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REVIEW

Outcomes and complications of Total Hip Arthroplasty in patients with a pre-existing pathologic spine-hip relation. A systematic review of the literature

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Abstract

Background There has been a growing interest in pathologic spine-hip relations (PSHR) in current literature, with the aim of reducing the risk of prosthetic impingement, dislocation, and edge loading in total hip arthroplasty (THA). The primary objective of this review is to determine the effect of different PSHR on primary THA outcomes and complication profile. The secondary objective is to stratify the risk of different subgroups of PSHR patients.

Methods A systematic review of the literature was performed in accordance with PRISMA guidelines. Randomised controlled trials, comparative cohort studies and case–control studies comparing outcomes and complication rates of primary THA in patients with and without a PSHR (spinal fusion; degenerative spinal conditions determining stiff spine and/or spinal misalignment) were included. The quality of the included studies and the risk of bias were assessed. The revision rate, complications, and clinical and radiological data were analysed. Complications included: aseptic loosening (AL), periprosthetic joint infections (PJI), hip dislocations and periprosthetic fractures (PF).

Results Fifteen articles were included with 3.306.342 THAs. The mean follow-up (FU) was 31.4 ± 21.7 months. The population was divided into three subgroups: spinal fusion patients (48.315 THAs); non-fused patients with spinal stiffness (106.110 THAs); non-fused patients with normal spines (3.151.917 THAs). A statistically significant risk stratification was observed about dislocation rate (5.98 ± 6.9% SF, 3.0 ± 1.9% non-SF Stiff and 2.26 ± 1.4% non-SF; $p = 0.028$). Similarly, about THA revision rate, a statistically significant risk stratification was also observed (7.3 ± 6.8% SF, 6.4 ± 3.1% non-SF Stiff and 2.7 ± 1.7% non-SF; $p = 0.020$). No statistically significant difference was observed when analysing AL, PJI and PF.

Conclusion A statistically significant risk stratification of dislocation and revision rate was observed in the different PHSR, as theorised by the Bordeaux classification. Fused patients present a higher risk, degenerated and/or stiff spine an intermediate risk and mobile spines a lower risk profile. A standardised approach to THA candidate patients must consider the possible PSHR to improve clinical outcomes and reduce adverse events of THA.

Keywords Hip-spine syndrome · Spine-hip syndrome · Total hip arthroplasty · Spinal fusion · Lumbo-pelvic complex · THA complications

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Introduction

The concept of lumbopelvic complex (LPC) has attracted increasing interest in the current literature [1]. The pelvis represents the core of a very complex biomechanical relationship between the spine and the lower limbs, especially with the hips [1, 2]. Alterations in one joint can potentially have an impact on the other [2]. This pathological situation is referred to as spine-hip syndrome (SHS) or hip-spine syndrome (HSS), depending on whether the primary pathological structure is the spine or the hip, respectively [2, 3].

Over the last decade, spine surgeons have extensively studied the compensation mechanism of the pelvis and lower limbs to sagittal misalignment to establish corrective surgical strategies and prevent mechanical complications in adult spinal deformity surgery [4–6].

Similarly, hip surgeons have shown growing interest in pathological spine-hip relations (PSHR) to reduce the risk of prosthetic impingement/dislocation and edge loading in THA.

In the current literature, unidentifiable causes of THA instability ranging from 7 to 18% have been reported [7]. A PSHR is very frequent (26% to 41%) in patients scheduled for primary THA [3, 8].

The Bordeaux Classification of Spine-Hip relations [9] is considered the most comprehensive and exhaustive [1]. It proposes an estimation of prosthetic impingement, prosthetic instability and edge loading risk based on a) type of LPC (according to individual Pelvic Incidence value), b) sagittal LPC kinematics and c) global sagittal spinal alignment. Three risk categories were therefore hypothesised: Category A—very low/low risk: mobile LPC; Category B and C—moderate/elevated risk: stiff LPC in a degenerated spine with a compensated spinal misalignment; Category D and E—very high risk: spine degeneration with an uncompensated spinal misalignment or fused spine.

Other authors have proposed simpler approaches to describe PSHR considering global sagittal spinal alignment and spinal stiffness/flexibility [10, 11].

Previous published reports, systematic reviews and meta-analysis have mainly investigated exclusively the effects of lumbar fusion on THA. Moreover, the analysis was limited to THA instability and revisions rates [12, 13]. These studies did not evaluate significant outcomes in THA such as AL, PF and PJI [14].

Furthermore, spinal fusion represents a subgroup of spinal stiffness, and the analysis could be extended to degenerative spinal conditions that result in spinal stiffness and/or spinal misalignment [15, 16]. Vigdorchik et al. reported that the vast majority (81%) of THA patients with a stiff spine condition weren't instrumented lumbar fusions [16].

