

Association between sagittal spinal alignment and mechanical complications after primary total hip arthroplasty: a systematic review

Journal of International Medical Research
50(8) 1–12

© The Author(s) 2022


Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/03000605221116976

journals.sagepub.com/home/imr



Hiltunen Susanna^{1,2} , Repo Jussi³,
Karjalainen Teemu¹ and Kyrölä Kati¹

Abstract

Objective: Total hip arthroplasty (THA) affects pelvic posture and spinal alignment. These postural changes may further predispose patients to mechanical complications (MCs) after THA. The aim of this study was to conduct a systematic review to investigate whether any high-quality studies have assessed the association between sagittal spinal alignment and MCs after primary THA.

Methods: Inclusion criteria for studies were adult patients (age ≥ 18 years), primary THA, pre- and postoperative spinopelvic standing sagittal radiographs acquired preoperatively and at a minimum of 6-month follow-up, measurements of spinopelvic parameters, and reporting of possible MCs after THA. The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.

Results: Six articles met the inclusion criteria. Although several studies confirmed the importance of spinal alignment when planning THA, these mainly investigated pelvic mobility as a risk factor for THA dislocation. Radiological follow-up imaging practices varied, and studies focused on different individual spinopelvic parameters.

³Department of Orthopaedics and Traumatology, Unit of Musculoskeletal Surgery, Tampere University Hospital and Tampere University, Tampere, Finland

Corresponding author:

Susanna Hiltunen, Orthopaedic Outpatient Clinic 3212 (Orthopedics, Traumatology, Hand Surgery), Puijo Hospital, Kaari Hospital, B, K, 1st floor, Kuopio 70029, Finland.

Email: susanna.hiltunen@kuh.fi

¹Department of Surgery, Central Finland Hospital Nova, Jyväskylä, Finland

²Department of Orthopaedics, Traumatology and Hand Surgery, Kuopio University Hospital, Kuopio, Finland



Conclusion: Based on our study findings, no conclusions can be drawn regarding the association between sagittal spinal alignment and MCs after primary THA. Further research is needed to improve our knowledge of the connection between MCs after THA and sagittal spinal alignment.

Keywords

Pelvic tilt, sagittal alignment, spinal alignment, total hip dislocation, total hip replacement, review

Date received: 13 April 2022; accepted: 14 July 2022

Introduction

Since the early years of modern total hip arthroplasty (THA), the Lewinnek safe zone (determined according to an inclination of $40^\circ \pm 10^\circ$ and an anteversion of $15^\circ \pm 10^\circ$) has been used for optimal acetabular component orientation to reduce the risk of hip dislocation.¹ However, several studies have since provided evidence that the Lewinnek safe zone does not always predict stability.²⁻⁴ When Lewinnek first described the safe zone, the acetabular anteversion and inclination were measured from a supine radiograph taken perpendicular to the anterior pelvic plane (APP).^{1,2} During postural changes, however, the acetabular cup does not remain static and instead moves with the spinopelvic motion. Furthermore, spinal malalignment may change pelvic mobility and position, which can result in an acetabular cup being out of the expected safe zone.³⁻⁵

Sagittal spinal malalignment and compensatory mechanisms are common in adults with symptomatic degenerative spinal conditions without previously diagnosed adult spinal deformity.^{6,7} Increased pelvic tilt (PT) leads to pelvic retroversion and excessively anteverted acetabular components and is one of the earliest changes seen in the development of spinal malalignment.^{6,8-10} Additionally, THA affects pelvic posture and spinal alignment.¹¹⁻¹⁶

These changes may further predispose to mechanical complications (MCs), such as hip dislocation, in cases where the sagittal spinal malalignment has not been adjusted with optimal acetabular cup positioning, even though the cup is positioned within the Lewinnek safe zone.^{11,12,14,17-20}

Despite advances in surgical techniques and improvements in implant design, dislocation is still a common complication (3.5%–4.8%) after THA^{21,22} that leads to early revision surgery (17%–33% of THA revisions).²³⁻²⁶ Recent studies on THA revision and THA dislocation rarely acknowledge the aspect of spinal alignment or mobility.^{5,12} Conversely, some studies appear to emphasize the importance of full spine radiographs in analyzing spinal alignment and compensatory mechanisms in patients undergoing THA surgery.^{6,12,27}

The aim of this study was to conduct a systematic review to investigate whether the association between sagittal spinal alignment and MCs after THA has been investigated in high-quality studies. A further aim of the study was to ascertain whether there are uniform methods for radiographic imaging and assessment of sagittal spinal alignment with spinopelvic parameters.

