The prevalence and risk factors of pubic bone marrow edema in femoroacetabular impingement and hip dysplasia

Hiroki Shimodaira, Akihisa Hatakeyama, Hitoshi Suzuki, Shinichiro Takada, Yoichi Murata, Akinori Sakai and Soshi Uchida

Department of Orthopaedic Surgery and Sports Medicine, Wakamatsu Hospital of University of Occupational and Environmental Health, 1-17-1 Hamamachi, Wakamatsu-ku, Kitakyushu, Fukuoka 808-0024, Japan

*Correspondence to: S. Uchida. E-mail: soushi@med.uoeh-u.ac.jp

ABSTRACT

Femoroacetabular impingement syndrome (FAIS) has been associated with osteitis pubis; however, it is still unclear whether hip dysplasia is associated with osteitis pubis. This study aimed to investigate (i) the incidence of pubic bone marrow edema (BME) on magnetic resonance imaging in symptomatic patients with FAIS, borderline developmental dysplasia of the hip (BDDH) and developmental dysplasia of the hip (DDH) undergoing hip arthroscopic surgery with labral preservation and (ii) the demographic and radiographic factors associated with pubic BME. A total of 259 symptomatic patients undergoing hip arthroscopic surgery between July 2016 and April 2019 were retrospectively reviewed and divided into three groups: FAIS (180 patients), BDDH (29 patients) and DDH (50 patients). Diffuse changes in the pubic bone adjacent to the pubic symphysis were labeled pubic BME, and the prevalence of their occurrence was examined. Multivariate logistic regression analysis was performed to identify factors involved in pubic BME, and odds ratios (ORs) for relevant factors were calculated. There was no significant difference in the prevalence of pubic BME among the three groups (20 [11.1%] of 180 FAIS patients, 6 [20.6%] of 29 BDDH patients and 7 [14%] of 50 DDH patients, \(P = 0.325\)). Multivariate logistic regression analysis showed that acetabular coverage was not associated with pubic BME, whereas younger age and greater alpha angle were still independent associated factors [age \(\leq 26\) years (OR, 65.7) and alpha angle \(\geq 73.5^\circ\) (OR, 4.79)]. Determining the possible association of osteitis pubis with cam impingement in dysplastic hips may provide insights toward a more accurate understanding of its pathophysiology.

INTRODUCTION

Osteitis pubis is an overuse syndrome characterized by pain and tenderness from the groin to the pubic symphysis caused by exercise [1]. Repeated traction forces caused by the rectus abdominis and adductor muscles attached to the pubic bone cause loading and instability of the pubic symphysis [2–5]. The cam type of femoroacetabular impingement syndrome (FAIS) is reported to be a risk factor for sports-related osteitis pubis [6–8]. Larson et al. [9] reported that 75% of American football players had the cam type of FAIS, and 53.6% demonstrated characteristic radiographic findings for osteitis pubis. Phillips et al. [10] also reported that osteitis pubis is 5.26 times more likely to occur with the cam type of FAIS than without it. Birmingham et al. [11] stated in a cadaver study that the direct force exerted by the impingement between the acetabulum and cam lesion can cause pelvic shear stress, leading to rotational instability of the pubic symphysis and resulting in osteitis pubis. Thus, the intra-articular lesion associated with cam deformity is thought to play a major factor in the onset of osteitis pubis.

In recent years, several studies have shown that a subset of patients with hip dysplasia, such as borderline developmental dysplasia of the hip (BDDH) and developmental dysplasia of the hip (DDH), have cam deformities [12–17]. Therefore, it has been suggested that osteitis pubis may occur in dysplastic hips as well as in FAIS. However, the recent literature has not provided clarity on the frequency and relevance of osteitis pubis in patients with dysplastic hips. It would be useful to know the incidence of osteitis pubis in FAIS, BDDH and DDH and the factors that are associated with these issues to facilitate a more detailed understanding of its pathophysiology.

