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Alexandra Maria Pereira Ferreira

Imaging parameters of ischiofemoral impingement – a systematic review

Parâmetros imagiológicos do conflito isquiofemoral – uma revisão sistemática

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TÍTULO DISSERTAÇÃO/~~MONOGRAFIA~~ (riscar o que não interessa)

Imaging parameters of ischiofemoral impingement – a systematic review

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Para todas as pessoas que me inspiraram e me apoiaram na minha jornada, com especial reconhecimento à minha família, amigos e orientadores da dissertação, Doutor Manuel Gutierres e Dr. Yaroslav.

Imaging parameters of ischiofemoral impingement – a systematic review

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ABSTRACT

Ischiofemoral impingement is a recently identified cause of hip pain, but, despite the recognized importance of imaging modalities in its detection, accurate diagnosis remains a challenge. This systematic review examined studies that evaluated qualitative and quantitative imaging parameters that may aid in the prediction of ischiofemoral impingement in adults. PRISMA guidelines were followed, and two databases, MEDLINE (PubMed) and Web of Science were searched without date restriction. The final review included 24 highly heterogeneous studies. Studies quality was assessed using the National Heart, Lung, and Blood Pressure Institute Study Quality Assessment Tools. Regarding qualitative imaging findings, eight studies found oedema, atrophy and/or tear of the quadratus femoris, hamstring, iliopsoas and/or gluteus muscles. All of the studies found quantitative parameters with ischiofemoral space and quadratus femoris space being the most evaluated. Other quantitative imaging parameters associated with ischiofemoral impingement were hamstring tendon area, total quadratus femoris muscle volume, femur neck angle, femur neck version, the angle between femur neck version and lesser trochanter version, pelvic width, and ischial angle. In relation to femoral offset, inclination angle, and inter-tuberous distance, there was no consistent finding among studies. Less trochanter version was found not to be associated with ischiofemoral impingement. Moreover, seven studies found that adduction, extension and/or external rotation of the hip were also associated with the development of ischiofemoral impingement. Clinical Significance: Ischiofemoral impingement patients vary in hip morphology and kinematics, with imaging having a crucial role in this diagnosis.

Keywords: Ischiofemoral impingement, imaging findings, hip morphology, hip kinematics

RESUMO

O conflito isquiofemoral é uma causa recentemente identificada de dor na anca, mas, apesar da reconhecida importância das modalidades de imagem na sua deteção, o diagnóstico preciso ainda é um desafio. Esta revisão sistemática examinou estudos que avaliaram parâmetros de imagem qualitativos e quantitativos que podem ajudar na predição do conflito isquiofemoral em adultos. As *guidelines* PRISMA foram seguidas e duas bases de dados, MEDLINE (PubMed) e Web of Science, foram pesquisadas sem restrição de data. A revisão final incluiu 24 estudos altamente heterogêneos. A qualidade dos estudos foi avaliada utilizando as ferramentas de avaliação da qualidade dos estudos do *National Heart, Lung and Blood Pressure Institute*. Em relação aos achados de imagem qualitativos, oito estudos encontraram edema, atrofia e/ou rotura dos músculos quadrado femoral, isquiotibial, iliopsoas e/ou glúteos. Todos os estudos encontraram parâmetros quantitativos, com o espaço isquiofemoral e o espaço quadrado femoral sendo os mais avaliados. Outros parâmetros de imagem quantitativos associados ao conflito isquiofemoral foram: área do tendão do músculo isquiotibial, volume total do músculo quadrado femoral, ângulo do colo do fêmur, anteversão do colo do fêmur, o ângulo entre a anteversão do colo do fêmur e a retroversão do trocânter menor, largura pélvica e ângulo isquiático. Quanto ao *offset* femoral, ângulo de inclinação e distância inter-tuberositária não houve achados consistentes entre os estudos. Não foi encontrada associação entre retroversão do trocânter menor e conflito isquiofemoral. Além disso, sete estudos encontraram que a adução, extensão e/ou rotação externa da anca também estavam associadas ao desenvolvimento do conflito isquiofemoral. Significado clínico: pacientes com conflito isquiofemoral apresentam variações na morfologia e cinemática da anca, tendo a imagiologia um papel crucial no seu diagnóstico.

Palavras-chave: Conflito isquiofemoral, achados imagiológicos, morfologia da anca, cinemática da anca

1. INTRODUCTION

Impingement syndromes are now increasingly recognized as a significant cause of hip pain [1]. Ischiofemoral impingement (IFI), a condition typically seen in middle-aged and elderly women, results from the entrapment of the quadratus femoris muscle (QFM) because of an abnormal narrowing of the space between the lesser trochanter of the proximal femur and the ischial tuberosity, known as ischiofemoral space (IFS) [1]. The anatomic relationship between the QFM and the sciatic nerve means IFI can also compress the sciatic nerve [2].

Patients with IFI typically experience nonspecific chronic pain in the posterior hip, buttock, deep medial groin, inner thigh and/or lower back [2-6]. The pain is exacerbated in the sitting position and near the end of the stance phase of gait, which cause patients to develop certain coping mechanisms to alleviate it, such as shifting their weight onto the healthy ischium or reducing the length of their strides, respectively [4, 6, 7]. Snapping sensation, crepitation, or locking in the joint are also common in IFI [1, 5]. Additionally, pain and sensory disturbances in the knee, leg, and foot may also occur due to compression of the sciatic nerve [4, 6]. Physical examination consists in provoke pain with tests that mimic hip kinematics in the end phase of the gait cycle [9, 10, 11] although they are not specific to IFI.

Initial treatment for IFI involves conservative measures such as activity modification, physical therapy [12], and gait control [13]. Additionally, CT-guided [12] and ultrasound-guided [14] corticosteroid injections can provide temporary pain relief. Decompression of QFM by open or arthroscopic surgery has been reported as a potential treatment [15]. However, there is limited information on IFI treatment due to diagnostic uncertainty.

Therefore, it is crucial to define how to diagnose IFI, with imaging having a crucial role in the diagnosis of IFI as clinical symptoms and physical examinations are not very specific for IFI. This study aims to systematically review the literature to sum up common qualitative and quantitative imaging findings in adult IFI patients.

2. METHODS

2.1 Study design

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analise (PRISMA) guidelines, wherefore making a systematic approach to structure the evidence on common qualitative and quantitative imaging findings in adult IFI patients. Level of evidence, III.

2.2 Data sources, search strategy and eligibility criteria

Two databases, MEDLINE (PubMed) and Web of Science, were used for this investigation, using the search terms displayed in Table 1 for both databases. Due to the limited research on IFI, with the first report of IFI imaging findings being only in 2008 [16], no publication date restrictions were applied. The literature search was conducted in November 2022 with the last update in January 2023.

Studies were included whenever they referred to: 1) the population of interest, i.e, adults; 2) the exposure of interest, i.e, qualitative and quantitative imaging findings; 3) the outcome of interest, i.e, diagnosis of IFI.

