The Journal of Arthroplasty xxx (2022) 1–8

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Risk Factors for Iliopsoas Tendinopathy After Anterior Approach Total Hip Arthroplasty

Jeroen C.F. Verhaegen, MD [a, b, c, *], Frans-Jozef Vandeputte, MD [a], Robin Van den Broecke, MD [a], Stijn Roose, MSc [e], Ronald Driesen, MD [a], Annick Timmermans, PhD [d], Kristoff Corten, MD, PhD [a, d, e]

[a] Ziekenhuis Oost-Limburg, Genk, Belgium
[b] University of Antwerp, Antwerp, Belgium
[c] Orthopaedic Center Antwerp, AZ Monica, Antwerp, Belgium
[d] University of Hasselt, Hasselt, Belgium
[e] Heuppraktijk/European Hip Clinic, Herselt, Belgium

ARTICLE INFO

Article history:
Received 4 July 2022
Received in revised form
9 October 2022
Accepted 11 October 2022
Available online xxx

Keywords:
total hip arthroplasty
anterior approach
iliopsoas tendinopathy
outcome
complications
spinal fusion

ABSTRACT

Background: Iliopsoas tendinopathy is a cause of groin pain following total hip arthroplasty (THA). With the anterior approach becoming increasingly popular, our aim was to determine the prevalence of iliopsoas tendinopathy following anterior approach THA, to identify risk factors and to determine an influence on patient-reported outcomes.
Methods: This is a retrospective case-control study of prospectively recorded data on 2,120 primary anterior approach THA (1,815 patients). The diagnosis of iliopsoas tendinopathy was based on (1) persistent postoperative groin pain, triggered by hip flexion; (2) absence of dislocation, infection, loosening, or fracture; and (3) decrease of pain after fluoroscopy-guided iliopsoas tendon sheet injection with xylocaine and corticosteroid. Outcomes included hip reconstruction (inclination/anteversion and leg-length), complication rates, reoperation rates, and patient-reported outcomes including Hip disability and Osteoarthritis Outcome Score.
Results: Forty four patients (46 THAs) (2.2%) were diagnosed with iliopsoas tendinopathy. They were younger than patients who did not have iliopsoas tendinopathy (51 years [range, 27-76] versus 62 years [range, 20-90]; $P < .001$). Logistic regression analyses demonstrated that younger age ($P < .001$) and presence of a spine fusion ($P = .008$) (odds ratio 4.6) were the significant predictors of iliopsoas tendinopathy. These patients had lower Hip disability and Osteoarthritis Outcome scores, reported more often low back pain (odds ratio 4.8), and greater trochanter pain (odds ratio 5.4).
Conclusion: We found an incidence of 2.2% of iliopsoas tendinopathy patients after anterior approach THA that compromised outcomes. Younger age and previous spine fusion were identified as most important risk factors. These patients were 5 times more likely to report low back pain and greater trochanter pain post-THA.

Iliopsoas tendinopathy is a potential cause of groin pain after primary total hip arthroplasty (THA), interfering with patient rehabilitation and satisfaction [1]. An incidence of 2.4%-4.4% has been reported in the literature [2,3]. Protrusion of the acetabular component due to insufficient bony coverage or component malposition can lead to irritation of the iliopsoas as its tendon runs over the anterior edge of the acetabulum [4]. Other causes such as retained cement, screws penetrating through the ilium, and a prominent femoral collar can cause iliopsoas tendinopathy through a similar mechanism [1,5].

Younger age patients and women are considered risk factors for the development of iliopsoas tendinopathy following primary THA [3,6]. This has been attributed to different surgical indications for THA in younger patients [3] and gender-specific anatomical

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2022.10.015.

* Address correspondence to: Jeroen Verhaegen, MD, Universiteit Antwerpen, University Hospital Antwerp, Antwerp, Belgium.

https://doi.org/10.1016/j.arth.2022.10.015
0883-5403/

differences of the acetabulum and the proximal femur [7,8]. Previous studies have shown that women tend to report lower functional outcomes scores than men after THA [9,10].

Some reports suggest that the use of the anterolateral approach is associated with an increased risk of iliopsoas tendinopathy in comparison to a posterior approach [4]. However, it is unclear what its prevalence is in patients treated with anterior approach THA. Excision of the anterior capsule increases the area of exposed metal surface, which might be a potential risk factor for iliopsoas tendinopathy after the anterior approach THA [4], although no clinical difference was found between resection and preservation of the anterior capsule in primary anterior approach THA [11].

We aimed to (1) determine the prevalence of iliopsoas tendinopathy in a large cohort of patients who underwent primary anterior approach THA; (2) identify risk factors for the development of iliopsoas tendinopathy; and (3) assess the effect of iliopsoas tendinopathy on patient-reported outcome measures (PROMs).

Methods

Study Design and Patient Population

This was a single-center, retrospective case control study of prospectively recorded data of patients who underwent a primary anterior approach THA between January 1, 2017 and December 31, 2019 who had a minimum follow-up of 2 years. The ethical committee approved this study (CTU nr Z-2021059) and all participants signed an informed consent.

A total of 2,189 primary THAs in 1,879 patients were performed. Study exclusion criteria were age below 18 years (n = 4), death from other cause than hip during follow-up (n = 33), history of septic arthritis (n = 2), different approach (n = 2), or patients lost to follow-up (n = 7). Patients who have complications requiring revision surgery were also excluded (n = 21). This left 2,120 anterior approach THAs in 1,815 patients (Fig. 1).