The primary objective of this systematic review of the literature is to determine the effect of different PSHR on primary THA outcomes and complication profile. The secondary objective is to stratify the risk of different subgroups of PSHR patients.

Materials and methods

Eligibility criteria

We included all retrospective or prospective English-language studies, which included randomised controlled trials, comparative cohort studies and case–control studies comparing the outcomes and complication rates of primary THA in patients with and without a PSHR. A PSHR was defined in case of spinal fusion and degenerative spinal conditions leading to spinal stiffness and/or spinal misalignment. All non-English articles, case reports, literature reviews, meta-analyses, technical notes, expert opinions, and editorial letters were excluded. Studies with no comparison or control groups, with revision THA surgeries and papers that included cases of hemiarthroplasty or hip resurfacing not distinguishable from THA cases were excluded. The use of dual mobility cup was also a reason for exclusion. If several studies were based on data from the same registry during the same period, the most recent study was included, and the others excluded to avoid overestimation. Furthermore, we excluded studies reporting indistinctly outcomes and complications of THAs performed before or after a lumbar fusion.

Search strategy

A systematic review of the available literature was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. The following databases were searched up to February 2023: Medline through PubMed, Embase and the Cochrane Central Register of Controlled Trials. The following keywords were combined using the Boolean operators AND/OR: "total hip arthroplasty", "total hip replacement", "spinal fusion", "lumbar fusion", "Ankylosing spondylitis", "Bechterew disease", "ankylosing spine", "spinal ankylosis", "stiff spine", "adult spinal deformity", "sagittal imbalance" and "spine-hip syndrome".

Selection and data collection

Once duplicates were removed, two authors (CU and EF) evaluated the relevance of the articles based on the title and abstract. The full text of the selected articles was obtained and then assessed according to pre-defined inclusion and exclusion criteria. Discrepancies were discussed and the final decision was made by a third author (EQ). The references section of the identified articles was manually checked for other relevant papers.

Data items

The included studies were classified according to types of pathological spine-hip relations analysed. Then, pooling the data, three subgroups of PSHR were assembled for the present analysis: spinal fusion patients (SF); non-fused patients with stiff spines (non-SF Stiff) and non-fused patients with normal spines (non-SF).

The following data were extracted: number of patients, mean age of the population (years), gender distribution, mean follow-up (months), number of THAs, type of implant fixation (cemented, uncemented), femoral head size (mm), number of fused levels and mean time from fusion to THA in case of spinal fusion, type of degenerative spine conditions, type of surgical approach for THA, clinical outcomes (patient-reported outcome measures (PROM)), radiological parameters (acetabular cup anteversion and inclination) and hip dislocation rates, reinterventions, revisions and complications. Complications included all operative and non-operative complications related to the THA procedure (AL, PJI, PF).

Every new operation was considered as a reoperation; revisions, on the other hand, included any prosthetic component revision, including liner change.

Appraisal of studies' quality and risk of bias

The level of evidence of the included studies was evaluated through the adjusted Oxford Centre For Evidence-Based Medicine 2011 Levels of Evidence [18].

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system was used to define the quality of the studies [19]. The criteria of the Methodological Index for Non-Randomized Studies (MINORS) were used to assess the quality of the methodology of the included studies [20].

Statistical analysis

Statistical analysis was performed with SPSS version 20.0 for Windows (IBM Corporation, Armonk, NY, USA). Categorical variables were expressed as number of cases or percentage. Continuous variables were reported as mean ± standard deviation (SD). Lower and upper limits of 95% confidence intervals (CI) were calculated. Between-group comparisons for continuous variables were assessed using the Mann–Whitney (MW) and the Kruskal–Wallis (KW) tests. Statistical significance was accepted for $p<0.05$.

Results

Fifteen articles were included in the final review: nine were LoE IV [21–29] and six LoE III [30–35]. Six studies were register-based [21–25, 29]. The flow chart of the selection process is illustrated according to the PRISMA guidelines (Fig. 1). The overall quality of the included studies was considered low to very low according to the GRADE system. The bias risk was very high with a mean MINORS score of 15.5 ± 1.46 (CI 95% 14.7 to 16.3). GRADE and MINORS scores were reported as supplementary material.

Study population

The global population analysed included 3.306.342 hip prostheses, divided in three subgroups: SF patients (48.315 THAs); non-SF patients (3.151.917 THAs); non-SF Stiff patients (e.g. Ankylosing Spondylitis) (106.110 THAs). Regarding fused populations, only three studies [21–29] reported fusion length and only one paper reported the extension of the fusion to the pelvis [29].

