of birth and MRI examination data were collected on the first visit.

The mean IFS, QFS, CDA and FVA values for all participants are shown in Table 2.

Ischiofemoral space

Measurements of the IFS were significantly correlated with the FVA (p = 0.025). This was visible with a slight negative

Figure 3. Axial hip MRI with SE T_1WI sequence. The FVA is the projection on the transverse plane of a longitudinal axis of the femoral neck at the centre of the femoral head. FVA, femoral version angle; T_1WI, T_1 weighted imaging.



relationship (−0.191) between them, where as the IFS decreases the FVA will increase, and vice versa.Figures 5 and 6

We also verified that there is a correlation between the IFS and QFS. In this case, there proved to be a strong positive correlation, with a correlation coefficient of 0.761. These findings indicate that if there is an increase in the IFS, the QFS will increase as well, and if one of them decreases, so will the other.

Table 2. Means and SD for pelvic measurements

Measurement	Mean ± SD
IFS	20,88 ± 5,96 mm
QFS	15,2 ± 6,18 mm
FVA	12,43 ± 6,98°
CDA	121,27 ± 4,6°

CDA, cervicodiaphyseal angle; FVA, femoral version angle; IFS, ischiofemoral space; QFS, quadratus femoris space;SD, standard deviation.

Finally, when we analysed both genders, we found a significant difference in the distance between the lesser trochanter and ischial tuberosity, measuring 12.42 ± 5.94 mm in females and 18.73 ± 4.48 mm in males (p = 0.000). Therefore, females have a smaller distance between these anatomical structures than males.

Quadratus femoris space

When we analysed the QFS in relation to the other measurements (cervicodiaphysal and femoral version angles), we concluded that there are no statistically significant relationships between these entities. However, when this space was compared between the two genders, we found again that females had significantly smaller spaces than males (12.42 ± 5.94 *vs* 18.73 ± 4.48 mm, p = 0.000).

Cervicodiaphyseal and femoral version angles

For these two entities, no significant correlations were found with any of the structures studied, and no significant changes were found regarding the gender of the patients.

Moreover, we were able to verify that there was a small but significant positive relationship between these two angles (p = 0.022), with a correlation coefficient of 0.195. Accordingly, participants

Figure 4. Axial hip MRI with (A) SE T_1WI and (B) SE T_2WI sequences. The IFS was reduced on both sides (B). QF atrophy was present without fat infiltration (A). IFS, ischiofemoral space; QF, Quadratus femoris; T_1WI, T_1 weighted imaging; T_2WI, T_2 weighted imaging.