Methods

This systematic review was conducted according to the Preferred Reporting

Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.²⁸ The review was registered in the PROSPERO international database of prospectively registered systematic reviews on April 28, 2020 (CRD42020167209). In this study, we received funding for a literature search and English language proofreading from Central Finland Hospital Nova, Jyväskylä, Finland.

Because of the systematic review study design, the data were anonymized, and none of the patients can be identified. Thus, approval from an ethics review committee for the study and patient consent was not required.

Literature search and study selection

We searched MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials, and Medic (University of Helsinki) databases. A trained informationist (TO) assisted in the development of the search strategy (Appendix A). The search period was from January 2000 through 6 May 2021. The initiation date was pre-evaluated to cover all recent published literature that includes THA and spinopelvic parameters. The end date was set to the beginning of the analysis. Any published observational studies, case-control studies, or randomized controlled trials assessing the association between the MCs of primary THA and spinopelvic parameters were considered.

Inclusion criteria for the studies were adult patients (age ≥ 18 years), primary THA, pre- and postoperative spinopelvic standing sagittal radiographs acquired preoperatively and at a minimum of 6-month follow-up, measurement of spinopelvic parameters, and reporting of possible MCs after THA. THA dislocation, subluxation, impingement, or aseptic loosening were defined as MCs, although studies that did not provide a more precise definition of

MCs were also included. Exclusion criteria were case reports or review articles, studies written in a language other than English, and those without clear documentation that the operation was primary THA. The types of outcome measures were (1) changes in spinopelvic parameters after THA and (2) MCs after THA during follow-up.

Data collection and analysis

After removing duplicates, three authors (JR, KK, SH) together screened the article titles and abstracts to identify potentially eligible studies. The full text of potentially eligible studies was assessed independently by the authors. Eighty-two full-text articles failed to meet the inclusion criteria and were excluded. Finally, six studies were included in the review (Figure 1).

From the included studies, three authors (JR, KK, SH) together extracted the study design, follow-up time points, primary endpoint, main and secondary outcomes, hip and spine measurements, MCs, inclusion and exclusion criteria, sample sizes, and patient characteristics (age, sex, and diagnosis leading to THA). Disagreements in screening, inclusion of studies for full-text review, and data extraction were resolved by the senior author (KK).

Measurement of changes in spinopelvic parameters

Two authors (KK, SH) of this review calculated the change in each spinopelvic parameter after THA by subtracting the reported preoperative parameter from the reported postoperative parameter. However, it was not possible to perform the calculation if the preoperative and/or postoperative parameters were not reported in the study. The change in spinopelvic parameters was reported as positive (+) if the magnitude of the parameter increased