Studies conducted in another language than English, as well as, unpublished or non-peer-reviewed articles, case reports, narrative reviews/comment articles, systematic reviews and meta-analyses were all excluded from this study. Cadaveric studies were also excluded as they did not use any imaging tool.

2.3 Study selection

Duplicate articles were removed using EndNote X20. Two researchers independently screened titles and abstracts based on eligibility criteria and resolved disagreements through

discussion. A second screening of available full text was conducted, resulting in 24 eligible articles.

2.4 Data extraction

Data extraction was individually organized in a spreadsheet (see Supplementary Table 1), and then compared by the investigators. The information collected includes reference and study details (first author name, publication year of the study, country, study type), participant information (study population, number of participants, number of females participants), imaging assessment details (imaging tool used, position of the hips in the imaging assessment), exposure details (qualitative and/or quantitative parameters evaluated in the study), and main study findings.

2.5 Risk of bias assessment

The National Heart, Lung and Blood Pressure Institute Study Quality Assessment Tools were used to evaluate bias risk in 24 studies. The appropriate tool was selected based on the study design of each study. Each study was assessed using the criteria, answered as Y (yes), N (no), CD (cannot determine), NA (not applicable), or NR (not reported), and rated as good, fair, or poor. Results are presented in Supplementary Tables 2, 3, and 4.

3. RESULTS

3.1 Study selection

A total of 280 articles were initially identified from the two databases, from which 75 duplicates were removed. Among the 205 articles that were screened, 179 were excluded based on titles and abstracts considering the inclusion and exclusion criteria. Of 29 articles, 2

full-texts were unavailable, leaving 27 for full-text review. 3 articles were excluded because they did not evaluate imaging findings; instead, measurements were conducted using direct measures with calipers or straight rulers on cadavers. As a result, 24 articles were included in the final systematic review. The flowchart in Figure 1 shows the search method and article selection. Regarding quality assessment, most of the studies [1, 3, 5, 17-22, 24-26, 28-34] were rated as "Fair", with a smaller proportion being classified as "Good" [7, 12, 13] and "Poor" [23, 27], as is presented in Table 2. In brief, most of the studies did not include a sample size justification and did not adjust statistically in the analyses of key potential confounding variables. Risk bias relative to blinding was also observed in some studies.

3.2 Study characteristics

Table 2 summarizes general information of studies included in this review. Out of the 24 articles, twenty studies [3, 5, 7, 13, 17-34] were published in the last ten years, in which half of them (n=10) [7, 13, 19, 20, 24, 26-29, 34] were published in 2020-2021. Regarding geographic distribution, twelve were from USA [3, 7, 12, 13, 21, 23, 25, 28-32], four were from Turkey [1, 20, 22, 33], two were from UK [5, 34], two were from China [19, 27], one was from Egypt [17], one was from Brazil [18], one was from Spain [24] and one was from South Korea [26]. Respecting to study design, all of them were observational studies, in which fifteen [1, 3, 5, 7, 12, 13, 19-26, 29] were retrospective and nine [17, 18, 27, 28, 30-34] were prospective studies. Eleven were case-control [1, 13, 17-23, 27, 28,], eleven were cross-sectional [3, 5, 24-26, 29-34] and two were case-series [7, 12].

3.3 Participants characteristics

A total of 2625 adults and 3328 hips were evaluated. In twelve studies [1, 12, 13, 17, 18-23, 27, 28], it was compared the hips of participants with clinical or imaging findings of IFI (IFI

group) with hips without imaging findings of IFI (control group). In three of these studies [1, 17, 23], the contralateral hip of clinical IFI participants was included in the control group. Two studies [5, 7] were realized in the hips of participants with clinical [7] or with imaging findings [5] of IFI. Two studies [24, 29] did not distinguish between the hips of participants with or without IFI. The remaining eight studies [3, 25, 26, 30-34] were realized in hips without imaging findings of IFI, although in one study [25], the hips evaluated were the contralateral hips of participants with clinical IFI.

The study population included different age ranges. The youngest asymptomatic population had a mean age of 23 years [32], while the youngest IFI population had a mean age of 35.2 years [17]. The oldest asymptomatic population had a mean age of 51.7 years [26], whereas the oldest IFI population had a mean age of 58.1 years [19]. Regarding gender, three studies [5, 12, 28] were conducted exclusively in females, and fifteen studies [1, 3, 7, 13, 17-25, 27, 29] had a higher percentage of females than males. In contrast, only four studies [26, 31-33] had more men than women, while two studies [30, 34] had an equal number of males and females.

3.4 Imaging tool

The preferred imaging tool for hip assessment was MRI, utilized in twenty of them [1, 5, 7, 12, 13, 17-25, 27, 28-30, 32, 34] while CT scan was used in four studies [3, 26, 32, 34] and ultrasound in one [31]. Atkins et al. [32] used both MRI and CT scans.

In seventeen studies [1, 3, 5, 7, 12, 13, 17-26, 33], hip assessments were done in one static position. In eight studies [1, 3, 17-20, 26, 33], hips were in a neutral position, while in five studies [12, 13, 21, 24, 25], hips were in internal rotation. One study [23] assessed hips in a functional walking position, and three studies [5, 7, 22] did not mention the hip position. Of the remaining seven studies [27-32, 34], five [27, 29-32] utilized multiple static positions to

assess the hips. Hatem et al. [29] conducted a study with two MRI assessments. The controlled MRI assessed the hips with the participants positioned supine with reproduction of the foot progression angle and the distances between right and left knees, ankles, and great toes measured in the standing position. The non-controlled MRI did not specify the participant's position. Zhang et al. [27] evaluated hips in the frontal plane at 0°, 30°, and 60° external rotation angles. Finnoff et al. [31] used ultrasound to assess hips at 9 different femoral positions, combining the transverse and frontal plane hip motions. Johnson et al. [30] assessed participants in three positions: two in supine and one in prone. The main difference between the two supine positions was the degree of flexion of the hips, with hips 25º flexed in supine 2 [30]. Atkins et al. [32] assessed hips using MRI in a neutral position. However, with CT scan dynamic assessments were performed in 5 positions: standing, internal/external rotation, level and incline treadmill walking at a self-selected speed. These dynamic assessments were performed in more two studies [28, 34].

3.5 Qualitative and quantitative imaging parameters

Table 3 summarizes the qualitative and quantitative imaging parameters evaluated in the studies included in this systematic review.

Regarding qualitative imaging parameters, there were found abnormalities in QFM [1, 5, 7, 12, 13, 17, 19, 33], hamstring [1, 5, 12, 13, 17, 33], iliopsoas [12, 33], and gluteus medius and minimus [5, 13].