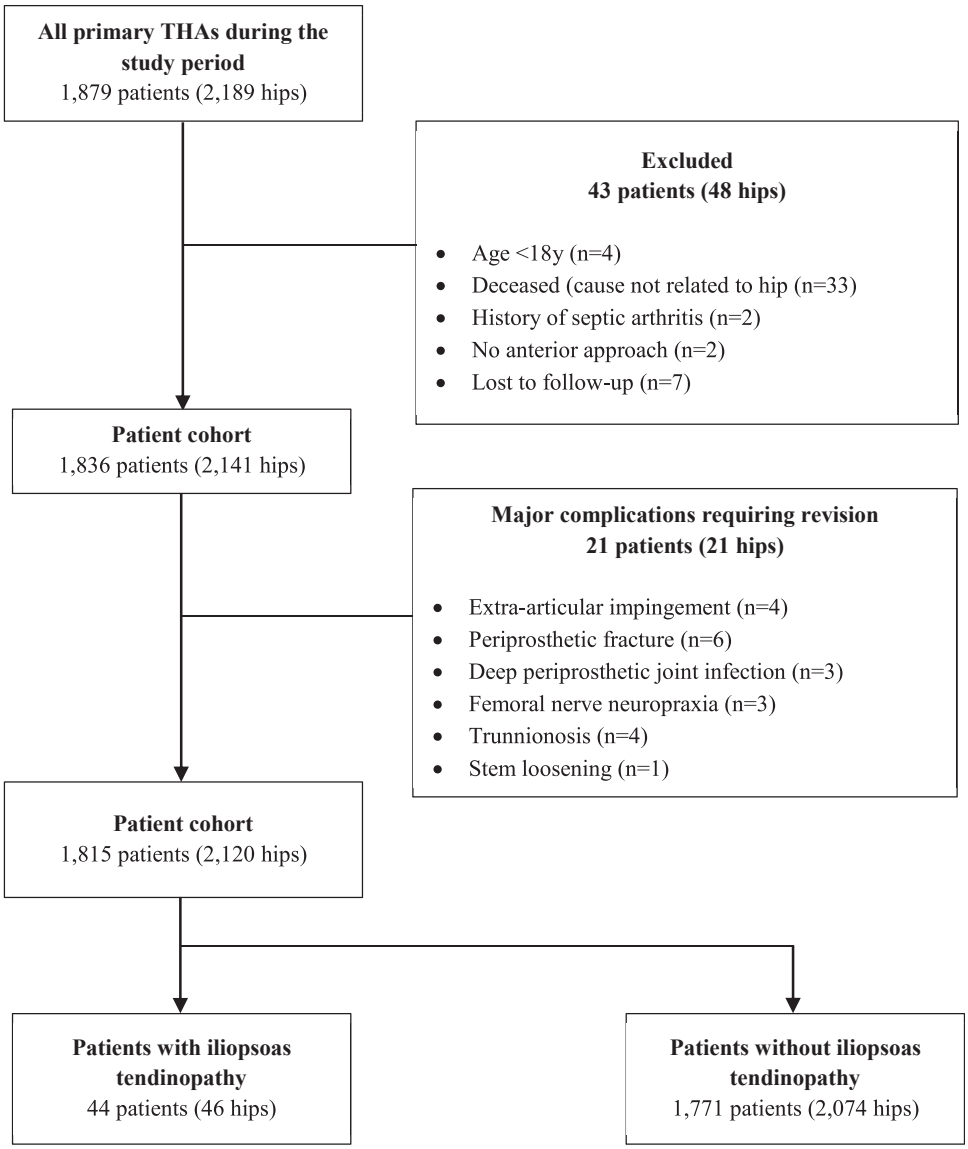

Fig. 1. Flowchart of the cohort included in the study.

Surgical Procedure

All procedures were conducted by two arthroplasty fellowship trained surgeons (K.C. and R.D.) who had a minimum of 10 years' experience and who predominantly use anterior approach for primary THA [12]. The anterior approach was conducted with the patient in supine position on a standard operating table [13]. Special attention was paid to avoid anterior cup prominence during cup reaming and insertion. A total of 2,015 (95.0%) stems were uncemented and 105 stems (5.0%) were cemented; 1,225 stems were collared (59.0%) and 869 collarless (41.0%). Capsular repair was performed systematically. Patients were allowed weight-bearing as tolerated postoperatively without any anterior/posterior hip precautions. No formal physiotherapy was initiated in the first 6 weeks after surgery and patients were instructed to avoid open-chain exercises.

Clinical Assessments

Clinical, surgical, and hospitalization notes were screened for patients who developed groin pain, periarticular muscle pain, and psoas-related symptoms after THA. All electronic medical records were screened both by an automated artificial intelligence–supported algorithm (LynxCare, Leuven, Belgium) and subsequently by one of the authors (J.V.) to double-check and complete for missing data. The accuracy of this algorithm has been described previously [14]. This algorithm is connected to the electronic medical record system of the hospital and screens patient files for key sentences, keywords, and clinical definitions. Surgery and implant characteristics were also extracted and collected into the database.

The diagnosis of iliopsoas tendinopathy was defined based on (1) persistent groin pain after anterior approach THA, triggered by active hip flexion; (2) absence of dislocation, infection, implant loosening, or (occult) postoperative periprosthetic fracture assessed with computed tomography; and (3) immediate improvement of groin pain during hip flexion after a fluoroscopy-guided injection with xylocaine and corticosteroid into the psoas tendon sheath. This injection procedure was conducted by the senior author (K.C.) and is illustrated in Figure 2 [15].

PROMs, namely the Hip disability and Osteoarthritis Outcome Score (HOOS) [16] and 36-item Short Form Survey (SF-36) [17], were obtained at 4 weeks preoperatively and at 12 months after surgery. The difference between the values of the PROMs at latest follow-up and the preoperative values was defined as delta (Δ). Length of follow-up was determined from the date of surgery to the last clinical review.

Radiographic Assessments

Standing antero-posterior (AP) pelvic radiographs were analyzed using Orthoview (Materialise, Leuven, Belgium) and a calibration marker was used to correct for magnification error. The longitudinal rotation of the pelvis was verified as correct when the tip of the coccyx was in line with pubic symphysis [11]. If the coccyx deviated $\geq$ 1 centimeter from the symphyseal line, the X-ray was considered unacceptable for measurement purposes.

A power analysis was performed to determine the minimum number of subjects requiring radiographic measurements. A sample size was calculated in SPSS v27 (IBM, New York, United States) with the intention to detect a difference in cup anteversion of 10° using an anteversion of 15° ± 10° as a reference [18]. A minimum of 16 per group was necessary to achieve sufficient power (1-$\beta = 0.80$, $\alpha = 0.05$). To increase power, we included control cases at a 5:1 ratio.

An orthopaedic resident (R.V.D.B.) and an arthroplasty fellowship-trained reviewer (F.J.V.) performed the radiographic analyses. Measurements of the first reviewer (R.V.D.B.) were repeated for 20 of randomly selected datasets (10%) in a blinded fashion by the second reviewer (F.J.V.). Interobserver reliability was calculated using the average correlation coefficient with a two-way mixed model; a value > 0.75 was considered to have excellent reliability [19] (range: 0.776-0.973).