Women (F) accounted for 60.8% of the overall population (SF, 63.9% F; non-SF, 60.7% F; non-SF Stiff, 61.7% F; $p>0.05$). The mean age was 63.2 ± 8.1 years (CI 95% 55.7 to 70.7) with the non-SF Stiff subgroup being statistically younger (SF 65.5 ± 4.4 Vs non-SF 66.6 ± 3.8 Vs non-SF Stiff 47.2 ± 15.4; $p<0.05$). The mean BMI was 27.6 ± 2.3 (CI 95% 23.9 to 31.2) with no statistically significant difference between groups ($p>0.05$). Mean follow-up (FU) was 31.4 ± 21.7 months (CI 95% 18.8 to 43.9) with no differences between groups ($p>0.05$) (Table 1).

Regarding the type of surgical approach used for THAs, the posterior approach was the most used (Posterior, 76.4%; Lateral, 16.6%; Anterior, 7%) (Table 2). Only four authors [28, 31, 34, 35] reported on femoral head size. With regard to the type of femoral stem fixation (cemented versus uncemented), mixed populations were analysed in the included studies.

Radiological parameters

The mean cup inclination was similar between the different groups with a mean value of: SF: 41.1 ± 4.3° (CI 95% 34.3 to 48), non-SF: 41.3 ± 2.4° (CI 95% 19.7 to 62.9) and non-SF stiff (AS): 42.2 ± 3.7° (CI 95% 8.7 to 75.8)) (KW: $p=0.840$; MW: SF Vs non-SF, $p=0.741$; SF Vs non-SF Stiff, $p=0.977$; non-SF Vs Non SF Stiff, $p=0.799$). Similarly, no differences were noticed in cup anteversion, the mean value of which was: SF: 21.3 ± 3.7° (CI 95% 15.4 to