Quantitative parameters measured included hamstring tendon area (HTA) [1], total quadratus femoris muscle (TQFMV) [1], ischiofemoral space (IFS) [1, 3, 5, 7, 12, 13, 17-34], quadratus femoris space (QFS) [1, 5, 7, 12, 13, 17-24, 27, 28, 34], inclination angle (IncA) [1, 3, 7, 20, 22, 24, 26, 32, 34], femur neck angle (FNA) [20-22, 24], femur neck version (FNV) [20, 23, 26, 32, 34], lesser trochanteric version (LTV) [3, 23, 25, 32, 34], the angle between FNV e

LTV (FNVLTV) [23], femoral offset [3, 24], pelvic width [34], ischial angle (IA) [20-22, 32], inter-tuberous distance (ITD) [19, 20, 32-34] and femoral metaphyseal and lesser trochanter centroid coordinates [28].

HTA is the area between the borders of all three hamstring tendons [1]. TQFMV is the total volume of quadratus femoris muscle [1]. IFS is the smallest distance between the lesser trochanter and ischial tuberosity [1, 3, 5, 7, 12, 13, 17-34]. QFS is the smallest distance between the lesser trochanter and the tendon of the hamstring [1, 5, 7, 12, 13, 17-24, 27, 28, 34]. IncA is the angle between the femoral shaft and femoral neck [1, 3, 7, 20, 22, 24, 26, 32, 34]. FNA is the angle between a line drawn through two circles around the femoral neck and the horizontal plane, measured at the level of the femoral neck without the femoral head [20-22, 24]. FNV is the angle between FNA and knee angle [20, 23, 26, 32, 34]. LTV is the angle between the lesser trochanteric angle and the posterior femoral condyles line [3, 23, 25, 32, 34]. FNVLTV the angle between FNV and LTV [23]. Femoral offset is the distance from the center of the femoral head to the axis of the femoral shaft [3, 24]. Pelvic width is the distance between femoral head centers [32]. IA is the angle between the ischiopubic ramus and the horizontal plane [20-22, 32]. ITD is the largest distance between the ischial tuberosity internal cortices at the hamstring tendon adhesion level [19, 20, 32-34].

Still in the quantitative parameters, seven studies [27-32, 34] assessed IFS and/or QFS in different hip movements, with five [27-29, 31, 32] focusing on hip rotation, four [29, 30, 32, 34] on hip flexion/extension, and three [29, 31, 32] on hip adduction/abduction. Femoral metaphyseal and lesser trochanter centroid coordinates were evaluated in relation to hip rotation [28].

3.6 Study findings

Studies demonstrated that in IFI patients is common to find oedema (n=8) [1, 5, 7, 12, 13, 17,

19, 33], fatty infiltration (n=6) [1, 5, 12, 13, 17, 33] or partial tear (n=2) [12, 17] of QFM. Xing et al. [19] demonstrated that as the grade of oedema in the quadratus femoris muscle increased, the corresponding IFS gradually decreased. Associated with these QFM abnormalities, it was found hamstring enthesopathy (n=2) [1, 5, 33] or tear (n=4) [12, 13, 17, 33], oedema extending to the adjacent iliopsoas tendon (n=2) [12, 33], gluteal enthesopathy (n=1) [5], gluteal atrophy (n=1) [13] and gluteal partial tears and full-thickness tears (n=1) [13].

Concerning quantitative imaging parameters in one static assessment, studies found that the IFI group compared with the control group had a statistically lower TQFMV (n=1) [1], IFS (n=10) [1, 12, 13, 17-23] and QFS (n=10) [1, 12, 13, 17-23], whereas had a statistically higher HTA (n=1) [1], IncA (n=2) [1, 20], FNA (n=3) [20-22], FNV (n=2) [20, 23], FNVLTV (n=1) [23] and IA (n=3) [20-22]. Conflicting results were found in relation to ITD measurements, with one study [19] showing significantly higher measurements in the IFI group compared to the control group and another study [20] showing no significant difference. No significant difference in LTV measurements was found between the IFI group and the control group in one study [23].

Other studies demonstrated the imaging parameters common in IFI through a demonstration of the correlation between these parameters and IFS and/or QFS. With respect to measurements related to the proximal femur, it was shown that FNA [24] and FNV [26] were negatively correlated with IFS – indicating that as FNA or FNV increase, IFS tends to decrease. Mixed findings were found related to correlations between femoral offset and or IncA with IFS. Hujazi et al. [3] found a positive correlation, while Audenaert et al. [34] did not find any correlation between them. Won et al. [26] reported a negative correlation between IFS and IncA, whereas two studies [7, 25] did not find a significant correlation between these variables. LTV was showed not to correlate with IFS in three studies [3, 25,

34]. Looking at pelvic-related measurements, three studies [19, 33, 34] found a negative correlation between ITD and IFS and/or QFS. Audenaert et al. [34] found a negative correlation between pelvic width and IFS.

Still in quantitative parameters, multiple static positions imaging and dynamic imaging showed the impact of hip kinematics in the development of IFI. IFS and/ or QFS were shown to be influenced by abduction/adduction (n=3) [30-32], flexion/extension (n=4) [29, 30, 32, 34] and external/internal rotation (n=5) [27-29, 31, 32]. These studies demonstrated that IFS and/or QFS were narrower in adduction, extension, and internal rotation. Whereas Zhang et al. [27] found that IFS in IFI patients was smaller than in the control group, regardless of the external hip rotation angles, Vicentini et al. [28] demonstrated that, during hip rotation, IFS reduction only begins to be significantly different between these two groups after neutral position. Moreover, they tracked hip bone movements during external rotation and found that the femoral metaphysis in IFI and control groups moved similarly, but the lesser trochanter had a different trajectory [28]. In control hips, the lesser trochanter moved closer to the midline, while in narrowed hips, it moved backward and toward the midline in a posteromedial crescentic trajectory [28].

4. DISCUSSION

This systematic review aimed to evaluate and sum up the qualitative and quantitative imaging findings of ischiofemoral impingement. There is usually a 2 cm gap between the lesser trochanter and the ischial tuberosity which allows the femur to rotate freely without space conflict [35]. However, when this gap is decreased, it can cause a condition called ischiofemoral impingement [12]. This impingement was initially noted by Johnson et al. [35], in 1877, on three post-surgical patients with hip pain on radiographs with hypertrophic changes in lesser trochanter suggesting impaction against ischium. Resection of the lesser

trochanter widened the space and provided relief in all cases [35]. Patti et al. [16] were the first to demonstrate MRI findings related to non-iatrogenic IFI in a case report in 2008, but the concept of IFI only become more recognized after an MRI study by Torriani et al. [12].