The following measurements were obtained: (1) leg length discrepancy defined as the difference of the leg length between the ipsilateral and contralateral hip, measured by the distance between the inter-teardrop line and the most medial margin of the lesser

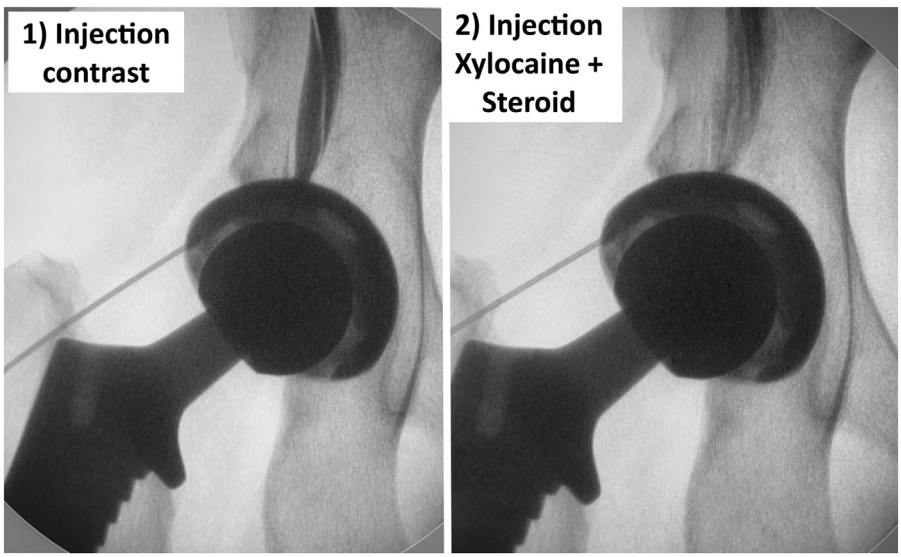

Fig. 2. Fluoroscopy-guided psoas tendon sheet injection. The procedure is done under sterile circumstances in the operating room. With the patient-positioned supine, the fluoroscopy C-arm is positioned to take an anteroposterior X-ray of the hip. Step (1) The target zone was the center of the superior acetabular roof. A spinal needle was used and its position was verified using fluoroscopy. The needle was advanced until the tip of the needle reached the acetabular bone. Correct needle position was confirmed by longitudinal spread of a small amount of injected contrast agent. Step (2) Injection of 4 mL of Xylocaïne and 1mL of Depo-medrol 40 mg/mL.

trochanter [20], (2) femoral offset defined as the shortest distance from the center of the femoral head to a line parallel to the long axis of the femur, (3) acetabular offset defined as the distance of the center of the femoral head to the medial teardrop, (4) cup inclination defined as the angle between the long axis of the cup and a transverse line connecting the bottom edge of the acetabular teardrops [21], and (5) acetabular cup anteversion defined as the inverse sine of the division between the distance of the short and long axis of the elliptical projection of the rim of the acetabular component [22].

Furthermore, the difference in diameter between the acetabular component and the native femoral head was calculated in millimeters and in a ratio between the two [23].

In patients who have signs of iliopsoas tendinopathy, additional imaging (cross-table lateral view or computed tomography scan) was performed to exclude anterior cup prominence. The bony coverage of the acetabular cup was measured.

Data Analyses

Statistical analyses were performed using SPSS v27 (IBM, New York, United States). A P value < .05 was considered significant. Normal distribution of data was tested using Q-Q plots and Kolmogorov-Smirnov tests. Mann-Whitney U-tests were used to compare continuous variables between groups if data were not normally distributed and independent sampled t-tests if there was a normal distribution. Paired sampled t-tests were used to compare preoperative and postoperative values and Chi-squared tests to compare categorical variables. Cross tabs were used to calculate odds ratio (including 95% confidence interval [CI]) for categorical variables. Furthermore, factors showing a significant correlation with the development of iliopsoas tendinopathy were added in binary logistic regression analyses.

Results

Prevalence of Iliopsoas Tendinopathy

A total of 90 patients who had 102 THAs (4.8%) developed postoperative groin pain at a mean of 8 months (range, 1-32). These symptoms settled with adjustment of exercises or nonsteroidal anti-inflammatory medication in 46 patients who had 56 THAs. Forty four patients (46 THAs; 2.2%) required an iliopsoas infiltration at a mean of 11 months (range, 2-32) postoperatively and were as such diagnosed with iliopsoas tendinopathy. The symptoms subsided in all except 1 case (0.1%), where a cerclage wire was removed.

Assessment of Risk Factors

The mean age of patients who had iliopsoas tendinopathy was younger than those who did not have it (51 years [range, 27-76 years] versus 62 years [range, 20-90 years]; $P < .001$). There was no difference between men and women ($P = .311$). Patients who had primary hip osteoarthritis (OA) were less likely to develop iliopsoas tendinopathy in comparison to patients who had secondary hip OA to dysplasia (odds ratio 3.4; 95% CI 1.6-7.0; $P < .001$) or femoro-acetabular impingement (odds ratio 3.8; 95% CI 1.7-8.4; $P < .001$). Patients who underwent a previous hip arthroscopy (odds ratio 9.6; 95% CI: 2.6-34.3; $P = .006$) and patients who had a spine fusion

Table 1
Demographic and Clinical Data of the Cohort.