We hypothesized that osteitis pubis is independent of acetabular morphology but correlates with femoral impingement-prone bone morphology and high levels of sport activity. This study aimed to investigate (i) the incidence of pubic bone marrow edema (BME) on magnetic resonance imaging (MRI) in symptomatic patients with FAIS, BDDH and DDH undergoing hip arthroscopic surgery with labral preservation and (ii) the demographic and radiographic factors associated
Fig. 1. Patient selection flowchart. Hip arthroscopic surgery patients remaining after application of the exclusion criteria were divided into three groups according to their LCEAs.

with pubic BME in symptomatic patients undergoing hip arthroscopy.

**MATERIALS AND METHODS**

This retrospective study included 289 consecutive symptomatic patients undergoing hip arthroscopic surgery with labral preservation who were diagnosed with FAIS, BDDH or DDH by a single surgeon (S.U.) between July 2016 and April 2019. The local institutional review board approved the study (Wakamatsu Hospital of University of Occupational and Environmental Health; authorization number H29-220), and all study participants provided informed consent. The indications for hip arthroscopic surgery were persistent groin pain, positive provocative maneuvers, refractory response to nonsurgical treatment, and acetabular labral tearing as detected by 3-Tesla MRI (3T-MRI). The patients were divided into three groups according to the lateral center–edge angle (LCEA): the FAIS group (LCEA >25°), BDDH group (LCEA of 20–25°) and DDH group (LCEA <20°). The diagnosis of FAIS was based on hip pain, a positive flexion adduction internal rotation (FADIR) test, and pincer or cam deformity. Radiographic evidence of a pincer deformity was defined as LCEA ≥40° or acetabular roof obliquity (ARO) ≤0°, and cam deformity was defined as a maximum alpha angle ≥55°. The diagnosis of BDDH and DDH was based on hip pain and a positive FADIR test. Revision cases and cases with arthritic changes of Tönnis Grade 2 or higher were excluded, resulting in 259 included patients: FAIS group (n = 180, male/female = 111/69, mean age 34.9 years), BDDH group (n = 29, male/female = 11/18, mean age 33.8 years) and DDH group (n = 50, male/female = 13/37, mean age 28.7 years) (Fig. 1).

**Radiographic evaluation**

We assessed the radiographs and computed tomography (CT) images at a PACS workstation to determine which radiographic parameters were predictors of pubic BME. The preoperative radiographic images, including the anteroposterior pelvis view in the supine position, false-profile view and Dunn view (flexion 45°; abduction 45°), and preoperative CT scans (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany) were taken with a 2-mm slice thickness including the area from the pelvis to the knee in all patients. The LCEA, Sharp angle and ARO were measured on the anteroposterior pelvis view images (Fig. 2A–C), and the vertical center anterior (VCA) angle was measured on the false-profile view images (Fig. 2D). Alpha angles were measured on the Dunn view images according to the methods described by Nötzli et al. [18] (Fig. 3). Femoral neck anteversion (FNA) was assessed by measuring the angle of FNA based on the posterior condylar axis of the femoral condyle on CT axial images. Evaluation of the pubic symphysis was performed using 3T MRI (Signa EXCITE HD; GE Healthcare, Chicago, IL, USA) images taken preoperatively. We assessed the presence of pubic BME in terms of the T2 fat suppression (T2 FS) in the coronal image (repetition time (TR)/echo time (TE), 4140/91; matrix, 360 × 448; slice thickness, 4.0 mm; field of view (FOV), 360 × 360 mm) and the short T1 inversion recovery in the axial image (TR/TE, 4600/67; matrix, 360 × 320; slice thickness, 4.0 mm; FOV, 360 × 360 mm), based on a study by Branci et al. [19], and defined an involved region ≥1 cm (T2 FS in the coronal image) as a positive finding of the presence of pubic BME [20] (Fig. 4). Two examiners (H.S. and Y.M., each with >10 years of experience in orthopedic surgery) evaluated each parameter and the...
We then calculated the area under the curve (AUC) as independent variables was performed to identify the factors variable and patient characteristics and radiographic parameters. The main finding of our study was that pubic BME occurred and identified the cutoff value for each factor by receiver operating characteristic (ROC) curve analysis. Finally, the stratified incidence of relevant factors was examined, and ORs were calculated from the cutoff values. Statistical analysis was performed with SPSS (version 26.0; IBM, Armonk, NY, USA), and a P value of <0.05 was considered significant. We performed post hoc analysis to determine whether the sample size was sufficient to compare the frequency of pubic BME among the three groups.