Although it is critical to consider subjective and objective clinical findings, imaging is the main tool to diagnose IFI. MRI is the preferred imaging tool for diagnosis, but CT scans, ultrasound, and radiography can also be used [2, 3, 26, 36, 37, 38]. CT scan is a more accurate imaging modality for cortical bone, being especially useful for measuring distances between bones of hip [3, 26]. Moreover, a CT scan with dual fluoroscopy has an important role in dynamic IFI because simplifies image interpretation and improves the evaluation of the relationship between QFM and adjacent osseous structures during hip motion [32]. US has an important role on evaluate the integrity of deep gluteal muscles that can also be involved in dynamic IFI [6]. Radiography is important to detect osseous changes associated with chronic IFI [2].

In clinical practice, the general trend is to present the diagnosis of IFI with findings of narrowed IFS and QFS with QFM abnormalities. Singer et al. [42] conducted a meta-analyse that found smaller IFS and QFS in IFI cases compared to controls. Twelve studies included in this systematic review [1, 12, 13, 17-23, 27, 28] were consistent with these data. Regarding QFM abnormalities, it was found that at the initial stage, it become oedematous, presenting with hyperintensity on T2 images. Tosun et al. [1] proposed a grading system for quadratus femoris muscle oedema, which includes four grades of oedema ranging from no oedema (Grade I) to severe (Grade IV) with oedema extending to surrounding tissues outside the muscle. As the grade of oedema in the quadratus femoris muscle increased, the corresponding IFS gradually decreased [19]. In the chronic stage, muscle shrinks and turns into fat. Tosun et al. [1] also proposed a grading system for quadratus femoris muscle atrophy based on T1 weighted imaging, which includes four grades ranging from no increase in signal intensity to

globular increases involving more than 50% of the muscle. Muscle atrophy can likewise be observed by a decrease of a quantitative imaging parameter – TQFMV [1]. In severe cases, the muscle can partially or completely rupture [12, 17]. Associated with QFM abnormalities, oedema and/or tears of the hamstring and iliopsoas muscle were also common in IFI [1, 5, 12, 13, 17, 33], because of their anatomic relations. The association between hamstring muscle and IFI can also be observed by an increase of another quantitative parameter - HTA [1].

However, there are many other qualitative and quantitative imaging parameters common in IFI that are related to its etiology. Frequently, IFI is associated with hip morphology features. About measurements related to proximal femur morphology, FNA [20-22, 24], FNV [20, 23, 26] and FNVLTV [23] were found to be related to IFI, while LTV [3, 23, 25, 34] did not show a statistically significant relationship. Considering that, the increased FNVLTV angle in IFI patients may be secondary to the increased FNV. Mixed findings were observed related to femoral offset and IncA. Whereas Audenaert et al. [34] did not find a correlation between femoral offset and IFS, Hujazi et al. [3] showed a positive correlation between them. In relation to IncA, three studies [1, 20, 26] found that IncA was associated with the development of IFI, while two studies [7, 24] did not show that. Regarding measurements related to pelvis morphology, pelvic width [34] and IA [20-22] are found to be related to IFI. Sussman et al. [43] performed a cadaveric study in which they stated that the IA widened due to ITD. However, the literature findings on the effect of ITD in IFI are not very consistent. Four studies included [19, 20, 33, 34] supported the relation between ITD and IFI, whereas one study [20] did not find an association between ITD and IFI. Overall, these mixed findings suggest that further research is needed to fully understand the relationship between femoral offset, IncA and ITD with IFI.

Nevertheless, IFI can also have dynamic etiology, which means that IFI may have different imaging parameters of mentioned above. The effect of hip kinematics on IFI can be observed

through quantitative assessments of the hip using multiple static or kinematic imaging studies as well [27-32, 34]. In a case report, Singer et al. [40] presented the first MRI evidence of the hip range of motion on IFS, demonstrating that passive external hip rotation led to a narrowing between the trochanter and the ischial tuberosity. Finnoff et al. [31] were the first to evaluate the impact of hip abduction/adduction on IFS measurements. On the other hand, a cadaveric study [41] conducted in 2016 was the first to demonstrate the effect of hip flexion/extension on IFS dimensions. Recent studies have reported a growing body of evidence demonstrating that external rotation [27-29, 31, 32, 40], adduction [29, 31, 32], and extension [29, 30, 32, 34, 41] reduce IFS. Therefore, IFI patients may be adults involved in certain sports or occupations that require repetitive hip motions, who can have a normal IFS measurement in one static imaging. This review found that dynamic IFI could be caused by hip abductor insufficiency as two studies included [5, 13] found abnormalities of the gluteus in IFI patients. A case report described by DiSciullo et al. [39] was the first to report that hip abductor insufficiency may dynamically contribute to the narrowing of IFS during hip motion. On the other hand, Vicentini et al. [28] evaluated femoral metaphyseal and lesser trochanter centroid coordinates, suggesting that, more than repetitive hip motions, IFI patients may have distinct biomechanisms during hip motion as it was found that while control hips externally rotated avoiding collision with the ischium, external rotation in IFI patients caused the lesser trochanter centroid to move posteriorly while translating to the midline, describing a posteromedial crescentic trajectory. This finding suggests that IFI patients can have distinct hip motion patterns, so distinct femoral metaphyseal and lesser trochanter centroid coordinates during hip motions are quantitative imaging parameters that may be found in IFI patients.

This systematic review has several limitations that need to be acknowledged. A lot of the studies included in the study were retrospective and cross-sectional, limiting our ability to

determine causality. The small size and the high heterogeneity of the population of the studies prevented a more detailed analysis. Moreover, the position of the hips in the imaging assessment was different among studies that evaluated hips in one static position. As mentioned above, hip kinematics affects IFS, so the comparation between the studies may not be very reliable. Therefore, more population-based studies with a larger sample size and considering the dynamic condition of IFI are necessary to validate the findings and establish the parameters that are still incongruous.

5. CONCLUSION

In conclusion, this systematic review helps to validate qualitative and quantitative imaging parameters that predict the development of static and dynamic IFI although further research is needed to confirm these results and to determine their clinical relevance.

6. ACKNOWLEDGMENTS

Not applicable.