Parameter	Whole Cohort (n = 2,120)	Patients with Signs of Iliopsoas Tendinopathy (n = 46)	Patients with No Signs of Iliopsoas Tendinopathy (n = 2,074)	*P* Value
Mean age [years ± Standard Deviation (SD) (range)]	62 ± 13 (20-90)	51 ± 12 (27-7)	63 ± 13 (20-90)	<.001[f,k]
Gender				.311[g]
Men (n, %)	905 (42.7)	23 (50.0)	882 (42.5)	
Women (n, %)	1,215 (57.3)	23 (50.0)	1,192 (57.5)	
Mean BMI [kg/m^2 ± SD (range)]	27 ± 5 (16-46)	26 ± 5 (18-37)	27 ± 5 (16-46)	.328[f]
Mean follow-up [years ±SD (range)]	3.6 ± 0.9 (2.0-4.9)	3.7 ± 0.7 (2.0-4.8)	3.6 ± 0.8 (2.0-4.9)	.216[f]
Simultaneous bilateral THA (n, %)	444 (20.9)	6 (13.0)	438 (21.1)	.195[g]
Indication				
Primary hip arthritis (n, %)	1,177 (55.5)	13 (28.3)	1,164 (56.1)	-
Secondary hip arthritis to dysplasia[a] (n, %)	494 (23.3)	18 (39.1)	476 (23.0)	<.001[i,k]
Secondary hip arthritis to FAI[b] (n, %)	297 (14.0)	12 (26.1)	285 (13.7)	<.001[i,k]
AVN[c] (n, %)	44 (2.1)	0 (0.0)	44 (2.1)	.619[j]
LCPD/SCFE sequelae[d] (n, %)	26 (1.2)	1 (2.2)	25 (1.2)	.265[j]
Femoral neck fracture (n, %)	51 (2.4)	0 (0.0)	51 (2.5)	.575[j]
Post-traumatic OA (n, %)	19 (0.9)	1 (2.2)	18 (0.9)	.202[j]
Conversion CMN/DHS[e] (n, %)	11 (0.5)	1 (2.2)	10 (0.5)	.123[j]
Conversion hip fusion (n, %)	1 (0.0)	0 (0.0)	1 (0.0)	.989[j]
Past Medical History				
Hip arthroscopy (n, %)	18 (0.8)	3 (6.5)	15 (0.7)	.006[g,k]
Previous femoral surgery (n, %)	59 (2.8)	1 (2.2)	58 (2.8)	.631[h]
Periacetabular osteotomy (n, %)	29 (1.4)	1 (2.2)	28 (1.4)	.473[h]
Spine fusion (n, %)	46 (2.2)	4 (8.7)	42 (2.0)	.016[g,k]
Perioperative Calcar fracture (n, %)	24 (1.1%)	1 (2.2%)	23 (1.1%)	.411[h]
Postoperative low back pain (n, %)	141 (6.7%)	11 (23.9%)	130 (6.3%)	< .001[g,k]
Greater trochanter pain postoperative (n, %)	41 (1.9%)	4 (8.7%)	37 (1.8%)	.011[h,k]
Heterotopic ossifications	7 (0.3%)	1 (2.2%)	6 (0.3%)	.143[h]

[a] Secondary hip arthritis due to dysplasia as per Lateral Centre-Edge Angle (LCEA) ≤ 20°.
[b] Secondary hip arthritis due to Femoro-Acetabular Impingement (FAI) as per CAM (alpha angle ≥ 55°) or pincer (presence of retroversion and/or coxa profunda LCEA > 40°).
[c] Avascular necrosis (AVN).
[d] Sequelae of Legg-Calvé-Perthes disease (LCPD) or Slipped Capital Femoral Epiphysis (SCFE).
[e] Conversion of pertrochanteric fracture treated with cephalomedullary nail (CMN) or dynamic hip screw (DHS) to THA.
[f] Independent samples t-test.
[g] Chi-squared test.
[h] Fisher's exact test.
[i] Chi-squared test (in comparison to primary hip OA).
[j] Fisher's exact test (in comparison to primary hip OA).
[k] Statistically significant (P value < .05).

Table 2
Surgical Data and Implant Details of the Cohort.

Parameter	Whole Cohort (n = 2,120)	Patients with Signs of Iliopsoas Tendinopathy (n = 46)	Patients with No Signs of Iliopsoas Tendinopathy (n = 2,074)	*P* Value
Bearing surface				.006[b,d]
CoC (n, %)	1,188 (56.0)	35 (76.1)	1,153 (55.6)	
CoP (n, %)	932 (44.0)	11 (23.9)	921 (44.4)	
Screws cup				.257[b]
Yes (n, %)	61 (2.9)	0 (0.0)	61 (2.9)	
No (n, %)	2,059 (97.1)	46 (100.0)	2,013 (97.1)	
Head Size				.909[b]
28 mm (n, %)	42 (2.0)	1 (2.2)	41 (2.0)	
32 mm (n, %)	905 (42.7)	21 (45.7)	884 (42.6)	
36 mm (n, %)	1,173 (55.3)	24 (52.2)	1,149 (55.4)	
Head Length[a]				.957[b]
Small (n, %)	766 (36.1)	17 (37.0)	749 (36.1)	
Medium (n, %)	1,128 (53.2)	25 (54.3)	1,105 (53.3)	
Large (n, %)	215 (10.1)	4 (8.7)	211 (10.2)	
Extra-Large (n, %)	9 (0.4)	-	9 (0.4)	
Cement				.325[c]
Cementless (n, %)	2,015 (95.0)	45 (97.8)	1,970 (95.0)	
Cemented (n, %)	105 (5.0)	1 (2.2)	104 (5.0)	
Stem offset				.139[b]
High offset/Lateral (n, %)	832 (39.2)	14 (30.4)	818 (39.4)	
Standard offset/Short neck (n, %)	1,288 (60.8)	32 (69.6)	1,256 (60.6)	
Collar				.539[b]
Collarless (n,%)	869 (41.0)	19 (41.3)	850 (41.0)	
Collar (n, %)	1,225 (59.0)	27 (58.7)	1,224 (59.0)	

[a] Head length: Small: −3.5mm Zimmer, 1.0 or 1.5 mm Depuy/Medium: 0.0mm Zimmer, 5.0 Depuy/Large: 3.5mm Zimmer, 8.5 or 9.0 mm Depuy/Extra-Large: 7.0mm Zimmer; 12.0mm Depuy.
[b] Chi-squared test.
[c] Fisher's exact test.
[d] Statistically significant (*P* value < .05).

(odds ratio 4.6; 95% CI: 1.6-13.4; $P = .016$) were more likely to develop iliopsoas tendinopathy (Table 1).

There was a higher incidence of psoas pain in patients who had a ceramic-on-ceramic (CoC) bearing surface in comparison to patients who had a ceramic-on-polyethylene (CoP) bearing (odds ratio 2.5; 95% CI 1.3-5.0; $P = .006$). There was no difference in the incidence of psoas pain between collared and collarless stems ($P = .539$) (Table 2). A perioperative calcar fracture, treated with cerclage wire at the level of the lesser trochanter, was not associated with a higher incidence of psoas pain ($P = .370$) (Table 1).

Logistic regression analyses demonstrated that younger age ($P < .001$) and presence of a spine fusion ($P = .004$) were the significant predictors of iliopsoas tendinopathy.