RESULTS

The intra- and interobserver reliability of each radiographic parameter and the determination of pubic BME were in substantial to almost-perfect agreement (Table I). Post hoc analysis revealed an effect size (Cramer’s V) of 0.28 for the frequency of occurrence of pubic BME among the three groups, an alpha level of 0.05, a total sample size of 259 and 2 degrees of freedom, resulting in a total power of 0.98, which indicates the adequacy of the sample size in this study.

A comparison of radiographic parameters among the FAIS, BDDH and DDH groups showed significant differences in demographic and acetabular dysplastic parameters (LCEA, Sharp angle, ARO and VCA). There was no difference in the alpha angle among the three groups, nor was there a difference in the percentage above 55°. Pubic BME was found in 20 patients (11.1%) with FAIS, 6 (20.6%) with BDDH and 7 (14%) with DDH, with no significant difference among the three groups (P = 0.325) (Table II). In comparisons according to the presence or absence of pubic BME, pubic BME was associated with younger age, male sex, higher HSAS grade and less FNA than no pubic BME, while there was no significant difference with longer age, male sex, higher HSAS grade and less FNA than pubic BME, whereas younger age and a greater alpha angle were still independent associated factors (Table III). Multivariate logistic regression analysis showed that sex, sports activity, femoral neck version and acetabular coverage were not factors associated with pubic BME, whereas younger age and a greater alpha angle were still independent associated factors (Table IV). ROC curve analysis of the factors involved showed that the cutoff value of age was 26 years old (AUC, 0.867; 95% CI, 0.820–0.914; sensitivity, 67.3%; specificity, 97.0%; P < 0.001) and the alpha angle was 73.5° (AUC, 0.697; 95% CI, 0.594–0.799; sensitivity, 51.5%; specificity, 81.9%; P < 0.001) (Fig. 5). The incidence of pubic BME, stratified according to relevant factors, showed a tendency for younger age and greater alpha angle to increase the frequency of pubic BME [age ≤26 years (OR, 65.7; 95% CI, 8.81–490.4; P < 0.0001) and alpha angle ≥73.5° (OR, 4.79; 95% CI, 2.23–10.2; P < 0.0001)] (Fig. 6).

DISCUSSION

The main finding of our study was that pubic BME occurred to the same extent in both FAIS and hip dysplasia. Moreover, the degree of acetabular dysplasia was weakly associated with pubic BME, and younger patient age (≤26 years, 65.7 times) and greater alpha angle (≥73.5°, 4.79 times) were more likely to be associated with pubic BME. Regarding the validity of the measurements, nearly perfect agreement on the alpha angle was observed in terms of both intra- and interobserver reliability in

![Alpha angle](image_url)
this study, although some studies have found that interobserver reliability is lower than intraobserver reliability [22, 23]. We believe that our relatively high reliability is the result of conducting measurements using computer software (PACS workstation) and closely following the method of Nötzli et al. [18]. As some studies have reported similar levels of reliability to our study using similar methods [24, 25], the validity of our measurement of the alpha angle seems to be satisfactory.

Although pubic BME was expected to occur less frequently in dysplastic hips than in FAIS in this study due to the higher proportion of women and lower levels of sports activity, we found that pubic BME occurred as frequently in dysplastic hips as in FAIS in this study due to the higher proportion of women and lower levels of sports activity, we found that pubic BME occurred as frequently in dysplastic hips as in FAIS in this study. This may be the reason why there was no difference in the occurrence of pubic BME among the three groups. The incidence of cam deformity in dysplastic hips varies widely in previous reports. Anderson et al. [12] reported cam deformity in 10% of dysplastic hips, whereas Clohisy et al. [13] reported it in 75% and Kraeutler et al. [15] reported it in as many as 96%, similar to the results of the present study. These studies, including the present one, included a small number of subjects, and imaging positions vary