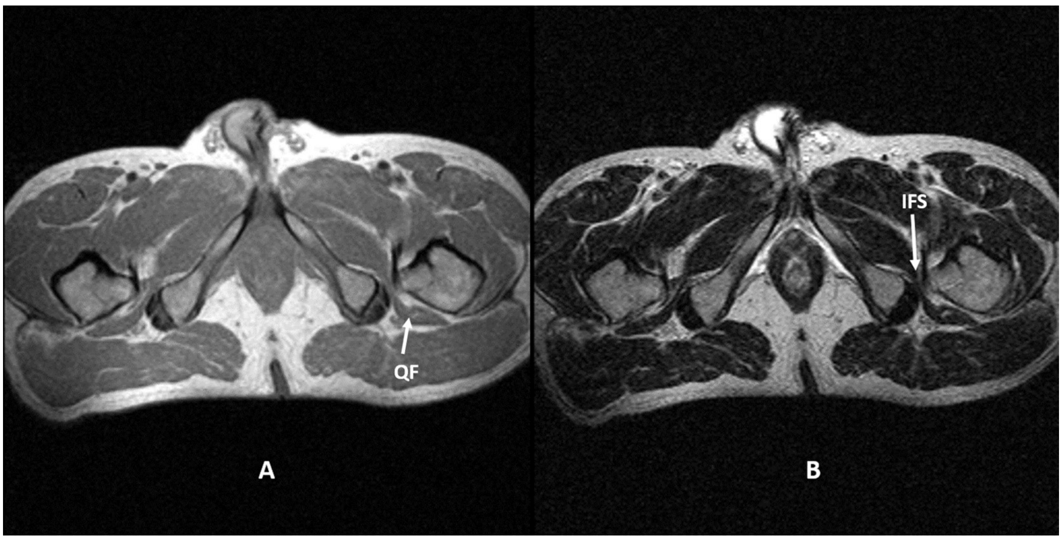
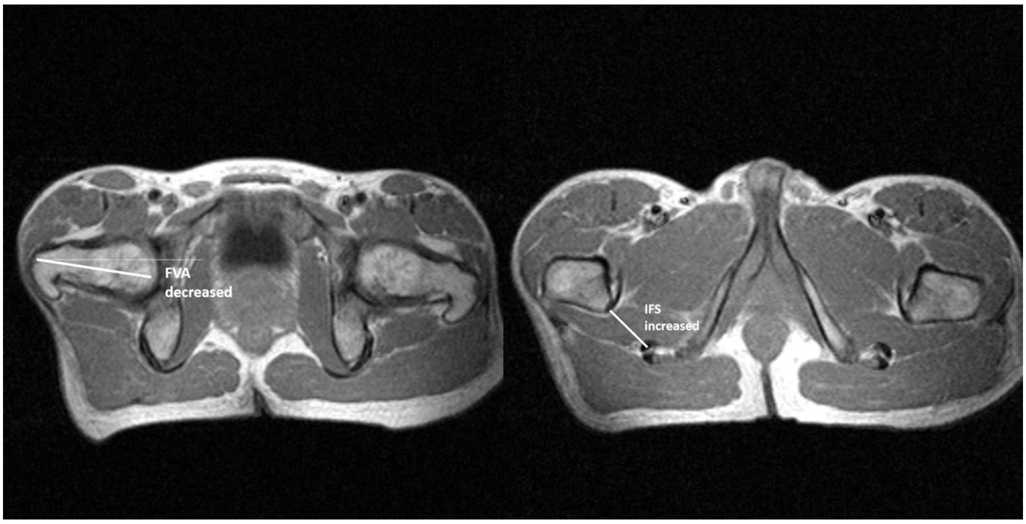


Figure 5. Axial hip MRI with SE T_1WI sequence. There was a negative relationship between the FVA and the IFS. Image showing (A) decreased FVA and (B) increased IFS. FVA, femoral version angle; IFS, ischiofemoral space; T_1WI, T_1 weighted imaging.



with a greater FVA of the femur presented a larger CDA of the femur.

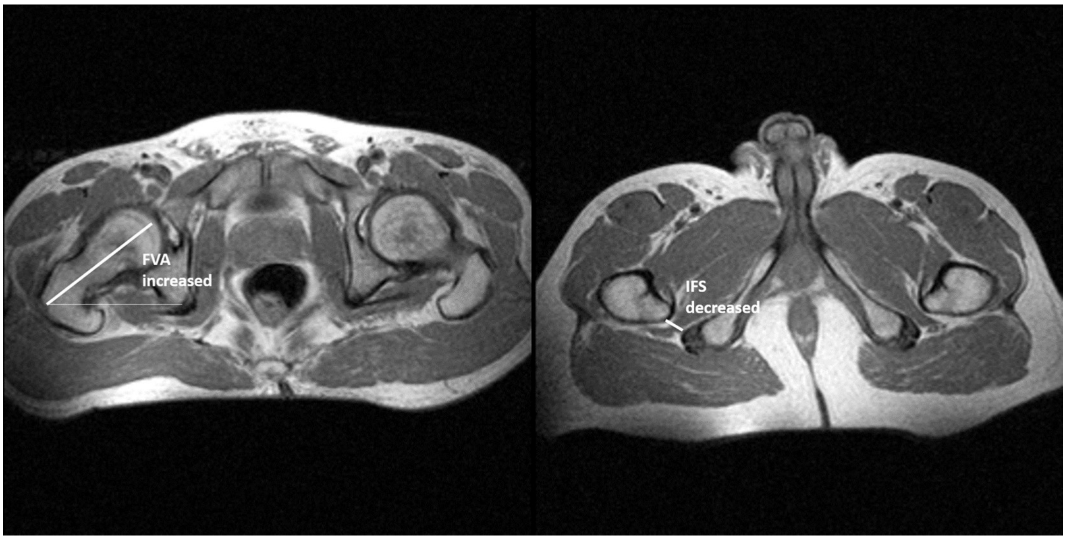
DISCUSSION

Our study shows that a relationship exists between the IFS, QFS and FVA, and between the FVA and CDA. In addition, we found differences in IFS and QFS with respect to the gender of the participants, with smaller measurements found in females than in males.