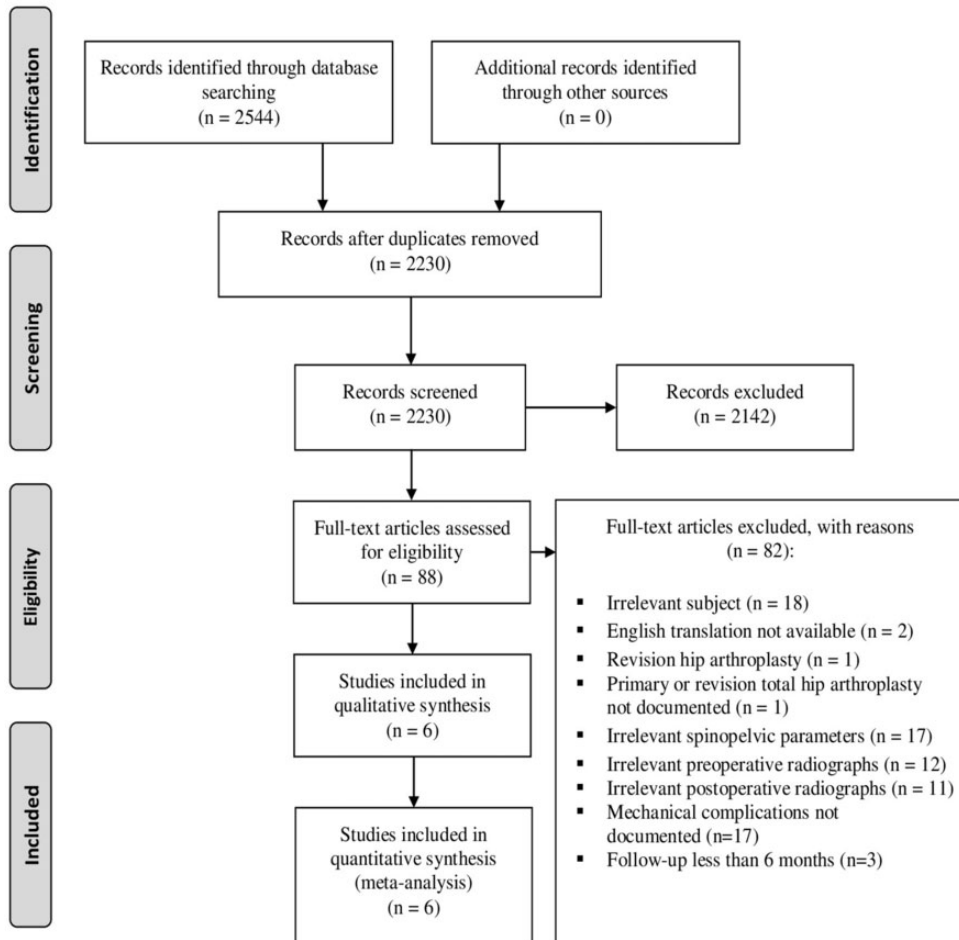


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2009 flow diagram.³⁶

after THA and negative (–) if the magnitude of the parameter decreased after THA.

Assessment of risk of bias in the included studies

Two authors (KK, SH) independently assessed the quality and evaluated the risk of bias for the included studies using the Quality In Prognosis Studies tool. This tool considers six bias domains: selection of study participants (I), study attrition (II), prognostic factor measurement (III),

outcome measurement (IV), study confounding (V), and statistical analysis and reporting (VI). The six domains each contain three to seven prompting items for which the adequacy of reporting is assessed “yes,” “partial,” “no,” or “unsure” to guide ratings of “low,” “moderate,” or “high” risk of bias.^{29,30} We considered a study to have a low risk of bias if rated low or moderate in all six domains, with at least four domains considered to be low. We considered a study to have high risk of bias if two or more domains were rated high.

Table 1. Information of six included articles.

Article title	Authors reference no.	Journal (publication year)
Acetabular and femoral anteversions in standing position are outside the proposed safe zone after total hip arthroplasty	Lazennec et al. ¹³	Journal of Arthroplasty (2017)
What preoperative factors predict postoperative sitting pelvic position one year following total hip arthroplasty?	Berliner et al. ¹¹	Bone & Joint Journal (2018)
Three-dimensional analysis of acetabular cup orientation and an evaluation of the relationship with pelvic sagittal parameters	Sahin et al. ¹⁶	Journal of Orthopedic Surgery, Hong Kong (2019)
Does it matter: total hip arthroplasty or lumbar spinal fusion first? Preoperative sagittal spinopelvic measurements guide patient-specific surgical strategies in patients requiring both	Parilla et al. ¹⁹	Journal of Arthroplasty (2019)
Impact of spinal alignment and stiffness on impingement after total hip arthroplasty: a radiographic study of pre- and postoperative spinopelvic alignment	Hagiwara et al. ¹²	European Spine Journal (2021)
Sagittal spinopelvic translation is combined with pelvic tilt during the standing to sitting position: pelvic incidence is a key factor in patients who underwent THA	Lazennec et al. ³	Arthroplasty Today (2020)

THA, Total hip arthroplasty.

Table 2. Characteristics of the included articles.