| Measurement     | Intraobserver 1 (95% CI) | Intraobserver 2 (95% CI) | Interobserver (95% CI) |
|-----------------|--------------------------|--------------------------|------------------------|
| LCEA            | 0.973 (0.899–0.993)       | 0.990 (0.961–0.997)       | 0.874 (0.687–0.950)    |
| Sharp angle     | 0.895 (0.605–0.974)       | 0.838 (0.390–0.959)       | 0.799 (0.506–0.920)    |
| ARO             | 0.975 (0.904–0.994)       | 0.997 (0.989–0.999)       | 0.937 (0.844–0.975)    |
| VCA angle       | 0.886 (0.570–0.971)       | 0.984 (0.938–0.996)       | 0.847 (0.609–0.940)    |
| Alpha angle     | 0.761 (0.151–0.940)       | 0.968 (0.883–0.992)       | 0.879 (0.665–0.954)    |
| FNA             | 0.890 (0.712–0.959)       | 0.995 (0.982–0.999)       | 0.936 (0.773–0.978)    |
| Pubic BME       | 1.000 (1.000–1.000)       | 0.871 (0.612–0.958)       | 0.932 (0.852–0.968)    |

in the literature. For further validation of our results, a study with a large number of images taken in the same position is necessary.

Several studies have reported an association between the alpha angle and osteitis pubis [6, 7, 9, 10], which are consistent with our findings. On the other hand, the association between dysplasia and the pubic symphysis was outside the scope of our investigation. In addition, several studies have reported associations with extra-articular lesions other than the pubic symphysis. Jacobsen et al. [26] reported that approximately 50% of patients with dysplastic hips had pain associated with the iliopsoas and adductor muscle of the hip, and Moulton et al. [27] reported that an increased anterior opening angle of the acetabulum was associated with tendinitis of the gluteus maximus. These findings may be the result of increased torque in the muscles surrounding the hip joint; this increased torque is compensatory for the hip instability resulting from acetabular shallowness and a reduced loading area [28]. In the present study, the degree of dysplasia did not differ with respect to the presence or absence of pubic BME, suggesting that hip instability was not associated with pubic BME. Osteitis pubis is also known as overuse syndrome, which occurs in active young adult athletes. In this study, young age remained a relevant factor. We thought of reasons why youth might be relevant, such that the stability of the pubic symphysis is more immature at a younger age, making it more prone to instability and inflammation, but we could not find any literature to prove this. Although sports activity was not a significant independent factor in the multivariate analysis, it was close to the level of significance and may be associated to some extent.

There are several limitations to this study. First, the study was single center rather than multicenter, and it was limited to surgical cases. However, a sufficient number of cases were obtained for comparisons between groups and for multivariate analysis according to the power analysis. Second, the study included patients with groin pain but did not confirm that the pain was from an extra-articular rather than an extra-articular source in all cases. As reported by Kheterpal et al. [29], the subject group would be stronger if a hip source of symptoms was proven with an anesthetic exam. However, the study included patients undergoing hip arthroscopic surgery, and all had acetabular labral tearing. We do not believe that this limitation influenced the results. Third, there were differences in demographic data between groups, including age, sex and sporting activity levels.

**Fig. 4.** The diffuse changes of the pubic bone adjacent to the pubic symphysis (white arrows) give rise to an abnormal signal in the T2 fat suppression image in the coronal image (A) and short T1 inversion recovery in the axial image (B).
Table II. Comparison of demographic and radiographic parameters among the FAIS, BDDH and DDH groups

| Parameter                  | FAIS (n = 180) | BDDH (n = 29) | DDH (n = 50) | P      |
|----------------------------|---------------|--------------|--------------|--------|
| Age, years                 | 34.9 ± 14.8 (14–74) | 33.8 ± 15.7 (13–64) | 28.7 ± 12.6 (14–54) | 0.031  |
| Sex, no.                   |               |              |              | <0.0001|
| Male                       | 111 (61.7)    | 11 (37.9)    | 13 (26.0)    |        |
| Female                     | 69 (38.3)     | 18 (62.0)    | 37 (74.0)    |        |
| HSAS, degrees              | 31.5 ± 5.5 (26–49) | 22.4 ± 1.1 (21–25) | 15.5 ± 3.3 (4–20) | <0.0001|
| Alpha angle, degrees       | 71.5 ± 10.5 (41–86) | 65.0 ± 9.0 (43–78) | 65.4 ± 11.6 (39–88) | 0.957  |
| VCA angle, degrees         | 153 (85.0%)   | 26 (89.6%)   | 41 (82%)     | 0.70   |
| ARO, degrees               | 17.1 ± 11.8 (–13–50) | 17.8 ± 10.8 (–1–38) | 21.6 ± 12.6 (–8–46) | 0.07   |
| Pubic BME, no.             | 20 (11.1%)    | 6 (20.6%)    | 7 (14.0%)    | 0.325  |

Data are presented as a median (range) or no. (%).