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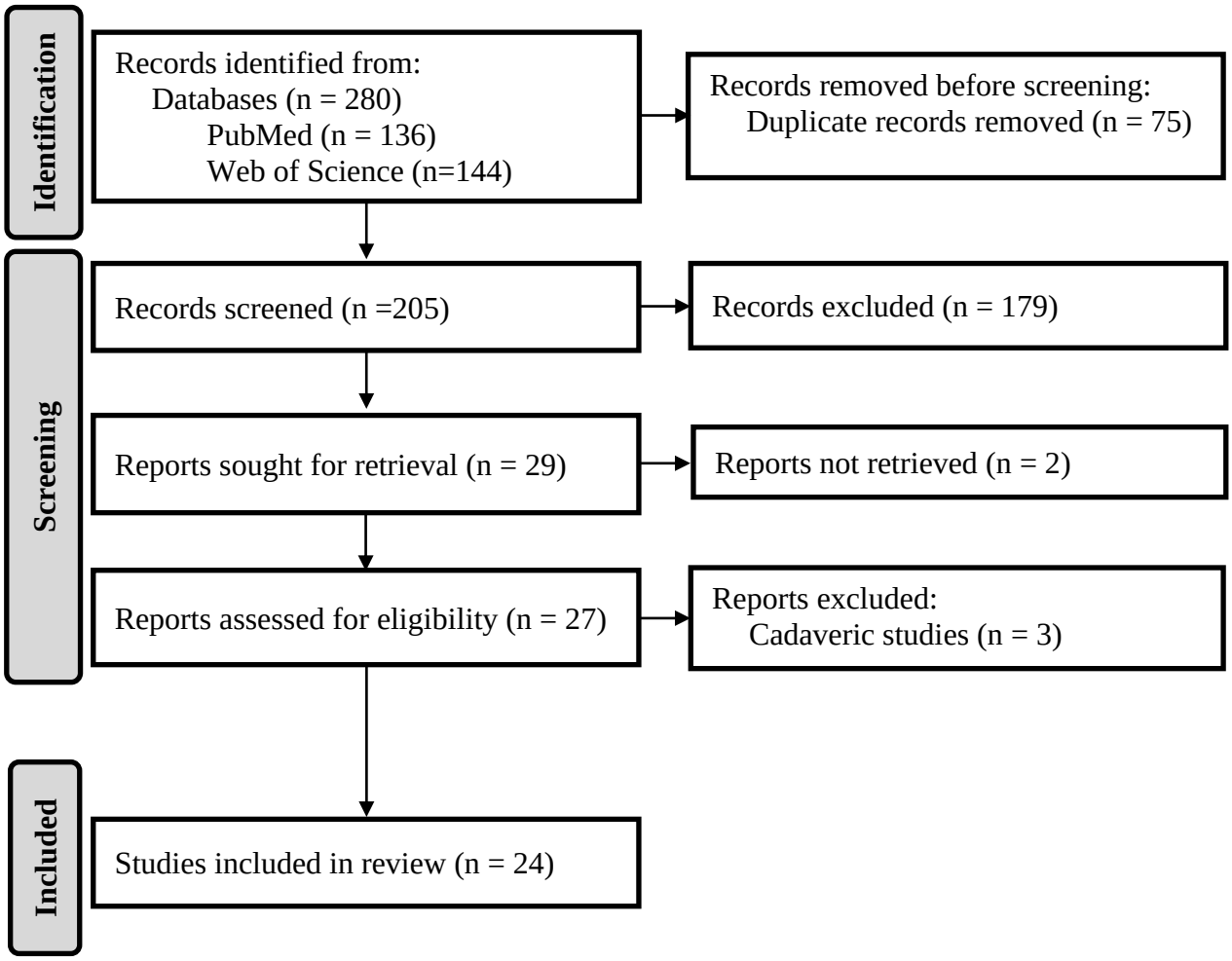
8. FIGURES

Figure 1: Flowchart showing the literature search method.



9. TABLES

Table 1: Search terms used in databases search.

1	Ischiofemoral impingement (All fields)
2	Ischiofemoral impingement syndrome (All fields)
3	Ischiofemoral space pathology (All fields)
4	IFS narrowing (All fields)
5	Quadratus femoris entrapment (All fields)
6	#1 OR #2 OR #3 OR #4 OR #5
7	Imaging (All fields)
8	Radiologic assessment (All fields)
9	Radiologic findings (All fields)
10	Radiographic findings (All fields)
11	#7 OR #8 OR #9 OR #10
12	#6 AND #11

Table 2: General information about studies included in this systematic review.

	Total number of studies (n=24)	
	n	%
Study type		
Case-control	11	46%
Cross-sectional	11	46%
Case-series	2	8%
Publication year		
2009-2019	14	58%
2020-2021	10	42%
Continents and countries		
USA	12	50%
Turkey	4	18%
UK	2	8%
China	2	8%
Egypt	1	4%
Brazil	1	4%
Spain	1	4%
South Korea	1	4%
Overall study quality		
Good	3	13%
Fair	19	79%
Poor	2	8%
Imaging tool		
MRI	20	83%
CT scan	4	17%
Ultrasound	1	4%
Static scans	17	71%
Multiple static scans	5	21%
Dynamic scans	3	13%

Table 3: General imaging parameters evaluated in studies included in this systematic review.

	Total number of studies (n=24)	
	n	%
Qualitative imaging parameters		
QFM abnormalities	8	33%
Hamstring abnormalities	6	25%
Iliopsoas abnormalities	2	8%
Gluteus abnormalities	2	8%
Quantitative imaging parameters		
HTA	1	4%
TQFMV	1	4%
IFS	24	100%
QFS	16	67%
IncA	9	38%
FNA	4	17%
FNV	5	21%
LTV	5	21%
FNVLTV	1	4%
Femoral offset	2	8%
Pelvic width	1	4%
IA	4	17%
ITD	5	21%
Femoral metaphyseal and lesser trochanter centroid coordinates	1	4%

QFM, quadratus femoris muscle; HTA, hamstring tendon area; TQFMV, total quadratus femoris muscle volume; IFS, ischiofemoral space; QFS, quadratus femoris muscle; IncA, inclination angle; FNA, femur neck angle; FNV, femur neck version; LTV, lesser trochanter version; FNVLTV, the angle between FNV and LTV; IA, ischial angle; ITD, inter-tuberous distance.

10.SUPPLEMENTARY TABLES

Supplementary table 1: Characteristics of studies included in this review.

Study authors, year	Article Title	Country	Study design	Study population	Number of participants	Age (mean age)	Gender (females)	Imaging tool	Main outcomes	Key findings
Torriani et al., 2009	Ischiofemoral impingement syndrome: an entity with hip pain and abnormalities of the quadratus femoris muscle	USA	Retrospective case-series	IFI group: Patients with quadratus femoris muscle oedema Control group: Patients who underwent MRI after a fall to rule out fracture (no fracture evidence).	IFI group: 9 (12 hips) Control group: 10 (11 hips)	IFI group: 53 Control group: 67	All (100%)	MRI (supine; internal rotation position)	IFS, QFS and QFM, hamstring and iliopsoas abnormalities	IFS and QFS were significantly narrower in the IFI group. There was a significant correlation between IFS and QFS measurements. Abnormalities of the quadratus femoris muscle included oedema, fatty infiltration, and partial tear. The hamstrings tendons of affected subjects showed evidence of oedema and partial tears. The iliopsoas tendon of four subjects showed mild oedema.
Khodair et al., 2014	Ischiofemoral impingement syndrome: spectrum of MRI findings in comparison to normal subjects	Egypt	Prospective case-control	IFI group: Patients with chronic hip joint pain. Control group: Patients with no history of hip joint pain or fractures contralateral hip of the patients of IFI group.	IFI group: 14 (14 hips) Control group: 20 (74 hips)	IFI group: 35.2 Control group: 34.0	IFI group: 12 (86%) Control group: 17 (85%)	MRI (supine; neutral position)	IFS, QFS and QFM abnormalities	The IFI group had significantly narrower IFS and QFS compared to the control group. QFM changes ranged from focal oedema to partial tear in affected joints: focal oedema, diffuse oedema, muscle atrophy with fat replacement, and partial tear.