Study reference no.	Country	Number of patients	Women	Men	Mean age of patients, years (min–max) [SD]
Lazennec et al. 2017 ¹³	France	66	40	26	65 (27–84) [N/A]
Berliner et al. 2018 ¹¹	United States	144	N/A	N/A	61 (N/A) [11]
Sahin et al. 2019 ¹⁶	Turkey	86	48	37	56 (31–75) [12]
Parilla et al. 2019 ¹⁹	United States	135*	79	56	68 (N/A) [N/A]
Hagiwara et al. 2021 ¹²	Japan	95	73	22	62 (21–84) [13]
Lazennec et al. 2020 ³	France	120	59	61	65 (37–81) [14]

*Of the 135 included patients, only 89 had sufficient preoperative and postoperative radiographic data for a complete series of measurements.

N/A, not available; SD, standard deviation.

The remaining studies were rated as having a moderate risk of bias. Any disagreements in the assessment between the two assessors were resolved by the senior author (KK).

Results

After exclusion, six studies were included in the review. The included studies were published between 2017 and 2021 (Table 1). Two studies were conducted in France,

Table 3. Imaging modalities in the six included articles.

Study reference no.	F-u (months)	F-u points	AP pelvis		Sagittal lumbopelvic ^a		Sagittal spinopelvic ^a		2D EOS		3D EOS		Pelvic CT	
			su	st	si	st	si	st	si	st	st	st	su	su
Lazennec et al. 2017 ¹³	12–36	Preop time N/A 3–6 mo postop										X ^d X ^d		
Berliner et al. 2018 ¹¹	12	Preop time N/A							X ^b X ^b	X ^b X ^b				
Sahin et al. 2019 ¹⁶	12–60	12 mo postop Preop time N/A 12–60 mo postop	X	X		X								
Parilla et al. 2019 ¹⁹	24	Preop time N/A 3, 6, 12, 18, and 24 mo postop				X								X
Hagiwara et al. 2021 ¹²	12–30	1 mo preop 6 mo postop			X		X							
Lazennec et al. 2020 ³	6–9	Preop time N/A 6–9 mo postop			X					X ^c X ^c				

^aPlain radiographs.^bLumbar–pelvic–femoral, AP, and sagittal.^cFull body, sagittal.^dFull body, 3D.

AP, anteroposterior; CT, computed tomography; 2D, two-dimensional; 3D, three-dimensional; EOS, EOS imaging system; F-u, follow-up; N/A, not available; si, sitting; st, standing; su, supine.

Table 4. Postoperative changes in spinopelvic parameters in different positions.

Study reference no.	Position	Δ PI	Δ SS	Δ LL	Δ (S)PT	Δ PI-LL	Δ APP	Δ SVA	Δ SSPT
Lazennec et al. 2017 ¹³	Standing	-0.19	-2.1	-	1.9	-	2.4	-	-
Berliner et al. 2018 ¹¹	Standing	-	-1.0	0.0	-	-	-	-	-
	Sitting	-	5.0	7.0	-	-	-	-	-
Sahin et al. 2019 ¹⁶	Standing	0.80	-0.50	-	1.3	-	-	-	-
Parilla et al. 2019 ¹⁹	Standing	3.4	0.29	-1.1	3.2	4.5	-	-	-
Hagiwara et al. 2021 ¹²	Standing	-	-2.3	-1.1	-	-	-	-3.1	-
	Sitting	-	-0.40	0.0	-	-	-	-2.3	-
Lazennec et al. 2020 ³	Standing	0.0	-0.90	0.70	-	-	-	-8.6	11
	Sitting	0.0	1.4	-0.60	-	-	-	-5.5	0.80
Mean value	Standing	1.0	-1.1	-0.38	2.1	4.5	2.4	-5.9	11
	Sitting	0.0	2.0	2.1	-	-	-	-3.9	0.80

PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis; (S)PT, (spino)pelvic tilt; PI-LL, pelvic incidence minus lumbar lordosis mismatch; APP, anterior pelvic plane; SVA, sagittal vertical axis; SSPT, sagittal spinopelvic translation.

(-) Information unavailable or mean could not be calculated.

two in the United States, one in Turkey, and one in Japan. Among 646 participants, sex was reported for 501 (78%). Of these 501 participants, 299 (60%) were women and 202 (40%) were men. Participants' ages ranged from 21 to 84 years (mean 63 years) (Table 2). Time points, follow-up periods, and the included views in radiographs are presented in Table 3.

