

## Original research

## Spinopelvic Mobility Pattern and Acetabular Anteversion in Stiff Hips With Ankylosing Spondylitis After Total Hip Arthroplasty

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## ABSTRACT

**Background:** Fused hips with spine stiffness in ankylosing spondylitis (AS) reduce spinopelvic mobility. We aimed to assess spinopelvic mobility pattern and acetabular anteversion in AS after total hip arthroplasty (THA).

**Material and methods:** Ninety-four stiff hips in 58 AS individuals (mean age: 37.05) who underwent THA between 2012 and 2018 with a modified lateral approach were included. Twenty-three hips were fused, and 71 hips had mean flexion of 37.67°. Pelvic tilt, pelvic inclination, sacral slope (SS), and lumbar lordosis were correlated with THA, and functional outcomes were assessed at 34.6-month mean follow-up.

**Results:** Thirty-seven had a stuck sitting pattern with stuck standing seen in 4 individuals. SS standing before and after THA were 25.08° and 27.30°. SS sitting was 8.99° compared to 16.80°. SS from sitting to standing was reduced (17.7°) in 17 individuals. Spine stiffness in extension was seen in 4 out of 37. Mean acetabular inclination after THA was 42.67°, and acetabular anteversion was 17.48°. Flexion after THA improved to mean 98.47°. Changes in SS from sitting to standing were correlated with THA (r-value: 0.93, P-value: .0001). The Harris Hip Score improved from 25.31 to 82.39 (P-value <.05), and the mean 12-item Short Form Survey at review was 52.18 and 59.55 (physical and mental components). The mean Western Ontario and Mc Master Universities Arthritis Index score was 17.56.

**Conclusions:** Spinopelvic mobility change was <10° after THA in AS, stuck sitting was seen in 37 of 58 (63.8%), and stuck standing was seen in 4 of 58 (6.9%), including spine stiffness in flexion or extension. Acetabular anteversion assessed was 17.48° (standard deviation: 4.41), with significant functional improvement.

**Level of Evidence:** Level 4.

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## Introduction

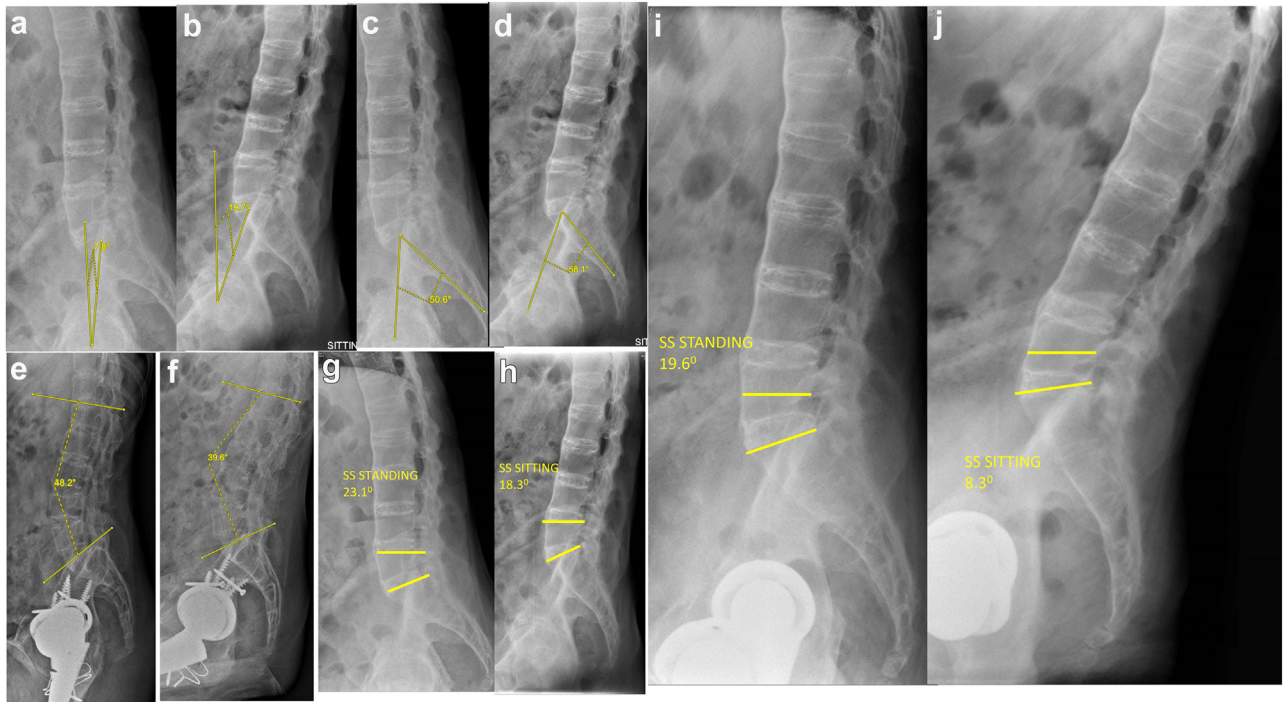
Fused hips with AS have a loss of spinopelvic mobility from the stiffness of the spine, and this needs to be recognized before total hip arthroplasty (THA) for adequate preoperative planning. Acetabular component anteversion needs consideration for altered