Table III. Comparison of parameters by pubic BME status

| Parameter                  | With pubic BME | Without pubic BME | P      |
|----------------------------|----------------|-------------------|--------|
| No. of patients            | 33             | 226               | <0.0001|
| Age, years                 | 18.4 ± 3.4 (13–29) | 35.8 ± 14.4 (14–74) | <0.0001|
| Sex, no.                   |                |                   | <0.0001|
| Male                       | 27 (81.8)      | 108 (47.8)        |        |
| Female                     | 6 (18.2)       | 118 (52.2)        |        |
| HSAS, degrees              |                |                   | <0.0001|
| 0–2                        | 4 (12.1)       | 120 (53.1)        |        |
| 3–4                        | 6 (18.2)       | 58 (25.7)         |        |
| 5–6                        | 4 (12.1)       | 12 (5.3)          |        |
| 7–8                        | 19 (57.6)      | 36 (15.9)         |        |
| LCEA, degrees              | 26.6 ± 8.3 (12–44) | 27.5 ± 8.0 (14–49) | 0.53   |
| Sharp angle, degrees       | 42.6 ± 3.9 (35–52) | 42.3 ± 4.3 (31–55) | 0.69   |
| ARO, degrees               | 7.6 ± 6.4 (0–22) | 7.7 ± 6.2 (–13–26) | 0.93   |
| VCA angle, degrees         | 28.2 ± 11.7 (5–48) | 29.4 ± 10.8 (–5–50) | 0.53   |
| Alpha angle                | 71.5 ± 10.9 (43–86) | 64.6 ± 10.2 (39–88) | <0.0001|
| FNA                        | 12.9 ± 13.4 (–12–36) | 18.8 ± 11.6 (–13–50) | 0.007  |

Data are presented as a median (range) or no. (%).

Table IV. Multivariate logistic regression model: risk factors for pubic BME

| Risk factor           | Odds ratio (95% CI) | P      |
|-----------------------|---------------------|--------|
| Age, years            | 0.817 (0.733–0.911) | <0.0001|
| HSAS                  | 1.206 (0.983–1.480) | 0.072  |
| Alpha angle, degrees  | 1.061 (1.017–1.108) | 0.006  |

It is difficult to align demographic data across the three groups in general, since FAIS is generally more common in men with high levels of sporting activity [30], and DDH is more common in women, regardless of sporting activity level [31]. However, the results of the present study do not change the fact that DDH with a greater alpha angle might also potentially cause pubic BME. Fourth, we used MRI signal changes to evaluate osteitis pubis in this study, but the clinical and imaging findings may be divergent. In general, in osteitis pubis, early signal changes in the pubic branch from the peripubic symphysis are seen on MRI [32, 33]. However, this signal change is thought to occur before the onset of symptoms [34] and may also progress asymptotically [19, 35]. Since many studies of the association between FAIS and osteitis pubis have considered MRI findings, including those of asymptomatic cases, superior in identifying osteitis pubis [6, 8–10, 36], we also used pubic BME on MRI to assess osteitis pubis in this study. We believe that this does not weaken the conclusions of the present study. Fifth, the assessors were not blinded to the hip joint parameters when assessing pubic BME, which may have resulted in information bias. However, the determination of pubic BME was clear, with good intra- and interobserver reliability; thus, the effect of the change seems to be small. Sixth, this study was a retrospective study, and sufficient information about the duration of the disease, clinical symptoms, examination findings and past sports history was unavailable. These items were not included in this study and could have been examined in more detail. However, the results of this study are unlikely to be invalidated. Seventh, we could not elucidate the mechanisms that greater alpha angle would be associated with pubic BME. More detailed studies such as cadaver studies or motion analysis studies are needed in the future. Finally, this study was limited to preoperative evaluations. Follow-up studies are needed to determine how pubic BME develops postoperatively.
CONCLUSION