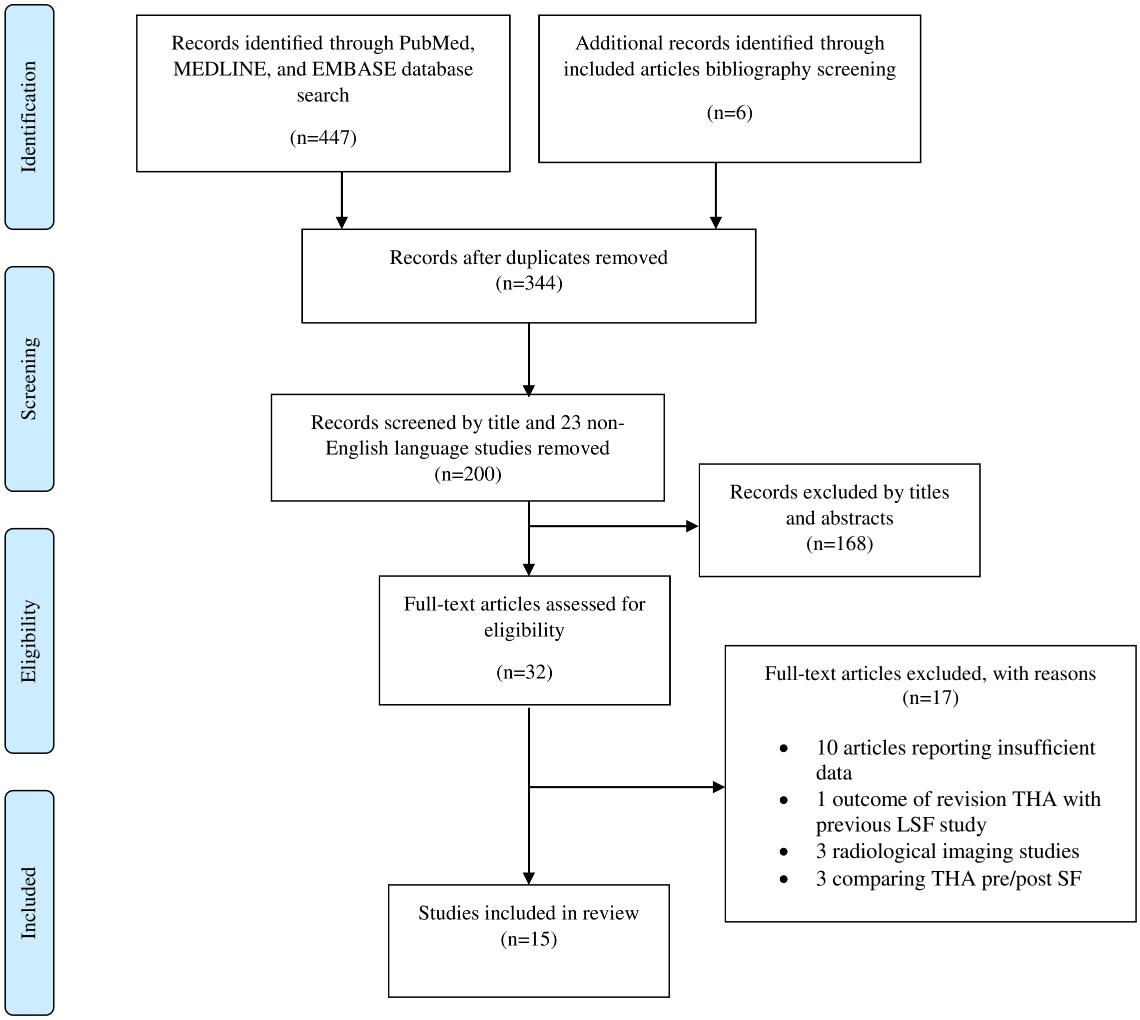

Fig. 1 PRISMA search flowchart and inclusion strategy

27.2); Non SF: 19.7 ± 2.4° (CI 95% -1.9 to 41.3); Non SF stiff (AS): 19.8 ± 1.2° (CI 95% 9 to 30.5) (KW: $p = 0.846$; SF Vs Non SF, $p = 0.621$; SF Vs Non SF Stiff, $p = 0.615$; Non SF Vs Non SF Stiff, $p = 0.980$) (Table 3).

Clinical outcomes

An analysis of patient-reported outcome measures (PROM) could not be performed because they were reported by one single author that found significantly better clinical outcomes in non-SF compared to SF patients [31].

Dislocation, revision and complication rates

The mean dislocation rates were 5.98 ± 6.9% in the SF, 3.0 ± 1.9% in the non-SF Stiff and 2.26 ± 1.4% in the non-SF groups, respectively, and a statistically significant difference was observed between the three groups (KW, $p = 0.028$). More specifically, in the one Vs one analysis, dislocations were clearly more frequent in the SF group than in the non-SF one (MW: $p = 0.007$) whereas no differences were observed in the other groups (SF Vs non-SF Stiff, MW: $p = 0.171$; Non-SF Vs non-SF Stiff, MW: $p = 0.512$) (Table 4). When analysing the risk of dislocation in relation to the surgical approach, no statistically significant difference was observed between the three groups using the KW test (Anterior, $p = 0.861$; Lateral, $p = 0.135$; Posterior, $p = 0.621$). The authors did not report a significant correlation between femoral head size and the risk of THA instability.

Dislocations represented the leading cause of THA revision. In fact, the mean THA revision rate was statistically different between the three groups (7.3 ± 6.8% in the SF, 6.4 ± 3.1% in the non-SF Stiff and 2.7 ± 1.7% in the non-SF groups; KW, $p = 0.020$). In one vs one analysis, differences were found between SF Vs non-SF groups (7.3 ± 6.8% Vs 2.7 ± 1.7%, respectively, MW: $p = 0.008$) and the non-SF Vs non-SF Stiff groups (2.7 ± 1.7% Vs 6.4 ± 3.1%, MW:

Table 1 Study details and patient demographics: LoE, level of evidence; BMI, body mass index; FU, follow-up; SF, spinal fusion

Article	Study design	LoE	Number of hips				Gender						Mean age			Mean BMI			Mean time from fusion to THA years	FU (months)
			SF	Non-SF	Non-SF Stiff	Total	SF		Non-SF		Non-SF Stiff		SF	Non-SF	Non-SF Stiff	SF	Non-SF	Non-SF Stiff		
							M	F	M	F	M	F								
Sing et al. 2016	Registry	IV	9695	589.300	–	598.995	3282	6412	224.523	364.777	–	–	–	–	–	–	–	–	–	24
Barry et al. 2017	Case–control	III	35	70	–	105	21	14	39	31	–	–	68.5	68.4	–	–	–	–	–	3
Buck-land et al. 2017	Registry	IV	14.668	839.004	–	853.672	5030	9638	323.673	515.331	–	–	–	–	–	–	–	–	–	12
Loh et al. 2017	Case–control	III	82	82	–	164	16	66	16	66	–	–	67.6	67.7	–	26.5	26.5	–	3.6	24
Perfetti et al. 2017	Case–control	III	934	934	–	1868	343	591	372	562	–	–	64.5	64.5	–	–	–	–	1.5	12
Blizzard et al. 2017	Registry	IV	–	660.240	1002	661.242	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Malkani et al. 2018	Registry	IV	1809	60.578	–	62.387	–	–	–	–	–	–	–	–	–	–	–	–	–	60
York et al. 2018	Retro-spec-tive	III	31	478	–	509	7	24	182	296	–	–	63.5	61.3	–	–	–	–	–	32
Salib et al. 2019	Case–control	III	97	194	–	291	43	54	86	108	–	–	71	71	–	30	30	–	–	72
Bala et al. 2019	Registry	IV	13.102	492.654	104.820	610.576	5006	8096	188.230	304.415	40.050	64.768	–	–	–	–	–	–	–	24