Barros et al, 2019	Evaluation of the ischiofemoral space: a case-control study	Brazil	Prospective case-control	Patients who underwent MRI of the hip joint. IFI group: Patients with deep gluteal pain positive clinical test, with quadratus femoris muscle abnormalities. Control group: Remaining patients.	IFI group: 6 (6 hips) Control group: 44 (44 hips)	IFI group: 50.5 Control group: 46.9	IFI group: 6 (100%) Control group: 27 (61%)	MRI (supine; neutral position)	IFS and QFS	The IFI group had smaller IFS and QFS than the control group with a strong direct correlation between IFS and QFS values.
Xing et al, 2021	MRI measurement assessment on ischiofemoral impingement syndrome	China	Retrospective case-control	IFI group: Patients with posterior hip pain and quadratus femoris abnormalities Control group: Patients with no hip pain or history of hip/pelvic fractures.	IFI group: 58 (91 hips) Control group: 61 (122 hips)	IFI group: 58.1 years Control group: 53.3	IFI group: 43 (74%) Control group: 44 (72%)	MRI (supine, neutral position)	IFS, QFS, ITD and QFM abnormalities	IFS and QFS were narrower in the IFI group than the control group, while ITD was larger in the IFI group. A positive correlation was observed between IFS and QFS, and a negative correlation was found between ITD and IFS or QFS. As the grade of oedema in quadratus femoris increased, corresponding IFS gradually decreased. The corresponding IFS width of grade 0 oedema was significantly higher than that of grade 1, 2, or 3.
Tosun et al., 2011	Ischiofemoral impingement: evaluation with new MRI parameters and assessment of their reliability	Turkey	Retrospective case control	IFI group: Patients with hip pain and QFM oedema. Control group: Patients with hip pain but without QFM abnormalities.	IFI group: 50 patients (70 hips) Control group: 30 cases (38 hips)	IFI group: 51 Control group: 47	IFI group: 42 (84%) Control group: 25 (83%)	MRI (supine; neutral position)	IFS, QFS, IncA, HTA, TQFMV and QFM abnormalities	The IFI group had lower IFS, QFS, and TQFMV values and higher HTA and IncA values compared to controls. QFM abnormalities included oedema and fatty replacement, which were significantly higher in the patient group. No oedema was observed in the control group.

Dablan et al., 2021	Ischiofemoral impingement syndrome: effect of morphological variations on the diagnosis	Turkey	Retrospective case-control	IFI group: Patients with QFM oedema and hip or buttock pain. Control group: Patients without QFM signal changes and hip pain.	IFI group: 20 (37 hips) Control group: 28 (56 hips)	IFI group: 51.1 years Control group: 48.2	IFI group: 19 (95%) Control group: 26 (93%)	MRI (supine; neutral position)	IFS, QFS, IncA, IA, ITD, FNA and FNV	IFI and control groups differed significantly in all MRI parameters, except ITD. Patients had lower IFS and QFS, and higher IncA, IA, FNA, and FNV values than controls.
Bredella et al., 2014	Pelvic morphology in ischiofemoral impingement	USA	Retrospective case-control	IFI group: Patients with hip/buttock pain and ipsilateral quadratus femoris oedema. Control group: Patients without hip/buttock pain who underwent MRI for neoplasm surveillance or pelvic fracture exclusion.	IFI group: 84 (97 hips) Control group: 51 (71 hips)	IFI group: 53 Control group: 52	IFI group: 73 (87%) Control group: 33 (65%)	MRI (supine; internal rotation position)	IFS, QFS, IA, FNA	Patients with IFI had decreased IFS and QFS, increased IA, and increased FNA compared with controls, independent of age and gender.
Akça et al., 2016	Ischiofemoral impingement: assessment of MRI findings and their reliability	Turkey	Retrospective case-control	IFI group: Patients with quadratus femoris abnormalities. Control group: Patients with normal MRI findings and no clinical symptoms of IFI syndrome.	IFI group: 20 (30 hips) Control group: 17 (25 hips)	IFI group: 49.5 Control group: 43.0	IFI group: 17 (85%) Control group: 11 (65%)	MRI (no refers position)	IFS, QFS, IA, and FNA	IFS and QFS were significantly lower in patients as compared to the control group. IA and FNA values were significantly higher in patients compared with the control group.

Gómez-Hoyos et al., 2016	Femoral neck anteversion and lesser trochanteric retroversion in patients with ischiofemoral impingement: a case-control magnetic resonance imaging study	USA	Retrospective case-control	IFI group: Patients with hip pain. Control group: Patients with contralateral hip pain and with bilateral version study.	IFI group: 11 (11 hips) Control group: 250 (250 hips)	IFI group: Mean age 40 years Control group: 39.48 years	IFI group: 9 (82%) Control group: 164 (66%)	MRI (walking position)	IFS, QFS, FNV, LTV, FNVLTV	Symptomatic patients had smaller mean IFS and QFS, and higher mean FNV and angle between FNV and LTV than asymptomatic patients. Mean LTV was not increased in symptomatic IFI patients compared to asymptomatic hips.
Gardner et al., 2020	Is there a relationship between femoral neck-shaft angle and ishiofemoral impingement in patients with hip pain	USA	Retrospective case series	Patients with hip/groin pain.	Total: 89 (100 hips) QF edema group: 18 hips No QF edema group: 82 hips	Total: 42.7 QF edema group: 51.1 No QF edema group: 40.8	Total: 73 (82%)	MRI (no refers position)	IFS, QFS and IncA	MRI showed QF oedema in 18% of patients with hip pain. These patients had narrower IFS and QFS, and similar average IncA compared to those without oedema. IncA had a weak positive correlation with IFS and a moderate positive correlation with QFS in patients with oedema.