In recent years, many studies have addressed the relationship between IFI and PHP in patients by means of MRI. Most concluded that patients with an IFS smaller than 15 mm presented IFI,[6,14] which is typically correlated with pain in this area. Furthermore, in a small sample of patients with hip pain showed that the QFS was significantly narrowed and all of the subjects presented edema in QF muscle. For this, we could think about the possibility and the relation between QF alterations and the IFS and hip pain.[6]

When the IFS was evaluated in healthy controls, the average ranged between 17.6 and 30.6 mm, with correspondingly larger dimensions.[1,6,8,11,14–16] In our study, the mean IFS was 20.88 mm, which is within the range of normal measurements. However, we found a large difference between the genders, with smaller values observed in females than in males. The increased prevalence of IFI in females might be due to the different osseous configuration of the female pelvis compared to the male anatomy. As reported in previous studies,[2,6,8,9,11] it is possible that as a result of the ischial tuberosities in females being further apart, with a correspondingly smaller IFS, there is less tolerance for any further narrowing.

Figure 6. Axial hip MRI with SE T_1WI sequence. Image showing (A) increased FVA and (B) decreased IFS. VA, femoral version angle; IFS, ischiofemoral space; T_1WI, T_1 weighted imaging



When considering QFS, the findings of the present study are in agreement with other studies[3,6] which found that the QFS is smaller in patients with an IFI. This space is very strongly correlated with IFS, and appears to be smaller in females than in males. According to Alvarez San Martin,[13] the femoral anteversion defines the functional offset, as an increase in the femoral anteversion can lead to later displacement of the greater trochanter, along with a decrease in the strength of the medium gluteus.

We found a definite correlation between the IFS and FVA. In fact, we demonstrated that if there is an increase in the FVA, causing anteversion of the femur head, there will be corresponding narrowing of the IFS. There is contradictory information in the literature about the femoral version and CDAs in symptomatic and asymptomatic subjects, as well as between females and males. Normally, an FVA larger than 25° is considered a predictor for IFI.[1] Patients with IFI show an increased CDA compared to controls, suggesting that a greater CDA may lead to narrowing of the IFS.[1,17] In one study,[7] it was suggested that a greater femoral neck-shaft angle may lead to narrowing of the IFS because patients with IFI tend to have larger femoral neck-shaft angles than controls. In our study, we did not find a statistically significant relationship between CDA and IFS, although it is possible that such a relationship existed given the increased angle of the minor trochanter vis-a-vis the ischion. Thus, we should consider the possibility that a narrowing of this space is present in such cases.

The main limitation of our study is that it is a retrospective study. In addition, we had to reject some MRI hip studies because they did not meet the inclusion criteria. Looking to the future, we are currently conducting a complementary study to assess the functional capacity in light of the anatomical findings of the current study. Specifically, we will attempt to determine whether patients with IFS present oedema, atrophy or fat infiltration in the QF and/or gluteal tendon pathology (morphological alterations and signal intensity of muscle fibres).

In addition, we were able to verify that a single conventional MRI sequence, available in any equipment, can alert us of an anatomical factor that might predispose individuals to a pathology of the IFS. Therefore, we can state that a simple MRI study can help to prevent and avoid possible pathologies that involve pain in the pelvic and hip area.

In conclusion, an increase in the FVA was correlated with a decrease in IFS in patients in our study. In addition, an increase in the CDA occurred in tandem with an increase in the FVA. Furthermore, the presence of femoral anteversion in the axial SE T_1WI MRI sequence led us to analyse the IFS. The latter likely predisposes individuals to the entrapment phenomena, and probably falls under the umbrella concept of "posterior hip pain". This is especially important in females. Finally, when we analysed both genders, we found significant differences in the distance between the less trochanter and ischial tuberosity, where females have a smaller distance between these anatomical structures than males.

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