Table 1 (continued)

Article	Study design	LoE	Number of hips				Gender						Mean age			Mean BMI			Mean time from fusion to THA years	FU (months)
			SF	Non-SF	Non-SF Stiff	Total	SF		Non-SF		Non-SF Stiff		SF	Non-SF	Non-SF Stiff	SF	Non-SF	Non-SF Stiff		
							M	F	M	F	M	F								
Katakam et al. 2020	Retro-spec-tive	III	135	–	142	277	53	82	–	–	75	67	66.3	–	58.1	29.6	–	28.1	–	62.1
Pollard et al. 2021	Registry	IV	328	14.217	–	14.545	121	207	4762	9455	–	–	–	–	–	–	–	–	–	24
Ofa et al. 2021	Registry	IV	382	28.608	–	28,990	136	246	9.738	18.871	–	–	–	–	–	–	–	–	–	12
Guan et al. 2021	Retro-spec-tive	IV	73	–	146	219	25	48	–	–	139	7	57.3	–	35.3	25.4	–	24.3	–	54
Yang et al. 2022	Registry	IV	6944	465.558	–	472,502	2709	4235	202.665	262.903	–	–	–	–	–	–	–	–	–	24

Table 2 THA approach: SF, spinal fusion

Article	THA approach								
	SF			Non-SF			Non-SF Stiff		
	Anterior	Lateral	Posterior	Anterior	Lateral	Posterior	Anterior	Lateral	Posterior
Sing et al. 2016	–	–	–	–	–	–	–	–	–
Barry et al. 2017	1	18	16	6	43	21			
Buckland et al. 2017	–	–	–	–	–	–	–	–	–
Loh et al. 2017	–	–	–	–	–	–	–	–	–
Perfetti et al. 2017	–	–	–	–	–	–	–	–	–
Blizzard et al. 2017	–	–	–	–	–	–	–	–	–
Malkani et al. 2018	–	–	–	–	–	–	–	–	–
York et al. 2018	–	–	31	–	–	478	–	–	–
Salib et al. 2019	9	49	39	18	98	78			
Bala et al. 2019	–	–	–	–	–	–	–	–	–
Katakam et al. 2020	38	3	94	–	–	–	25	9	108
Pollard et al. 2021	–	–	–	–	–	–	–	–	–
Ofa et al. 2021	–	–	–	–	–	–	–	–	–
Guan et al. 2021	–	5	68	–	–	–	1	7	138
Yang et al. 2022	–	–	–	–	–	–	–	–	–

Table 3 Patients cup anteversion and inclination angles: SF, spinal fusion

Article	Outcome measure	SF	No SF	Non SF Stiff
Sing et al. 2016	–	–	–	–
Barry et al. 2017	–	–	–	–
Buckland et al. 2017	–	–	–	–
Loh et al. 2017	–	–	–	–
Perfetti et al. 2017	–	–	–	–
Blizzard et al. 2017	–	–	–	–
Malkani et al. 2018	–	–	–	–
York et al. 2018	Cup Anteversion°	26.8	21.4	–
	Cup Inclination °	39.9	39.6	–
Salib et al. 2019	Cup Anteversion°	20	18	–
	Cup Inclination°	45	43	–
Bala et al. 2019	–	–	–	–
Katakam et al. 2020	Cup Anteversion°	18.96	–	18.91
	Cup Inclination°	44.02	–	44.85
Pollard et al. 2021	–	–	–	–
Ofa et al. 2021	–	–	–	–
Guan et al. 2021	Cup Anteversion°	19.4	–	20.6
	Cup Inclination°	39.59		39.57
Yang et al. 2022	–	–	–	–

$p = 0.023$), whereas no difference was observed comparing SF Vs non-SF Stiff (MW, $p = 0.855$) (Table 5).

Furthermore, no statistically significant difference was observed when analysing the rate of the other major THA complications: PJI, KW: $p = 0.379$ (MW: SF Vs non-SF, $p = 0.18$; SF Vs non-SF Stiff, $p = 0.643$; non-SF Vs non-SF Stiff, $p = 0.857$); PF, KW: $p = 0.875$ (MW: SF Vs non-SF, $p = 0.559$; SF Vs non-SF Stiff, $p = 0.604$; non-SF Vs non-SF Stiff, $p = 0.692$); AL, MW: $p = 0.589$ (the latter comparison could only be performed between SF and non-SF due to missing data in the non-SF Stiff subgroup) (Table 6).