There was no significant difference about pubic BME on MRI among the three groups. Acetabular morphology was not a risk factor for pubic BME, but younger age (age ≤ 26 years) and greater alpha angle (alpha angle ≥ 73.5°) were risk factors for pubic BME. The surgeon should be aware of the possibility of osteitis pubis as well as FAIS in dysplastic hips, especially those with a large cam lesion.

DATA AVAILABILITY

The data supporting the conclusions of this article are included within the article.

ACKNOWLEDGEMENT

We would like to thank American Journal Experts (https://www.aje.com) for editing and reviewing this manuscript for English language.

FUNDING

None declared.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Radic R, Annear P. Use of pubic symphysis curettage for treatment-resistant osteitis pubis in athletes. Am J Sports Med 2008; 36: 122–8.
2. Angoulès AG. Osteitis pubis in elite athletes: diagnostic and therapeutic approach. World J Orthop 2015; 6: 672–9.
3. Hammoud S, Bedi A, Voos JE et al. The recognition and evaluation of patterns of compensatory injury in patients with mechanical hip pain. Sports Health 2014; 6: 108–18.
4. Meyers WC, McKechnie A, Philippon MJ et al. Experience with “sports hernia” spanning two decades. Ann Surg 2008; 248: 656–65.
5. Shortt CP, Zoga AC, Kavanagh EC et al. Anatomy, pathology, and MRI findings in the sports hernia. Semin Musculoskelet Radiol 2008; 12: 54–61.
6. Akgun AS, Agirman M. Association between cam-type femoroacetabular impingement and osteitis pubis in non-athletic population on magnetic resonance imaging. J Orthop Surg Res 2019; 14: 329.
7. Munegato D, Bigoni M, Gridavilla G et al. Sportsherniaandfemoroacetabular impingement in athletes: a systematic review. World J Clin Cases 2015; 3: 823–30.
8. Varada S, Moy MP, Wu F et al. The prevalence of athletic pubalgia imaging findings on MRI in patients with femoroacetabular impingement. Skeletal Radiol 2020; 49: 1249–58.
9. Larson CM, Sikka RS, Sardelli MC et al. Increasing alpha angle is predictive of athletic-related “hip” and ‘groin’ pain in collegiate National Football League prospects. Arthroscopy 2013; 29: 405–10.
10. Phillips E, Khoury V, Wilmot A et al. Correlation between cam-type femoroacetabular impingement and radiographic osteitis pubis. Orthopedics 2016; 39: e417–22.
Prevalence and risk factors of pubic bone marrow edema