Overall mean cup anteversion was 21° (range; 8°-42°) and the mean cup inclination was 32° (range, 14°-50°). There were no differences in cup orientation between both groups (Fig. 3 and Table 3). Mean postoperative leg length difference in the group

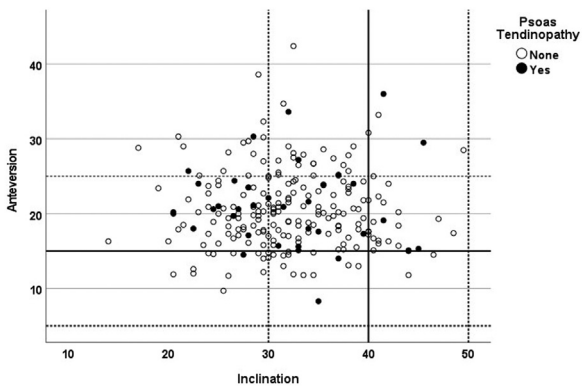

Fig. 3. Distribution of cup inclination and anteversion in patients with and without iliopsoas tendinopathy.

patients who had iliopsoas tendinopathy was 0 mm (range: −11 to 14). The mean bony coverage of the acetabular cup was 2 mm (range, 0-6) (Table 3). There was no difference in acetabular cup/native femoral head ratio between groups ($P = .588$).

Influence of Iliopsoas Tendinopathy on Patient-Reported Outcomes

Patients who had iliopsoas tendinopathy reported more low back pain (odds ratio 4.7; 95% CI: 2.3-9.5; $P < .001$) and greater trochanteric pain (odds ratio 5.2; 95% CI 1.8-15.4; $P = .011$) (Table 1).

Preoperatively, patients who had iliopsoas tendinopathy had lower PROM scores than controls but only for the HOOS-Pain subscore and SF-36 social functioning subscore; these differences were significant (Tables 4 and 5). At 1-year postoperative, differences in HOOS and SF-36 score between patients who did and did not have iliopsoas tendinopathy were significant, with these patients having lower scores throughout. The difference (Δ) between both PROM scores was similar between both groups, except for the difference in HOOS-Sport subscore, which was significantly lower in patients who had iliopsoas tendinopathy (20.9 [range: −68.8 to 93.8] versus 42.4 [range: −75.0 to 100.0]; $P = .003$).

Discussion

Iliopsoas tendinopathy has been described as a debilitating problem following primary THA [1–4]. Over the recent years, the anterior approach has been popularized because it aims to minimize damage to the periarticular muscle envelope, potentially leading to fast recovery and low dislocation rates [24]. This study describes the prevalence of iliopsoas tendinopathy in a large cohort of patients treated with anterior approach THA, and we identified a prevalence of 2.2%. Younger age and previous spine fusion were identified as the most important risk factors. Patients who had iliopsoas tendinopathy were more likely to report low back pain

Table 3
Radiographic Measurements.

Parameter	Whole Cohort (n = 235)	Patients with Signs of Iliopsoas Tendinopathy (n = 36)	Patients with No Signs of Iliopsoas Tendinopathy (n = 199)	*P* Value[a]
Leg Length difference (mm)	2 ± 8 (−18 to 39)	0 ± 6 (−11 to 14)	2 ± 8 (−18 to 39)	.043[b]
Cup anteversion (°)	21 ± 5 (8 to 42)	21 ± 6 (8 to 36)	21 ± 5 (10 to 42)	.632
Cup inclination (°)	32 ± 5 (14 to 50)	32 ± 7 (21 to 46)	32 ± 6 (14 to 50)	.647
Femoral offset (mm)	44 ± 6 (31 to 66)	44 ± 6 (34 to 55)	44 ± 6 (31 to 66)	.974
Acetabular offset (mm)	29 ± 4 (15 to 41)	28 ± 4 (20 to 36)	29 ± 4 (15 to 41)	.422
Acetabular cup size (mm)	53 ± 3 (44 to 64)	52 ± 4 (48 to 58)	53 ± 3 (44 to 64)	.152[a]
Native femoral head size (mm)	49 ± 4 (41 to 60)	49 ± 4 (41 to 55)	50 ± 4 (42 to 60)	.429
Difference between acetabular cup and native femoral head (mm)	3 ± 2 (−7 to 7)	3 ± 2 (−2 to 7)	3 ± 2 (−7 to 7)	.546
Ratio acetabular cup/native femoral head	1.06 ± 0.05 (0.87 to 1.17)	1.07 ± 0.04 (0.96 to 1.17)	1.06 ± 0.05 (0.87 to 1.15)	.588
Bony coverage acetabular cup [mm±SD (range)]	-	2 ± 2 (0 to 6)	-	-

Values presented as mean ± standard deviation (range).
[a] Mann-Whitney U test.
[b] Statistically significant (*P* value < .05).

and greater trochanter pain post-THA. These patients had significantly lower postoperative PROM scores than patients who did not have iliopsoas tendinopathy after anterior approach THA, although they were already more symptomatic preoperatively.

The prevalence of 2.2% iliopsoas tendinopathy among anterior approach THA compares similarly to previous reports [2–4,6,25]. A prevalence of 2.4%-4.3% was found in smaller cohorts by Howell et al (1,000 patients) and Ala Eddine et al (206 patients), whereas a surgical approach was not specified [2,3]. In a posterior or anterolateral approach, Ueno et al reported an incidence of 3.9% in 586 THAs, stating that their approach was associated with a higher risk of psoas tendinopathy [4].

Younger age was an important risk factor for iliopsoas tendinopathy. This is in accordance with Howell et al, who also suggested younger age as a risk factor. Their hypothesis was that iliopsoas tendinopathy is due to a higher tension on the iliopsoas tendon with an increased leg length and offset after THA for dysplasia [3]. We did not find any difference in hip reconstruction parameters between both groups. However, we found secondary OA to dysplasia and femoro-acetabular impingement to be associated with the development of iliopsoas tendinopathy. These are typical reasons for individuals to have their hip replaced at a younger age [26,27]. Zhu et al reported no difference in the incidence of psoas tendinopathy between hips with dysplasia and a control group undergoing THA through a posterolateral approach [28]. They did not include Crowe grade 1 patients, while we used a LCEA $\leq 20°$ as a cut-off for dysplasia [29], and included Crowe grade 1-4 patients. Furthermore, patients who had a history of hip arthroscopy were more likely to develop iliopsoas tendinopathy, which might be attributable to iatrogenic soft tissue damage or the consequence of a preoperatively existing muscle imbalance.