Discussion

In recent years, great improvements have been achieved in understanding the physiological and pathological biomechanical relationships between the spine and the hips. Nevertheless, the current literature is characterised by a poor overall quality of the studies with a considerable risk of bias. The present analysis demonstrates a statistically significant risk stratification regarding the dislocation rate as theorised by the Bordeaux classification ($5.98 \pm 6.9\%$ in the SF, $3.0 \pm 1.9\%$ in the non-SF Stiff and $2.26 \pm 1.4\%$ events in the non-SF (KW, $p = 0.028$)). The THA instability appears to be the primary indication for THA revision. Similarly, in a

Table 4 Hip dislocations: SF, spinal fusion

Article	SF		Non SF		Non SF Stiff	
	Events (%)	Total	Events (%)	Total	Events (%)	Total
Sing et al. 2016	488 (5.03%)	9695	13,907 (2.36%)	589,300	–	–
Barry et al. 2017	1 (2.86%)	35	0 (0%)	70	–	–
Buckland et al. 2017	464 (3.16%)	14,668	12,982 (1.55%)	839,004	–	–
Loh et al. 2017	1 (1.21%)	82	1 (1.21%)	82	–	–
Perfetti et al. 2017	28 (3%)	934	4 (0.43%)	934	–	–
Blizzard et al. 2017	–	–	22,989 (3.48%)	660.240	53 (5.29%)	1002
Malkani et al. 2018	134 (7.41%)	1809	2908 (4.8%)	60,578	–	–
York et al. 2018	9 (29%)	31	19 (3.97%)	478	–	–
Salib et al. 2019	5 (5.15%)	97	4 (2.06%)	194	–	
Bala et al. 2019	608 (4.64%)	13,102	11,229 (2.28%)	492,654	3329 (3.18%)	104,820
Katakam et al. 2020	16 (4.44)	135	–	–	4 (2.82%)	142
Pollard et al. 2021	28 (8.54%)	328	567 (3.99%)	14,217	–	–
Ofa et al. 2021	3 (0.79%)	382	341 (1.19%)	28,608	–	–
Guan et al. 2021	3 (4.11%)	73	–	–	1 (0.68%)	146
Yang et al. 2022	303 (4.36%)	6944	9437 (2.03%)	465,558	–	–

Table 5 THA Revisions: SF, spinal fusion

Article	SF		Non SF		Non SF Stiff	
	Events (%)	Total	Events (%)	Total	Events (%)	Total
Sing et al. 2016	589 (6.7%)	9695	20,213 (3.43%)	589,300	–	–
Barry et al. 2017	5 (14.3%)	35	2 (2.86%)	70	–	–
Buckland et al. 2017	43 (0.36%)	12,079	1691 (0.2%)	839,004	–	–
Loh et al. 2017	0 (0%)	82	0 (0%)	82	–	–
Perfetti et al. 2017	36 (3.85%)	934	8 (0.85%)	934		
Blizzard et al. 2017	–	–	36,729 (5.56%)	660,240	86 (8.58%)	1002
Malkani et al. 2018	125 (6.91%)	1809	2787 (4.6%)	60,578	–	–
York et al. 2018	8 (25.1%)	31	5 (1.04%)	478		
Salib et al. 2019	4 (4.12%)	97	5 (2.58%)	194		
Bala et al. 2019	745 (5.69%)	13,102	16,198 (3.29%)	492.654	4387 (4.19%)	104.820
Katakam et al. 2020	–	–	–	–	–	–
Pollard et al. 2021	31 (9.45%)	328	605 (4.26%)	14,217	–	–
Ofa et al. 2021	18 (4.71%)	382	1036 (3.62%)	28,608	–	–
Guan et al. 2021	–	–	–	–	–	–
Yang et al. 2022	392 (6.65%)	6944	14.405 (3.09%)	465.558	–	–

global comparison concerning THA revision rate, a statistically significant risk stratification was also noted (7.3 ± 6.8% in SF, 6.4 ± 3.1% in the non-SF Stiff and 2.7 ± 1.7% in the non-SF (KW, $p = 0.020$)). Nevertheless, if a direct comparison between one group and the other is performed, the finding is more evident in the revision rate analysis, showing significant differences between SF and non-SF groups (MW: $p = 0.008$) and the non-SF Vs non-SF Stiff groups (MW: $p = 0.023$), whereas no difference was observed between SF and non-SF Stiff (MW, $p = 0.855$). Regarding THA instability, dislocations were clearly more frequent in the SF group than in the non-SF one (MW: $p = 0.007$), whereas no differences were observed in the other groups. The type of surgical approach used to perform THA does not appear to be a risk factor for dislocation. In the current literature, the use of large diameter femoral heads and dual mobility cups are proposed as possible solutions to reduce THA instability and consequently the revisions rate [36]. With regard to this review, only four studies analysed the role of the femoral head size and implant instability [28, 31, 34, 35]. These authors did not report significant correlation between femoral head size and the risk of THA instability. Katakam