spinopelvic mobility during THA [1,2]. The spinopelvic mobility is compromised with progressive stiffness of the spine and hips. The expected change in inclination and anteversion from sitting to standing is absent [3–5]. Posterior pelvic tilt (PT) with spine stiffness has an associated risk of posterior impingement with subsequent anterior dislocation if there is an increased acetabular component anteversion in AS [2,6,7].

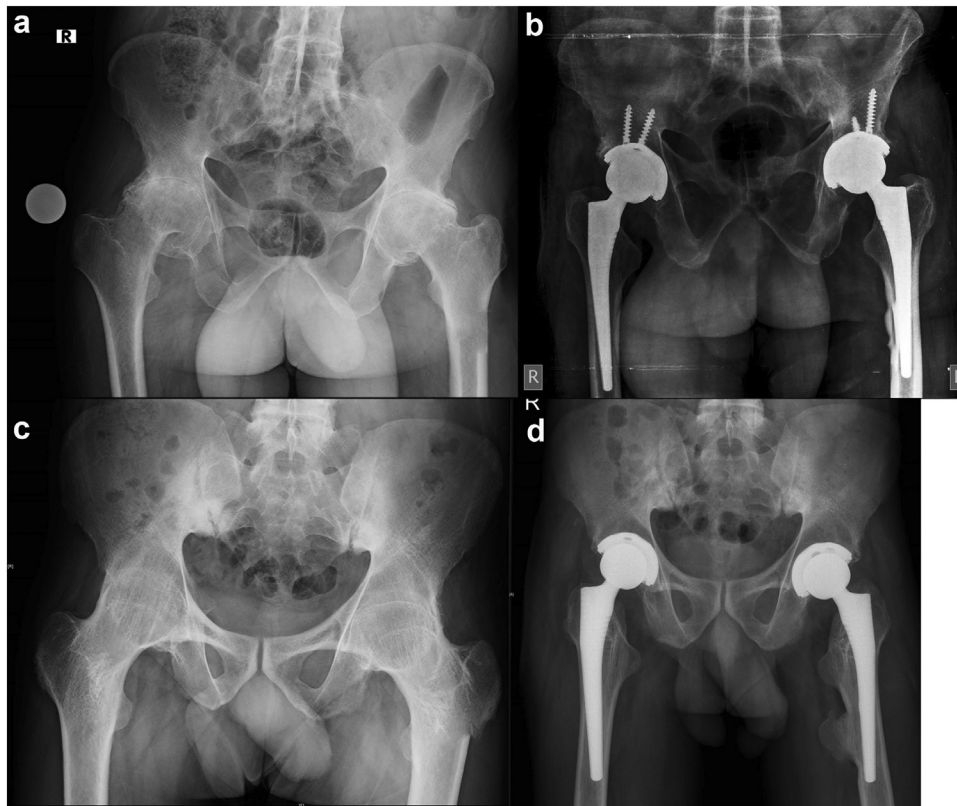
The significance of acetabular anteversion and its relationship to spinopelvic mobility has been described [5,6], and this needs to be assessed. The stiff spine requires preoperative assessment to evaluate change with THA [8–11].