As a consequence of reduced hip flexion, patients who have hip OA have an increased posterior pelvic tilt when adopting a seated position, leading to an increased lumbar spine flexion to maintain sagittal balance [30]. It has been shown that spinopelvic

Table 4
Hip Disability and Osteoarthritis Outcome Scores (HOOS) and Short Form-36 Scores Preoperatively and at 1 Y Postoperatively.

Patient-Reported Outcome Score	Timing	Patients with Signs of Iliopsoas Tendinopathy (n = 46)	Patients with No Signs of Iliopsoas Tendinopathy (n = 2,074)	*P* Value[a]
HOOS Symptoms	Preoperatively	33.3 ± 13.8 (10.0 to 65.0) (n = 29)	36.8 ± 19.5 (0.0 to 100.0) (n = 1,111)	.388
	At 1 y follow-up	67.0 ± 23.0 (25.0 to 100.0) (n = 25)	76.3 ± 20.9 (10.0 to 100.0) (n = 1,225)	.038[b]
	Difference between preoperative and postoperative score	35.9 ± 24.2 (−15.0 to 85.0) (n = 23)	39.3 ± 24.9 (−60.0 to 100.0) (n = 1,005)	.383
HOOS Pain	Preoperatively	32.8 ± 17.9 (0.0 to 67.5) (n = 29)	40.9 ± 18.3 (0.0 to 100.0) (n = 1,111)	.015[b]
	At 1 y follow-up	65.9 ± 23.9 (10.0 to 100.0) (n = 25)	82.3 ± 19.6 (7.5 to 100.0) (n = 1,225)	<.001[b]
	Difference between preoperative and postoperative score	34.6 ± 25.8 (−10.0 to 90.0) (n = 23)	40.9 ± 23.3 (−57.5 to 100.0) (n = 1,005)	.083
HOOS Activities daily life	Preoperatively	36.1 ± 20.4 (7.4 to 79.4) (n = 29)	41.6 ± 19.2 (0.0 to 100.0) (n = 1,111)	.115
	At 1 y follow-up	66.5 ± 22.8 (16.2 to 100.0) (n = 25)	82.0 ± 19.4 (2.9 to 100.0) (n = 1,225)	<.001[b]
	Difference between preoperative and postoperative score	34.9 ± 24.4 (−1.5 to 72.1) (n = 23)	39.8 ± 23.1 (−45.6 to 100.0) (n = 1,005)	.299
HOOS Sport	Preoperatively	18.8 ± 17.8 (0.0 to 75.0) (n = 29)	20.3 ± 21.2 (0.0 to 100.0) (n = 1,111)	.978
	At 1 y follow-up	36.5 ± 34.6 (0.0 to 100.0) (n = 25)	63.6 ± 29.2 (0.0 to 100.0) (n = 1,225)	<.001[b]
	Difference between preoperative and postoperative score	20.9 ± 37.1 (−68.8 to 93.8) (n = 23)	42.4 ± 31.4 (−75.0 to 100.0) (n = 1,005)	.003[b]
HOOS Quality of life	Preoperatively	22.4 ± 16.2 (0.0 to 62.5) (n = 29)	26.9 ± 17.8 (0.0 to 100.0) (n = 1,111)	.190
	At 1 y follow-up	56.0 ± 28.0 (6.3 to 100.0) (n = 25)	70.7 ± 23.9 (0.0 to 100.0) (n = 1,225)	.009[b]
	Difference between preoperative and postoperative score	36.1 ± 26.6 (0.0 to 87.5) (n = 23)	43.4 ± 26.7 (−43.8 to 100.0) (n = 1,005)	.195
Mean SF-36	Preoperatively	41.7 ± 14.2 (19.9 to 65.3) (n = 29)	46.7 ± 15.7 (10.9 to 87.8) (n = 1,111)	.103
	At 1 y follow-up	54.9 ± 22.4 (20.8 to 85.6) (n = 17)	72.6 ± 15.1 (17.8 to 99.4) (n = 668)	<.001[b]
	Difference between preoperative and postoperative score	16.9 ± 18.8 (−14.2 to 45.3) (n = 15)	25.6 ± 16.2 (−17.1 to 69.4) (n = 549)	.101

Values presented as mean ± standard deviation (range).
[a] Mann-Whitney U test.
[b] Statistically significant (*P* value < .05).

Table 5
Short Form-36 Subscores Preoperatively and at 1 Y Postoperatively.

SF-36	Patients with Signs of Iliopsoas Tendinopathy (n = 46)		Patients with No Signs of Iliopsoas Tendinopathy (n = 2,074)		*P* Value[a]	*P* Value[b]
	Preoperative (n = 29)	Postoperative (n = 18)	Preoperative (n = 1111)	Postoperative(n = 672)		
Physical functioning	45.2 ± 21.7 (5.0-85.0)	61.9 ± 25.6 (20.0-100.0)	45.2 ± 23.5 (0.0-100.0)	78.6 ± 21.9 (0.0-100.0)	.910	.003[c]
Role limitations due to physical health	21.6 ± 28.9 (0.0-100.0)	50.0 ± 47.7 (0.0-100.0)	27.4 ± 36.3 (0.0-100.0)	74.5 ± 36.9 (0.0-100.0)	.860	.017[c]
Role limitations due to emotional problems	51.7 ± 43.2 (0.0-100.0)	53.7 ± 50.0 (0.0-100.0)	56.4 ± 45.7 (0.0-100.0)	79.5 ± 36.2 (0.0-100.0)	.444	.012[c]
Vitality	52.6 ± 20.7 (5.0-90.0)	53.6 ± 29.8 (0.0-95.0)	58.3 ± 19.8 (0.0-100.0)	69.8 ± 18.2 (0.0-100.0)	.180	.028[c]
Mental health	57.5 ± 12.7 (32.0-80.0)	62.8 ± 17.9 (30.0-100.0)	61.5 ± 12.0 (16.0-88.0)	65.8 ± 11.0 (20.0-100.0)	.095	.474
Social functioning	52.6 ± 23.0 (12.5-87.5)	67.3 ± 33.9 (0.0-100.0)	65.9 ± 23.4 (0.0-100.0)	83.7 ± 20.1 (0.0-100.0)	.003[c]	.036[c]
Pain	30.8 ± 21.2 (0.0-77.5)	48.3 ± 35.5 (0.0-100.0)	37.3 ± 20.8 (0.0-100.0)	77.2 ± 24.2 (0.0-100.0)	.118	< .001[c]
General health	39.5 ± 19.3 (10.0-70.0)	36.1 ± 22.1 (0.0-70.0)	36.4 ± 14.8 (5.0-85.0)	35.7 ± 17.4 (5.0-100.0)	.446	.921