The mean postoperative changes in spinopelvic parameters are shown in Table 4. In the six included studies, spinopelvic parameters were measured pre- and postoperatively at a minimum of 6 months follow-up, as follows: sacral slope in all six studies, lumbar lordosis in four studies, spinopelvic tilt in three studies, pelvic incidence in four studies, sagittal vertical axis (SVA) in two studies, APP in one study, sagittal spinopelvic translation (SSPT) in one study, and pelvic incidence minus lumbar lordosis mismatch (PI-LL) in one study. Thoracic kyphosis or any other angular measurement of global sagittal spinal alignment (T1 pelvic angle, T1 or T9 sagittal angle) were not measured in any of the six included studies. The measurement of sagittal spinopelvic parameters is shown in Figure 2.

During follow-up, MCs of THA were reported in two studies.^{3,19} No MCs occurred in the remaining studies. In total, 29 of the 646 (4.5%) patients had an MC (Table 5).

Three studies were considered to have low risk of bias, two to have moderate risk, and one to have high risk (Table 6). Study participation was rated as moderate risk of bias in all studies. Study attrition was judged as low risk of bias in only two studies. Prognostic factor measurement was the only domain rated as low risk of bias in every study; outcome measurement was rated as low risk of bias in five studies. Study confounding was scored as low risk of bias in three studies, moderate in two studies, and high risk in one study. Statistical analysis and reporting were assessed as low risk of bias in four studies, moderate in one, and high risk in one study.

Discussion

The findings of this systematic review suggested that there is limited evidence on how spinopelvic parameters change after primary THA and whether these changes are a risk factor for MCs, such as dislocation.

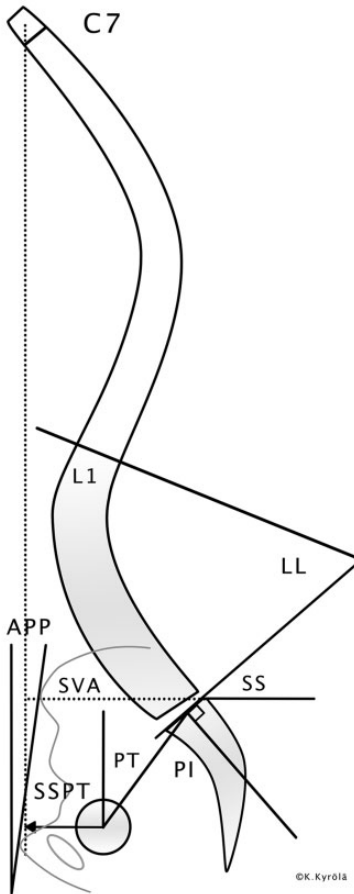


Figure 2. Sagittal spinopelvic parameters reported in the included articles (courtesy of Kati Kyrölä).

SS, sacral slope; LL, lumbar lordosis; (S)PT, (spino) pelvic tilt; PI, pelvic incidence; SVA, sagittal vertical axis; APP, anterior pelvic plane; SSPT, sagittal spinopelvic translation; C, cervical.

Even though three of the included studies were judged to have a low risk of bias because of incompletely reported and heterogeneous data, no clear conclusions could be drawn regarding how spinal sagittal alignment and MCs after primary THA are associated.

According to our review, it can be concluded that radiographic imaging practices are neither standard nor uniform. Indeed,

in some studies included in this review, spinopelvic parameters were followed with a full-body low-dose 2D or 3D X-ray imaging system (EOS) whereas in other studies, spinopelvic parameters were followed with lumbopelvic or full-spine radiographs (Table 3).

In the discussions, three of the included studies seem to confirm the importance of global spinal alignment when planning THA to better understand the hip–spine relationship and identify those patients at high risk for MCs after THA.^{3,11,12} In the data, however, the articles did not focus on spinal alignment. SVA was the only reported parameter that measures global sagittal alignment of the spine (Table 4). Unlike angular measurements, SVA is prone to image scaling bias and the compensatory mechanisms of the malalignment.³¹ Global angular parameters were not reported in any of the included studies. Other spinopelvic parameters were inconsistently measured across the six studies. The terminology of spinopelvic parameters was also not completely uniform. As an example, an anteversion could refer to either a pelvic anteversion or an acetabular anteversion, depending on whether the author was an orthopedic spine surgeon or a joint replacement orthopedic surgeon. There is evidence of a strong correlation between certain spinopelvic parameters (SVA, PT, and PI-LL) and disability and health-related quality of life among adult patients with spinal deformities,³² and these parameters were measured in some included studies.