López-Royo et al., 2020	Anatomical analysis of the pelvis to identify any predisposing anatomical factors for ischiofemoral space pathology: a retrospective study	Spain	Retrospective cross-sectional	Patients who underwent to MRI for any cause.	137 (137 hips)	50.15	75 (55%)	MRI (supine; internal rotation)	IFS, QFS, IncA and FNA	IFS was correlated with QFS and FNA. As IFS decreased, QFS decreased and FNA increased. IncA was weakly positively related to FNA.
Schroeder et al., 2015	An MRI study of the lesser trochanteric version and its relationship to proximal femoral osseous anatomy	USA	Retrospective cross-sectional	Patients with contra-lateral hip pain.	250 (250 hips)	39.5	164 (66%)	MRI (supine; internal rotation position)	IFS and LTV	A weak correlation was found between IFS and LTV, but LTV did not affect the width of IFS.
Won et al., 2020	Normal ischiofemoral distance and its associated factors: computer tomography-based study	South Korea	Retrospective cross-sectional	Patients with contralateral femoral head osteonecrosis.	517 (517 hips)	51.7	215 (42%)	CT scan (supine, neutral position)	IFS, IncA, FNV	IFS correlates negatively with IncA and FNV. IncA up by 1° leads to IFS down by 0.2mm, FNV up by 1° leads to IFS down by 0.3mm.
Hujazi et al., 2016	The normal ischiofemoral distance and its variations	USA	Retrospective cross-sectional	Patients with pathology unrelated to the hip, proximal femur or associated soft tissue.	149 (298 hips)	51	78 (52%)	CT scan (supine, neutral position)	IFS, IncA, LTV, femoral offset	The highest correlations were between offset and IFS and offset and IncA. IFS is up by 1.06mm with 1mm offset, down by 0.09mm per year of age. IncA had no significant correlation with IFS.

Zhang et al., 2021	The utility of MRI to diagnose ischiofemoral impingement by assessing the ischiofemoral and quadratus femoris spaces during femoral external rotation	China	Prospective case-control	IFI group: Patients with hip/groin pain and quadratus femoris abnormalities. Control group: Healthy volunteers without hip pain and with normal quadratus femoris.	IFI group:43 (43 hips) Control group: 50 (50 hips)	IFI group: 48 Control group: 43.6	IFI group:37 (86%) Control group: 26 (52%)	MRI (externally rotated at: 0º, 30º and 60º)	IFS and QFS	IFI patients had smaller IFS and QFS than the control group, regardless of external hip rotation. An increasing external rotation led to decreased IFS and QFS. The QFS changes from 0° to 30° and 60° external rotation were significantly smaller in IFI patients than in the control group, but not for IFS. 0° was determined as the optimal position for IFI diagnosis.
Vicentini et al., 2020	Kinematic MRI of ischiofemoral impingement	USA	Prospective case-control	IFI group: Patients with narrowed IFS. Control group: Volunteers recruited through an internet platform, matched for age and sex, with no hip pain, fracture, or prior surgery.	IFI group: 7 (14 hips) Control group: 5 (10 hips)	58	All (100%)	MRI (kinematic imaging during active hip rotation;	IFS and QFS	External rotation reduced IFS and QFS more in narrowed hips (59% and 71%) than in control hips (41% and 50%), but only when exceeding the neutral position. Control hips didn't narrow IFS with external rotation, while narrowed hips moved lesser trochanter posteriorly in a posteromedial crescentic trajectory.
Hatem et al., 2021	Frequency of ischiofemoral space discrepancy when comparing magnetic resonance images of distinct institutions for the same patient	USA	Retrospective cross-sectional	Patients with prior hip MRI from an outside institution (noncontrolled), and MRI at the author's institution after the first visit (controlled).	62 (95 hips)	46 years	52 (84%)	MRI (controlled MRI - standing position)	IFS	When comparing MRIs, 18 hips (19%) changed the IFS category, and 32 hips (34%) had ≥4mm difference in IFS measurement. Most changes were due to hip flexion/extension (47%) or rotation (44%), with abduction/adduction accounting for only 9%.

Johnson et al., 2016	Variability of ischiofemoral space dimensions with changes in hip flexion: an MRI study	USA	Prospective cross-sectional	Asymptomatic volunteers recruited through word-of-mouth.	10 (20 hips)	29.2	5 (50%)	MRI (3 positions: S1 supine-neutral position, S2 supine-25° flexed position, P prone-neutral position)	IFS	IFS was larger in S2 than in S1, and smaller in the supine than in the prone position.
Finnoff et al., 2015	Variability of ischiofemoral space relative to femur position: an ultrasound study	USA	Prospective cross-sectional	Healthy, asymptomatic adult volunteers recruited via word-of-mouth at an academic institution.	10 (10 hips)	31.5	4 (40%)	Ultrasound (US) (prone, in 9 different hip positions with varying degrees of abduction/adduction and rotation).	IFS	Largest ischiofemoral space with hip abduction and internal rotation, and narrowest with hip adduction and external rotation.

Atkins et al., 2017	In vivo measurements of the ischiofemoral space in recreationally active participants during dynamic activities	USA	Prospective cross-sectional	Asymptomatic, recreationally active young adults recruited through word-of-mouth.	11 (11 hips)	23	5 (45%)	3D-CT DF (five activities: standing, internal rotation, external rotation and level and incline treadmill walking at a self-selected speed) MRI (supine, neutral position)	IFS IFS, FNV, LTV, IA, ITD and IncA	Minimum IFS occurred at greater adduction and extension angles for all activities and greater external rotation for rotation and incline walking, compared to maximum IFS angles.
Kheterpal et al., 2020	Hip abductor tears in ischiofemoral impingement	USA	Retrospective case-control	. IFI group: Patients with hip/buttock pain and MRI findings of IFI (narrowing of IF space ≤ 15mm or QF space ≤ 10 mm + ipsilateral quadratus femoris oedema/fatty infiltration/atrophy). Control group: Participants with similar age and sex, screened for no pelvic fracture/malignancy.	IFI group: 140 (140 hips) Control group: 140 (140 hips)	IFI group: 56 Control group: 55.5	IFI group: 130 (93%) Control group: 130 (93%)	MRI (supine; internal rotation)	IFS, QFS, QFM, hamstring and gluteus medius and minimus abnormalities	IFI patients had decreased IFS and more quadratus femoris oedema/atrophy and hamstring tears than controls. They also had more gluteus medius/minimus tears and atrophy. Abductor insufficiency may lead to IF narrowing due to increased hip adduction.

Ali et a, 2013	Ischiofemoral impingement: a retrospective analysis of cases in a specialist orthopaedic centre over a four-year period	UK	Retrospective cross sectional	Patients with quadratus femoris oedema/atrophy and IFS narrowing.	13 (16 hips)	36 years	All (100%)	MRI (no refers position)	IFS, QFS, QFM abnormalities	QFM abnormalities: 7 had oedema, 6 had wasting. In 2 with QFM oedema, there was gluteus medius enthesopathy, and in 1 there was hamstring enthesopathy. IFI may be due to injury in other hip-moving muscles, like the hamstrings and gluteus medius.
Ozdemir et al., 2015	Ischiofemoral space on MRI in an asymptomatic population: normative width measurements and soft tissue signal variations	Turkey	Prospective cross-sectional	Healthy volunteers or patients with pathology unrelated to the hip and pelvis, without hip pain.	209 (418 hips)	35.9	83 (40%)	MRI (supine, neutral position)	IFS, QFS, ITD, QFM abnormalities	MRI can show IF space abnormalities in asymptomatic individuals with a negative correlation between ITD and IFS and QFS, and a correlation between ITD and soft tissue abnormalities.
Audenaert et al., 2021	Ischiofemoral impingement: the evolutionary cost of pelvic obstetric adaptation	UK	Prospective cross-sectional	Adults who underwent CT scanning for vascular work-up formed the virtual cohort.	40 000	---------- --	20000 (50%)	CT scan (no refers position	IFS, FNV, LTV, IncA, femoral offset, femoral head radius, pelvic width, ITD	There was a low correlation between femoral offset and LTV and the IFS, while there was a significant and strong correlation between the overall hip geometry and the IFS. The IFS was found to be at its smallest during femoral extension.