11. Birmingham PM, Kelly BT, Jacobs R et al. The effect of dynamic femoroacetabular impingement on pubic symphysis motion: a cadaveric study. Am J Sports Med 2012; 40: 1113–8.
12. Anderson LA, Erickson JA, Swann RP et al. Femoral morphology in patients undergoing periacetabular osteotomy for classic or borderline acetabular dysplasia: are cam deformities common? J Arthroplasty 2016; 31: 259–63.
13. Clohisy JC, Nunley RM, Carlisle JC et al. Incidence and characteristics of femoroacetabular deformities in the dysplastic hip. Clin Orthop Relat Res 2009; 467: 128–34.
14. Ida T, Nakamura Y, Hagi T et al. Prevalence and characteristics of cam-type femoroacetabular deformity in 100 hips with symptomatic acetabular dysplasia: a case control study. J Orth Surg Res 2014; 9: 93.
15. Kraeutler MJ, Goodrich JA, Fioravanti MJ et al. The “outside-in” lesion of hip impingement and the “inside-out” lesion of hip dysplasia: two distinct patterns of acetabular chondral injury. Am J Sports Med 2019; 47: 2978–84.
16. Paliobeis CP, Villar RN. The prevalence of dysplasia in femoroacetabular impingement. Hip Int 2011; 21: 141–5.
17. Wells J, Neple JJ, Crook K et al. Femoral morphology in the dysplastic hip: three-dimensional characterizations with CT. Clin Orthop Relat Res 2017; 475: 1045–54.
18. Nötzli HP, Wyss TF, Stoecklin CH et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br 2002; 84: 556–60.
19. Branci S, Thorborg K, Bech BH et al. MRI findings in soccer players with long-standing adductor groin pain and asymptomatic controls. Br J Sports Med 2015; 49: 681–91.
20. Saito M, Utsunomiya H, Hatakeyama A et al. Hip arthroscopic management can improve osteitis pubis and bone marrow edema in competitive soccer players with femoroacetabular impingement. Am J Sports Med 2019; 47: 408–19.
21. Naal FD, Miozzari HH, Kelly BT et al. The Hip Sports Activity Scale (HSAS) for patients with femoroacetabular impingement. Hip Int 2013; 23: 204–11.
22. Carlisle JC, Zebala LP, Shia DS et al. Reliability of various observers in determining common radiographic parameters of adult hip structural anatomy. Iowa Orthop J 2011; 31: 52–8.
23. Neple JJ, Martell JM, Kim YJ et al. Interobserver and intraobserver reliability of the radiographic analysis of femoroacetabular impingement and dysplasia using computer-assisted measurements. Am J Sports Med 2014; 42: 2393–401.
24. Clohisy JC, Nunley RM, Otto RJ et al. The frog-leg lateral radiograph accurately visualized hip cam impingement abnormalities. Clin Orthop Relat Res 2007; 462: 115–21.
25. Mast NH, Impellizzeri F, Keller S et al. Reliability and agreement of measures used in radiographic evaluation of the adult hip. Clin Orthop Relat Res 2011; 469: 188–99.
26. Jacobsen JS, Holmich P, Thorborg K et al. Muscle-tendon-related pain in 100 patients with hip dysplasia: prevalence and associations with self-reported hip disability and muscle strength. J Hip Preserv Surg 2018; 5: 39–46.
27. Moulton KM, Aly AR, Rajasekaran S et al. Acetabular anteverision is associated with gluteal tendinopathy at MRI. Skeletal Radiol 2015; 44: 47–54.
28. Skalshøi O, Iversen CH, Nielsen DB et al. Walking patterns and hip contact forces in patients with hip dysplasia. Gait Posture 2015; 42: 529–33.
29. Kheterpal AB, Bunnell KM, Husseini JS et al. Value of response to anesthetic injection during hip MR arthrography to differentiate between intra- and extra-articular pathology. Skeletal Radiol 2020; 49: 555–61.
30. Langner JL, Black MS, MacKay JW et al. The prevalence of femoroacetabular impingement anatomy in Division 1 aquatic athletes who tread water. J Hip Preserv Surg 2020; 7: 233–41.
31. Kim CH, Park JJ, Shin DJ et al. Prevalence of radiologic acetabular dysplasia in asymptomatic Asian volunteers. J Hip Preserv Surg 2019; 6: 55–9.
32. Khan W, Zoga AC, Meyers WC. Magnetic resonance imaging of athletic pubalgia and the sports hernia: current understanding and practice. Magn Reson Imaging Clin N Am 2013; 21: 97–110.
33. Omar IM, Zoga AC, Kavanagh EC et al. Athletic pubalgia and “sports hernia”: optimal MR imaging technique and findings. Radiographics 2008; 28: 1415–38.
34. Arendt EA, Griffiths HJ. The use of MR imaging in the assessment and clinical management of stress reactions of bone in high-performance athletes. Clin Sports Med 1997; 16: 291–306.
35. Robinson P, Grainger AJ, Hensor EM et al. Do MRI and ultrasound of the anterior pelvis correlate with, or predict, young football players’ clinical findings? A 4-year prospective study of elite academy soccer players. Br J Sports Med 2015; 49: 176–82.
36. Krishnamoorthy VP, Kunze KN, Beck EC et al. Radiographic prevalence of symphysis pubis abnormalities and clinical outcomes in patients with femoroacetabular impingement syndrome. Am J Sports Med 2019; 47: 1467–72.