The total number of dislocations was reported in all studies, but different MCs were comprehensively specified in only one study¹⁹ (Table 5). Indeed, some of the included studies mainly investigated pelvic mobility instead of global spinal alignment as a risk factor for THA dislocation. Berliner et al. found that patients with fixed spinal alignment are at higher risk

Table 5. Mechanical complications of total hip arthroplasty during the follow-up period.

Study reference no.	Dislocations	Subluxations	Aseptic component loosening	Periprosthetic fractures	All mechanical complications
Lazennec et al. 2017 ¹³	0/66	N/A	N/A	N/A	0/66
Berliner et al. 2018 ¹¹	0/144	N/A	N/A	N/A	0/144
Sahin et al. 2019 ¹⁶	0/86	N/A	N/A	N/A	0/86
Parilla et al. 2019 ¹⁹	11/135	N/A	5/135	9/135	25/135
Hagiwara et al. 2021 ¹²	0/95	N/A	N/A	N/A	0/95
Lazennec et al. 2020 ³	0/120	4/120	N/A	N/A	4/120
Total	11/646	–	–	–	29/646

N/A, not available.

(–) Total amount could not be calculated because of incomplete information.

Table 6. Summary of risk of bias according to the Quality In Prognosis Studies tool.

Study reference no.	Study participation	Study attrition	Prognostic factor measurement	Outcome measurement	Study confounding	Statistical analysis and reporting	Overall risk of bias
Lazennec et al. 2017 ¹³	●	◇	◇	◇	●	◇	◇
Berliner et al. 2018 ¹¹	●	●	◇	◇	◇	●	●
Sahin et al. 2019 ¹⁶	●	◇	◇	◇	◇	◇	◇
Parilla et al. 2019 ¹⁹	●	●	◇	◇	□	□	□
Hagiwara et al. 2021 ¹²	●	□	◇	●	●	◇	●
Lazennec et al. 2020 ³	●	●	◇	◇	◇	◇	◇

□ High risk of bias. ● moderate risk of bias. ◇ low risk of bias.

for posterior dislocation in the seated position after THA compared with patients who have normal spinal mobility.¹¹ Moreover, those authors reported that even when hip arthritis has been treated with THA, patients with fixed spinal alignment are unable to accommodate and flex through their spine because the pelvis does not roll back. This may therefore predispose patients to a higher risk for posterior dislocation in the seated position.¹¹ Hagiwara et al. suggested that a pre-operative flatback with a rigid spine leads to post-operative posterior impingement, and a pre-operative well-balanced spine leads to post-operative anterior impingement.¹² Lazennec et al. found that patients with negative sitting SSPT are at higher risk

for THA dislocation than patients with positive sitting SSPT.³

The main strength of our study is that it covered the entire period during which the spinopelvic parameters are in frequent clinical use.^{33–35} Additionally, we performed a comprehensive literature search of various electronic databases. This study has several limitations, however. For example, our search did not cover articles published before 2000. The inclusion criterion concerning possible MCs eliminated several relevant articles. Furthermore, the follow-up time was relatively short and concentrated only on the immediate risks related to a possible association with spinal alignment, not long-term changes in the spinopelvic structure.

In conclusion, the findings of this systematic review suggest that there are no high-quality studies on how spinopelvic parameters change after primary THA and whether these changes are risk factors for MCs. According to our study, no conclusions can be drawn regarding the association between sagittal spinal alignment and MCs after primary THA. Because the mechanical measurement of Lewinnek's safe zone does not guarantee the absence of complications, further studies with larger patient series, standard uniform full-spine sagittal radiographs, and long-term follow-up are required. Such studies would increase our understanding and knowledge of the association between MCs after primary THA and sagittal spinal alignment.