Table 6 All complications: SF, spinal fusion; PJI, periprosthetic joint infection; PF, periprosthetic fracture; AL, aseptic loosening

Article	SF					Non SF					Non SF Stiff				
	All (%)	PJI (%)	PF (%)	AL (%)	Total	All (%)	PJI (%)	PF (%)	AL (%)	Total	All (%)	PJI (%)	PF (%)	AL (%)	Total
Sing et al. 2016	1155 (11.91%)	301 (3.1%)	128 (1.32%)	225 (2.32%)	9695	43,019 (7.3%)	10,843 (1.84%)	5126 (0.87%)	7837 (1.33%)	589.300	–	–	–	–	–
Barry et al. 2017	12 (34.29%)	3 (8.57%)	1 (2.86%)	0 (0%)	35	6 (8.57%)	0 (0%)	1 (1.43%)	1 (1.43%)	70	–	–	–	–	–
Buckland et al. 2017	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loh et al. 2017	1 (1.22%)	–	–	–	82	1 (1.22%)	–	–	–	82	–	–	–	–	–
Perfetti et al. 2017	36 (3.85%)	–	–	–	934	8 (0.86%)	–	–	–	934	–	–	–	–	–
Blizzard et al. 2017	–	–	–	–	–	65,052 (9.85%)	17,218 (2.61%)	8678 (1.31%)	–	660,240	147 (14.67%)	39 (3.89%)	18 (1.8%)	–	1002
Malkani et al. 2018	–	7 (5.6%)	25 (20%)	19 (15.2%)	125	–	156 (5.6%)	262 (9.4%)	338 (12.13%)	2787	–	–	–	–	–
York et al. 2018	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Salib et al. 2019	11 (11.34%)	2 (2.06%)	1 (1.03%)	1 (1.03%)	97	5 (2.58%)	–	–	1 (0.52%)	194	–	–	–	–	–
Bala et al. 2019	3974 (30.33%)	352 (2.69%)	179 (1.37%)	220 (1.68%)	13,102	95,216 (19.31%)	8531 (1.73%)	4236 (0.86%)	4243 (0.86%)	492,654	26,861 (25.63%)	2470 (2.36%)	1174 (1.12%)	1267 (1.21%)	104,820
Katakam et al. 2020	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pollard et al. 2021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ofa et al. 2021	36 (9.42%)	18 (4.71%)	3 (0.79%)	15 (3.93%)	382	2309 (8.07%)	1394 (4.87%)	341 (1.2%)	574 (2.01%)	28,608	–	–	–	–	–
Guan et al. 2021	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Yang et al. 2022	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

et al. [35] in their analysis observed an increasing temporal trend in the use of larger diameter femoral heads without a reduction in dislocation rate. Nevertheless, the lack of an extensive and precise analysis of femoral head diameter as a risk factor for THA instability in pathological spine-hip relations appears to be an important limitation of the current literature.

The use of dual mobility cups has been advocated by several authors as protective factor against impingement and THA dislocations [1–3], however the evidence in the literature is limited. Nessler et al. [37], in a retrospective multicentre study of 93 patients with previous lumbar fusion, reported no dislocations. These very promising results were characterised by several limitations, such as the small population, the retrospective multicentre design and the short-term follow-up. In particular, short-term follow-up could underestimate the rate of intra-prosthetic dislocations secondary to component impingement in PSHR. Further studies should analyse results of dual mobility cups in the PSHR population in a medium-to-long follow-up.

No statistically significant difference was observed when analysing the rate of the other major THA complications (PJI, AL and PF). A limitation of the present review is the lack of precise analyses on the type of stem fixation and periprosthetic fractures.

A comparative analysis of patient-reported outcome measures (PROM) between the groups could not be performed, underlining a significant limitation of the current literature. Mean cup inclination and cup anteversion were similar between groups, demonstrating the lack of a tailored approach to different patient LPC kinematics.

The present review highlights the enormous limitations of the current literature due to the lack of routine reporting of key parameters such as type of previous spinal surgery, number of fused levels (short Vs long fusions), fused spinal area, sagittal characteristics of spinal fusion (good alignment, flat back, hypercorrection etc.), type of spinal fusion and timing between spinal fusion and THA surgery. The literature non-specifically reports 'previous spinal surgery' as a risk factor for THA instability and implant-related complications; however, neural decompression or total disc arthroplasty do not affect spinal mobility [38, 39]. The lack of an estimated number of fused levels appears to be the most obvious limitation. The spine is a sequence of motion segments and when one of these is blocked, the contiguous regions of the spine with free movement can compensate for the physiological kinematics of the LPC during daily activities. If more segments are blocked, the compensation may be less. Only in three studies [21–29] was the SF population classified according to fusion length: Sing et al. [21] reported a dislocation rate of 4.26% in less than two fused levels and of 7.51% in more than three fused levels; similarly, Buckland et al. [22] reported a dislocation rate of 2.96% in less than two fused levels and of 4.12% in more than three fused levels; finally, Yang et al. [29] further stratified the dislocation risk rates in 4.3% in one level, 4.7% in two to five levels and 9% in spinopelvic fixations. Furthermore, the compensatory ability of the spine must be considered: the adjacent non-fused spine could not be able to compensate due to degenerative processes. This consideration can justify the high dislocation rate even in the presence of a single fused motion segment compared to long fusion, as reported by Yang et al. [29].