Values presented as mean ± standard deviation (range).
[a] Mann-Whitney U test comparing preoperative subscores between patients with and without psoas symptoms.
[b] Mann-Whitney U test comparing postoperative subscores between patients with and without psoas symptoms.
[c] Statistically significant (*P* value < .05).

parameters can "normalize" in patients who have primary hip OA in the first year after THA in patients who did not have previous spinal surgery [31,32], whereas patients who had a spine fusion more often have so-called spinopelvic hypermobility (large difference in pelvic tilt between standing and seated position), putting them at risk for instability and inferior outcomes [33]. Improvement of low back pain symptoms after THA has been attributed to the correction of spinopelvic alignment [34], whereas new onset low back pain has also been described [14]. Patients who have a spine fusion were at a higher risk for iliopsoas tendinopathy, and we found a higher incidence of low back pain and greater trochanteric pain among patients who have iliopsoas tendinopathy. Because the iliopsoas tendon is an important stabilizer of the hip joint [35], it is plausible that it contributes to changes in spinopelvic motion following THA [31,36]. However, future studies are necessary to establish the relationship between the periarticular muscle envelope and changes in spinopelvic characteristics.

A higher incidence of iliopsoas tendinopathy in patients who had a CoC-bearing surface was found. However, this bearing surface was selected for most patients aged less than 60 years and, consequently, our results show a strong correlation between young age and CoC bearing. Prominence of the anterior rim of the socket is a well-known risk factor for iliopsoas tendinopathy [4] and an increased acetabular cup to native femoral head ratio [23]. Both senior authors address any intraoperative overhang very carefully and aimed for an acetabular cup size 2-4 millimeters larger than the native femoral head to avoid oversizing the acetabular cup. As a consequence, none of the acetabular cups in this study were found to be prominent nor did we find a difference in acetabular cup to native femoral head ratio between both groups. Although it has previously been shown that there is no clinical difference between capsular repair and capsular resection during anterior approach THA [11], the anterior hip capsule decreases the area of exposed metal surface, which might help in decreasing the risk of iliopsoas tendinopathy after anterior approach THA [4]. Mean cup anteversion was within the safe zone but on average on the higher end of this spectrum [18]. As only 2 dislocations emerged in this cohort (0.1%), both treated with a closed reduction and none requiring a revision, this did not affect THA stability. Low cup anteversion (<10°) was extremely rare, which explains why socket orientation was not found to be a risk factor for iliopsoas tendinopathy in this series.

Patients who developed iliopsoas tendinopathy were already more symptomatic preoperatively in comparison to non-tendinopathy patients. Although not significant, all their PROM scores were lower preoperatively. Similarly, the change in PROM scores in case of iliopsoas tendinopathy was lower during the first postoperative year, and at 1-year follow-up, the differences between both groups became significant. A higher activity level among younger patients has also been suggested as the reason for the higher prevalence of iliopsoas tendinopathy among young patients [25]. However, the HOOS and SF-36 subscores for physical activity and sport were very similar preoperatively but improved significantly less in iliopsoas tendinopathy patients after THA.

This study has some limitations. Postoperative groin pain remains a challenging entity to evaluate. The diagnosis of iliopsoas tendinopathy is usually based on clinical findings, in the absence of reliable imaging modalities to differentiate between inflammation and structural damage of the muscle tendon. Therefore, we used an injection of the iliopsoas tendon sheath as a cut-off criterion. Also, the prevalence of subjective adverse events such as low back pain was based on clinical notes and might have underestimated its true prevalence. We also did not use any PROM scores to quantify low back pain, such as the Oswestry Disability Index. In addition, preoperative and postoperative PROMs were available in only 60% of patients, although it has been shown that a maximal effort to increase this response rate is not necessarily justifiable from a value-based healthcare perspective [37]. Nevertheless, this might have caused bias in interpreting these results. Also, all patients underwent THA through an anterior approach and there was no control group to compare the incidence of psoas tendinopathy between different approaches. Both senior authors have a large experience with the anterior approach. Therefore, these results might not be representative to surgeons in an earlier stage of their learning curve.

Conclusion

After anterior approach THA, iliopsoas tendinopathy was present in 2.2% of patients, compromising normal evolution of PROMs. Younger age and previous spine fusion were identified as most important risk factors. In addition, the incidence of low back and trochanter pain was 5 times higher among patients with iliopsoas tendinopathy. This indicates a link between the periarticular pelvic muscle envelope and low back pain, which is most likely the result of spinopelvic adjustments following THA.

References

[1] Jasani V, Richards P, Wynn-Jones C. Pain related to the psoas muscle after total hip replacement. J Bone Joint Surg Br 2002;84B:991–3.