IFI, ischiofemoral impingement; IFS, ischiofemoral space; QFS, quadratus femoris muscle; QFM, quadratus femoris muscle; ITD, inter-tuberous distance; IncA, inclination angle; HTA, hamstring tendon area; TQFMV, total quadratus femoris muscle volume; IA, ischial angle; FNA, femur neck angle; FNV, femur neck version; LTV, lesser trochanter version; FNVLTV, angle between FNV and LTV.

Supplementary table 2: Qualitative assessment of case-control studies included in this review.

Criteria	Khodair et al. [17]	Barros et al. [18]	Xing et al. [19]	Tosun et al. [1]	Dablan et al. [20]	Bredella et al. [21]	Akça et al. [22]	Gómez-Hoyos t al. [23]	Zhang et al. [27]	Vicentini et al. [28]	Kheterpal et al. [13]
1. Was the research question or objective in this paper clearly stated and appropriate?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3. Did the authors include a sample size justification?	N	N	N	N	N	N	N	N	N	N	N
4. Were controls selected or recruited from the same or similar population that gave rise to the cases (including the same timeframe)?	NR	Y	Y	Y	N	N	Y	N	N	N	Y
5. Were the definitions, inclusion and exclusion criteria, algorithms or processes used to identify or select cases and controls valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
6. Were the cases clearly defined and differentiated from controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7. If less than 100 percent of eligible cases and/or controls were selected for the study, were the cases and/or controls randomly selected from those eligible?	N	CD	CD	NA	CD	CD	CD	N	N	N	Y
8. Was there use of concurrent controls?	N	N	N	N	N	N	N	N	N	N	Y
9. Were the investigators able to confirm that the exposure/risk occurred prior to the development of the condition or event that defined a participant as a case?	N	N	N	N	N	N	N	N	N	N	N
10. Were the measures of exposure/risk clearly defined, valid, reliable, and implemented consistently (including the same time period) across all study participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
11. Were the assessors of exposure/risk blinded to the case or control status of participants?	NR	Y	Y	Y	Y	NR	NR	NR	NR	Y	NR
12. Were key potential confounding variables measured and adjusted statistically in the analyses? If matching was used, did the investigators account for matching during study analysis?	N	N	N	N	N	N	N	N	N	N	N
QUALITY RATING (G, F, P)	F	F	F	F	F	F	F	P	P	F	G

Y, yes; N, no; NA, not applicable; NR, not reported; CD, cannot determine; G, good; F, fair; P, poor.

Supplementary table 3: Qualitative assessment of cross-sectional studies included in this review.

Criteria	López-Royo et al. [24]	Schroeder et al. [25]	Won et al. [26]	Hujazi et al. [3]	Hatem et al. [29]	Johnson et al. [30]	Finnoff at al. [31]	Atkins et al. [32]	Ali et al. [5]	Ozdemir et al. [33]	Audenaert et al. [34]
1. Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50%?	Y	Y	Y	Y	Y	Y	NR	NR	NR	NR	NR
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
5. Was a sample size justification, power description, or variance and effect estimates provided?	N	N	N	N	N	Y	Y	N	N	N	Y
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	N	N	N	N	N	N	N	N	N	N	N
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	N	N	N	N	N	N	N	N	N	N	N
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	NA	NA	NA	NA	N	Y	Y	Y	N	Y	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
10. Was the exposure(s) assessed more than once over time?	N	Y	Y	Y	Y	N	Y	Y	N	Y	N
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
12. Were the outcome assessors blinded to the exposure status of participants?	NR	Y	Y	Y	Y	Y	Y	NR	NR	N	NR
13. Was loss to follow-up after baseline 20% or less?	NA	NA	Y	Y	NA	NA	NA	NA	NA	NA	NA
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N	N	N	N	N	N	N	N	N	N	Y
QUALITY RATING (G, F, P)	F	F	F	F	F	F	F	F	F	F	F

Y, yes; N, no; NA, not applicable; NR, not reported; G, good; F, fair; P, poor.

Supplementary table 4: Qualitative assessment of case-series studies included in this review.

Criteria	Torriani et al. [12]	Gardner et al. [7]
1. Was the study question or objective clearly stated?	Y	Y
2. Was the study population clearly and fully described, including a case definition?	Y	Y
3. Were the cases consecutive?	Y	Y
4. Were the subjects comparable?	Y	Y
5. Was the intervention clearly described?	NA	NA
6. Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y
7. Was the length of follow-up adequate?	NA	NA
8. Were the statistical methods well-described?	Y	Y
9. Were the results well-described?	Y	Y
QUALITY RATING (G, F, P)	G	G

Y, yes; N, no; NA, not applicable; NR, not reported; G, good; F, fair; P, poor.

APPENDICES

Reporting guidelines: PRISMA 2009 - Checklist for systematic review

Section/topic	#	Checklist item	Reported on page and paragraph/ table #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Page 1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Page 2 and 3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Page 4 (“Impingement syndromes…IFI.”)
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Page 4 (“This study… IFI patients.”)
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Not applicable
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Page 5 (“Studies were included… imaging tools.”)
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Page 5 (“Two databases… January 2023.”)
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Page 5 (“Two databases… both databases.”) and Table 1

Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Page 5-6 ("Duplicate articles… articles.")
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Page 6 ("Data extraction… investigators.")
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Page 6 ("The information… study findings.")
Risk of bias in individual studies / Risk of bias across studies	12/ 15	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Page 6 ("The National Heart… Supplementary Tables 2, 3 and 4.") and Supplementary Tables 2, 3 and 4
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Not applicable
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	Not applicable
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	Not applicable
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Page 6-7 ("A total of… article selection.") and Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Page 7-12 ("Out of … crescentic trajectory"), Tables 2 and 3, and Supplementary Table 1
Risk of bias within and across studies	19/ 22	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Page 7 ("Regarding studies quality assessment… some studies.") and Supplementary Tables 2, 3, and 4.
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. –	Not applicable
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Not applicable
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Not applicable

DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Page 12-15 (“This systematic review… IFI patients.”)
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Page 15-16 (“This systematic review… still incongruous.”)
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Page 16 (“In conclusion… clinical relevance.”)
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Not applicable

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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