Another important limitation of the current literature is the lack of differentiation of the spinal fusion area. Spinal surgeons have demonstrated the key role of the lower lumbar lordosis (L4S1) and that the more caudally the correction is applied, the more powerful the effect on the pelvis and specifically on the LPC [40–42]. In this context, fusion of the lower lumbar spine extended to the sacrum or to pelvis has a clear impact on the physiological kinematic of the LPC during daily activities. Indeed, Yang et al. reported a twice higher rate of hip dislocations in spinopelvic fixation [29].

The sagittal characteristic of spinal fusion is another critical issue largely underestimated in the literature concerning PSHR. The spine can be fused in the target lordosis, creating a condition known as "stuck-standing" with excess lumbar lordosis and the inability of pelvic retroversion when sitting, leading to an increased risk of anterior impingement of the implant and consequently posterior dislocation [1]. On the other hand, the spine may be fused in hypo-lordosis or in kyphosis, creating a condition known as "stuck-sitting" with lumbar hypo-lordosis, an excess of pelvic retroversion, an increased risk of posterior implant impingement and consequently anterior dislocation when standing [1]. The clinical scenario termed "stuck-standing" is also present to a lesser extent in case of a well-aligned stiff spine. On the other hand, the clinical scenario kwon as "stuck-sitting" is also present to a lesser extent in cases of stiff degenerative spinal deformities. The limitations of the previously discussed literature adversely impact the current knowledge concerning clinical outcomes and complication profile of primary THA in patients with a PSHR.

Recently, the Hip-Spine Classification Group [43] proposed a simpler approach to define a PSHR considering the presence of spinal deformity (yes or no) and of spinal stiffness (yes or no). Four categories are determined: 1A—normal spinal alignment and normal spinal mobility; 1B—normal spinal alignment and stiff spine; 2A—flat back deformity and normal spinal mobility; 2B group – flat back deformity and stiff spine. Groups 1B and 2A present a higher risk of instability than group 1A. Category 2B has the highest risk of dislocation of all. In the current literature, the concept of functional acetabular safe zones based on patient-specific factors appears to be the most promising clinical solution for ensuring optimal component stability compared to traditional safe zones based on static targets. In the recent years, the Hip-spine Classification Group has reported several proposals for the most appropriate cup inclination and anteversion in relation to the type of PSHR [43–45]. Nevertheless, recently, Ramkumar et al. [46] demonstrated that Hip-spine Classification proposed qualitative component targets, but a patient-specific mathematical approach based on the precise analysis of spinopelvic parameters increases implant stability by significantly reducing the dislocations rate. Further research is needed to clarify the best and easiest method to establish components positioning and also the role of computer navigation and robotics as additional tools to achieve targeted positioning within the functional safe zone.

The present study has some advantages over previous reviews and meta-analyses. Firstly, we reported a comprehensive overview of THA outcomes (not only instability) in all possible configurations of PSHR (SF, non-SF stiff spine and non-SF). Secondly, we attempted to demonstrate the risk stratification related to THA outcomes theorised by the Bordeaux classification of separate groups of PSHR. Furthermore, we excluded several recent studies that included redundant results from the same database. Lastly, we critically analysed weaknesses in the current literature regarding the type of previous spinal surgery, number of fused levels (short Vs long fusions), fused spinal area and sagittal characteristics of spinal fusion.

This review has some important limitations that deserve consideration. First, there was significant heterogeneity among the included studies in the definition of complications. Secondly, a possible bias in the present analysis is the assumption that non-SF patients reported by the studies as control groups were non-stiff spines: the current literature does not investigate this key parameter. Third, the follow-up duration of the included studies was short, which could potentially lead to underestimation of THA survival, risk of aseptic loosening, instability, and revision.

Conclusion

This analysis demonstrates a statistically significant risk stratification regarding dislocation and revision rate, as theorised by the Bordeaux classification for different PSHR. Fused patients present a higher risk, degenerated and/or stiff spine an intermediate risk and mobile spine a lower risk profile. A standardised approach for THA candidate patients must consider and differentiate possible PSHR to improve clinical outcomes and reduce adverse events.

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Declarations

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