[2] Ala Eddine T, Remy F, Chantelot C, Giraud F, Migaud H, Duquennoy A. Anterior iliopsoas impingement after total hip arthroplasty: diagnosis and conservative treatment in 9 cases. Rev Chir Orthop Reparatrice Appar Mot 2001;87:815–9.
[3] Howell M, Rae F, Khan A, Holt G. Iliopsoas pathology after total hip arthroplasty: a young person's complication. Bone Joint J 2021;103:305–8.
[4] Ueno T, Kabata T, Kajino Y, Inoue D, Ohmori T, Tsuchiya H. Risk factors and cup protrusion thresholds for symptomatic iliopsoas impingement after total hip arthroplasty: a retrospective case-control study. J Arthroplasty 2018;33:3288–96.
[5] O'Sullivan M, Chin Tai C, Richards S, Skyrme A, Walter W, Walter W, et al. A complication after total hip arthroplasty. J Arthroplasty 2007;22:166–70.
[6] Bin Nasser A, Beaule P, O'Neill M, Kim P, Fazekas A. Incidence of groin pain after metal-on-metal hip resurfacing. Clin Orthop Relat Res 2010;468:392–9.
[7] Noble P, Box G, Kamaric E, Fink M, Alexander J, Tullos H. The effect of aging on the shape of the proximal femur. Clin Orthop Relat Res 1995;316:31–44.
[8] Vandenbussche E, Saffarini M, Taillieu F, Mutschler C. The asymmetric profile of the acetabulum. Clin Orthop Relat Res 2008;466:417–23.
[9] Holtzman J, Saleh K, Kane R. Gender differences in functional status and pain in a Medicare population undergoing elective total hip arthroplasty. Med Care 2002;40:461–70.
[10] Röder C, Parvizi J, Eggli S, Berry D, Müller M, Busato A. Demographic factors affecting long-term outcome of total hip arthroplasty. Clin Orthop Relat Res 2003;417:62–73.
[11] Vandeputte F-J, Vanbiervliet J, Sarac C, Driesen R, Corten K. Capsular resection versus capsular repair in direct anterior approach for total hip arthroplasty: a randomized controlled trial. Bone Joint J 2021;103:321–8.
[12] Gofton W, Ibrahim M, Kreviazuk C, Kim P, Feibel R, Beaulé P. Ten-year experience with the anterior approach to total hip arthroplasty at a tertiary care center. J Arthroplasty 2020;35:1281–9.
[13] Corten K, Holzapfel B. Direct anterior approach for total hip arthroplasty using the "bikini incision". Oper Orthop Traumatol 2021;33:318–30.
[14] Van de Meulebroucke C, Beckers J, Corten K. What can we expect following anterior total hip arthroplasty on a regular operating table? A validation study of an artificial intelligence algorithm to monitor adverse events in a high-volume, nonacademic setting. J Arthroplasty 2019;34:2260–6.
[15] Agten C, Rosskopf A, Zingg P, Peterson C, Pfirrmann C. Outcomes after fluoroscopy-guided iliopsoas bursa injection for suspected iliopsoas tendinopathy. Eur Radiol 2015;25:865–71.
[16] Nilsdotter A, Lohmander L, Klässbo M, Roos E. Hip disability and osteoarthritis outcome score (HOOS)–validity and responsiveness in total hip replacement. BMC Musculoskelet Disord 2003;4:1–8.
[17] Ware Jr J, Sherbourne C. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30:473–83.
[18] Lewinnek G, Lewis J, Tarr R, Compere C, Zimmerman J. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978;60:217–20.
[19] Fleiss J. The design and analysis of clinical experiments. New York: John Wiley and Sons; 1986.
[20] Woolson S, Hartford J, Sawyer A. Results of a method of leg-length equalization for patients undergoing primary total hip replacement. J Arthroplasty 1999;14:159–64.
[21] Engh C, Griffin W, Marx C. Cementless acetabular components. J Bone Joint Surg Br 1990;72:53–9.
[22] Nho J-H, Lee Y-K, Kim HJ, Ha Y-C, Suh Y-S, Koo K-H. Reliability and validity of measuring version of the acetabular component. Bone Joint Surg Br 2012;94:32–6.
[23] Buller L, Menken L, Hawkins E, Bas M, Roc Jr G, Cooper H, et al. Iliopsoas impingement after direct anterior approach total hip arthroplasty: epidemiology, risk factors, and treatment options. J Arthroplasty 2021;36:1772–8.
[24] Wang Z, Hou J-Z, Wu C-H, Zhou Y-J, Gu X-M, Wang H-H, et al. A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. J Orthop Surg Res 2018;13:1–8.
[25] Bartelt R, Yuan B, Trousdale R, Sierra R. The prevalence of groin pain after metal-on-metal total hip arthroplasty and total hip resurfacing. Clin Orthop Relat Res 2010;468:2346–56.
[26] Ganz R, Leunig M, Leunig-Ganz K, Harris W. The etiology of osteoarthritis of the hip: an integrated mechanical concept. Clin Orthop Relat Res 2008;466:264–72.
[27] Wyles C, Heidenreich M, Jeng J, Larson D, Trousdale R, Sierra R. The John Charnley Award: redefining the natural history of osteoarthritis in patients with hip dysplasia and impingement. Clin Orthop Relat Res 2017;475:336–50.
[28] Zhu J, Li Y, Chen K, Xiao F, Shen C, Peng J, et al. Iliopsoas tendonitis following total hip replacement in highly dysplastic hips: a retrospective study. J Orthop Surg Res 2019;14:1–8.
[29] Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint with special reference to the complication of osteoarthritis. JAMA 1940;115:83.
[30] Innmann M, Merle C, Phan P, Beaulé P, Grammatopoulos G. Differences in spinopelvic characteristics between hip osteoarthritis patients and controls. J Arthroplasty 2021;36:2808–16.
[31] Innmann M, Reichel F, Schaper B, Merle C, Beaulé P, Grammatopoulos G. How does spinopelvic mobility and sagittal functional cup orientation affect patient-reported outcome 1 year after THA?-A prospective diagnostic cohort study. J Arthroplasty 2021;36:2335–42.
[32] Innmann M, Verhaegen JCF, Reichel F, Schaper B, Merle C, Grammatopoulos G. Spinopelvic characteristics normalize 1 year after total hip arthroplasty: a prospective, longitudinal, case-controlled study. J Bone Joint Surg Am 2022;104:675–83.
[33] Grammatopoulos G, Gofton W, Jibri Z, Coyle M, Dobransky J, Kreviazuk C, et al. 2018 Frank Stinchfield Award: spinopelvic hypermobility is associated with an inferior outcome after THA: examining the effect of spinal arthrodesis. Clin Orthop Relat Res 2019;477:310–21.
[34] Offierski C, MacNab I. Hip-spine syndrome. Spine (Phila Pa 1976) 1983;8:316–21.
[35] Hirase T, Mallett J, Barter L, Dong D, McCulloch P, Harris J. Is the iliopsoas a femoral head stabilizer? A systematic review. Arthrosc Sports Med Rehabil 2020;2:e847–53.
[36] Haffer H, Wang Z, Hu Z, Hipfl C, Perka C, Pumberger M. Total hip replacement influences spinopelvic mobility: a prospective observational study. J Arthroplasty 2022;37:316–24.
[37] Pronk Y, Pilot P, Brinkman J, van Heerwaarden R, van der Weegen W. Response rate and costs for automated patient-reported outcomes collection alone compared to combined automated and manual collection. J Patient Rep Outcomes 2019;3:1–8.