Acknowledgement

The authors thank Tuulevi Ovaska (TO, University of Eastern Finland), who assisted in the development of the search strategy.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary material. Further information can be requested in writing from the corresponding author.


Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research received funding for a literature search and English language proofreading from Central Finland Hospital Nova, Jyväskylä, Finland.

ORCID iD

Susanna Hiltunen  <https://orcid.org/0000-0001-5962-5302>

References

- Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 1978; 60: 217–220.
- Burapachaisri A, Elbuluk A, Abotsi E, et al. Lewinnek Safe Zone References are Frequently Misquoted. *Arthroplasty Today* 2020; 6: 945–953.
- Lazennec JY, Kim Y, Folinais D, et al. Sagittal Spinopelvic Translation Is Combined With Pelvic Tilt During the Standing to Sitting Position: Pelvic Incidence Is a Key Factor in Patients Who Underwent THA. *Arthroplasty Today* 2020; 6: 672–681.
- Tezuka T, Heckmann ND, Bodner RJ, et al. Functional Safe Zone Is Superior to the Lewinnek Safe Zone for Total Hip Arthroplasty: Why the Lewinnek Safe Zone Is Not Always Predictive of Stability. *J Arthroplasty* 2019; 34: 3–8.
- Homma Y, Ishii S, Yanagisawa N, et al. Pelvic mobility before and after total hip arthroplasty. *Int Orthop* 2020; 44: 2267–2274.
- Kyrölä K, Repo J, Mecklin JP, et al. Spinopelvic Changes Based on the Simplified SRS-Schwab Adult Spinal Deformity Classification. *Spine (Phila Pa 1976)* 2018; 43: 497–502.
- Schwab F, Dubey A, Gamez L, et al. Adult Scoliosis: Prevalence, SF-36, and Nutritional Parameters in an Elderly Volunteer Population. *Spine (Phila Pa 1976)* 2005; 30: 1082–1085.
- Buckland AJ, Vigdorichik J, Schwab FJ, et al. Acetabular Anteversion Changes Due to Spinal Deformity Correction: Bridging the Gap Between Hip and Spine Surgeons. *J Bone Joint Surg Am* 2015; 97: 1913–1920.
- Le Huec JC, Charosky S, Barrey C, et al. Sagittal imbalance cascade for simple degenerative spine and consequences: algorithm of decision for appropriate treatment. *Eur Spine J* 2011; 20: 699–703.
- Berjano P and Lamartina C. Classification of degenerative segment disease in adults with deformity of the lumbar or thoracolumbar spine. *Eur Spine J* 2014; 23: 1815–1824.
- Berliner JL, Esposito CI, Miller TT, et al. What preoperative factors predict

- postoperative sitting pelvic position one year following total hip arthroplasty? *Bone Joint J* 2018; 100-B: 1289–1296.
12. Hagiwara S, Orita S, Nakamura J, et al. Impact of spinal alignment and stiffness on impingement after total hip arthroplasty: a radiographic study of pre- and post-operative spinopelvic alignment. *Eur Spine J* 2021; 30: 2443–2449.
 13. Lazennec JY, Thauront F, Robbins CB, et al. Acetabular and Femoral Anteversions in Standing Position are Outside the Proposed Safe Zone After Total Hip Arthroplasty. *J Arthroplasty* 2017; 32: 3550–3556.
 14. Luthringer TA and Vigdorichik JM. A Preoperative Workup of a “Hip-Spine” Total Hip Arthroplasty Patient: A Simplified Approach to a Complex Problem. *J Arthroplasty* 2019; 34: S57–S70.
 15. Ranawat CS, Ranawat AS, Lipman JD, et al. Effect of Spinal Deformity on Pelvic Orientation from Standing to Sitting Position. *J Arthroplasty* 2016; 31: 1222–1227.
 16. Sahin A, Simsek ME, Gursoy S, et al. Three-dimensional analysis of acetabular cup orientation and an evaluation of the relationship with pelvic sagittal parameters. *J Orthop Surg (Hong Kong)* 2019; 27: 230949901986122.
 17. DelSole EM, Vigdorichik JM, Schwarzkopf R, et al. Total Hip Arthroplasty in the Spinal Deformity Population: Does Degree of Sagittal Deformity Affect Rates of Safe Zone Placement, Instability, or Revision? *J Arthroplasty* 2017; 32: 1910–1917.
 18. Katakam A, Bedair HS and Melnic CM. Do All Rigid and Unbalanced Spines Present the Same Risk of Dislocation After Total Hip Arthroplasty? A Comparison Study Between Patients With Ankylosing Spondylitis and History of Spinal Fusion. *J Arthroplasty* 2020; 35: 3594–3600.
 19. Parilla FW, Shah RR, Gordon AC, et al. Does It Matter: Total Hip Arthroplasty or Lumbar Spinal Fusion First? Preoperative Sagittal Spinopelvic Measurements Guide Patient-Specific Surgical Strategies in Patients Requiring Both. *J Arthroplasty* 2019; 34: 2652–2662.
 20. Stefl M, Lundergan W, Heckmann N, et al. Spinopelvic mobility and acetabular component position for total hip arthroplasty. *Bone Joint J* 2017; 99-B: 37–45.
 21. Hermansen LL, Viberg B, Hansen L, et al. “True” Cumulative Incidence of and Risk Factors for Hip Dislocation within 2 Years After Primary Total Hip Arthroplasty Due to Osteoarthritis. *J Bone Joint Surg Am* 2021; 103: 295–302.
 22. Malkani AL, Ong KL, Lau E, et al. Early- and Late-Term Dislocation Risk After Primary Hip Arthroplasty in the Medicare Population. *J Arthroplasty* 2010; 25: 21–25.
 23. Gwam CU, Mistry JB, Mohamed NS, et al. Current Epidemiology of Revision Total Hip Arthroplasty in the United States: National Inpatient Sample 2009 to 2013. *J Arthroplasty* 2017; 32: 2088–2092.
 24. Dobzyniak M, Fehring TK and Odum S. Early Failure in Total Hip Arthroplasty. *Clinical Orthopaedics & Related Research* 2006; 447: 76–78.
 25. Bozic KJ, Kurtz SM, Lau E, et al. The Epidemiology of Revision Total Hip Arthroplasty in the United States. *J Bone Joint Surg Am* 2009; 91: 128–133.
 26. Bozic KJ, Kamath AF, Ong K, et al. Comparative Epidemiology of Revision Arthroplasty: Failed THA Poses Greater Clinical and Economic Burdens Than Failed TKA. *Clin Orthop Relat Res* 2015; 473: 2131–2138.
 27. Lamartina C and Berjano P. Classification of sagittal imbalance based on spinal alignment and compensatory mechanisms. *Eur Spine J* 2014; 23: 1177–1189.
 28. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372: n71.
 29. Hayden JA, Côté P and Bombardier C. Evaluation of the Quality of Prognosis Studies in Systematic Reviews. *Ann Intern Med* 2006; 144: 427–437.
 30. Hayden JA, Van der Windt DA, Cartwright JL, et al. Assessing Bias in Studies of Prognostic Factors. *Ann Intern Med* 2013; 158: 280.
 31. Protosaltis T, Schwab F, Bronsard N, et al. The T1 Pelvic Angle, a Novel Radiographic Measure of Global Sagittal Deformity, Accounts for Both Spinal Inclination and

- Pelvic Tilt and Correlates with Health-Related Quality of Life. *J Bone Joint Surg Am* 2014; 96: 1631–1640.
32. Schwab FJ, Blondel B, Bess S, et al. Radiographical Spinopelvic Parameters and Disability in the Setting of Adult Spinal Deformity. *Spine (Phila Pa 1976)* 2013; 38: E803–E812.
 33. Schwab F, Lafage V, Farcy JP, et al. Surgical Rates and Operative Outcome Analysis in Thoracolumbar and Lumbar Major Adult Scoliosis. *Spine (Phila Pa 1976)* 2007; 32: 2723–2730.
 34. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society—Schwab Adult Spinal Deformity Classification. *Spine (Phila Pa 1976)* 2012; 37: 1077–1082.
 35. Kyrölä K. *Adult spinal deformity: Imaging, diagnostics and outcome*. University of Helsinki, 2019.
 36. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; 339: b2535–b2535.