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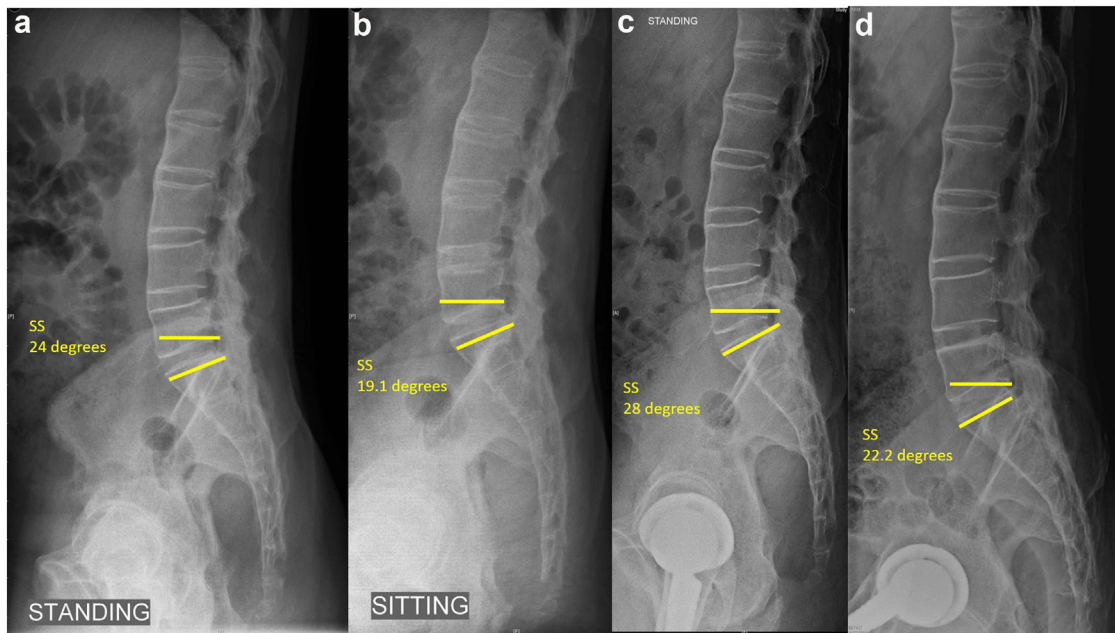
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**Figure 1.** Spinopelvic mobility assessment with lateral spine radiographs in ankylosing spondylitis (AS) with spine stiffness. Measurements were made both in the sitting and standing positions before and after THA. Evaluation of spinopelvic mobility was done as shown. (a) Pelvic tilt standing. (b) Pelvic tilt sitting. (c) Pelvic inclination standing. (d) Pelvic inclination sitting. (e) Lumbar lordosis standing post-THA. (f) Lumbar lordosis sitting post-THA. (g, h) Sacral slope preoperative standing and sitting. (i, j) Post-THA SS standing and sitting.



**Figure 2.** Pelvis anteroposterior view with features of the stiff spine, stiff hips in AS in a 55-year-old male preoperatively and 12 months post THA. (a) AP preoperatively with obturator foramen open and pelvic inlet closed. These features combined with the stiff spine are indicative of loss of anterior pelvic tilt and lumbar lordosis obliteration. (b) AP post THA at 1-year review indicating a similar pattern suggestive of loss of spinopelvic mobility. The spine lateral radiographs had features of a stuck sitting pattern. A 27-year-old male with AS preoperative bilateral fused hips with pelvis AP preoperative and post-THA. (c) AP view preoperative with the obturator foramen partly closed and open pelvic inlet. This is indicative of increased anterior pelvic tilt. This could be suggestive of increased lumbar lordosis due to hip flexion deformity. (d) Pelvis AP at 1-year review after bilateral THA indicative of similar pelvic tilt and spine lateral X-rays confirmed a stuck standing pattern with decreased spinopelvic mobility. Spine lateral views before and after THA showed lumbar lordosis with the stuck standing pattern in 4 individuals.



**Figure 3.** A 51-year-old male with AS with stiff left hip before and 24 months after THA. The Harris Hip Score improved from 40 to 88 at follow-up, with the SF-12 of 52 and 60 for the physical and mental components, respectively. The WOMAC score was 18 with a good functional outcome. Spinopelvic mobility was assessed with spine lateral radiographs pre and post THA. His right hip had a good range of movement and was symptom-free at the time of review. (a) Sacral slope (SS) standing preoperatively, (b) SS sitting preoperatively, (c) SS standing post THA, and (d) SS sitting post THA. SS < 30° is typical of the common stuck sitting pattern seen in AS: 37 out of 58 (63.8%) in our series. Anteversion of the acetabular component post left THA measured 13.2°.

We hypothesized that patients with AS lose lumbar lordosis (LL), with posterior PT, and reduced spinopelvic mobility [2]. The aim was to study spinopelvic mobility in AS and assess acetabular anteversion after THA.

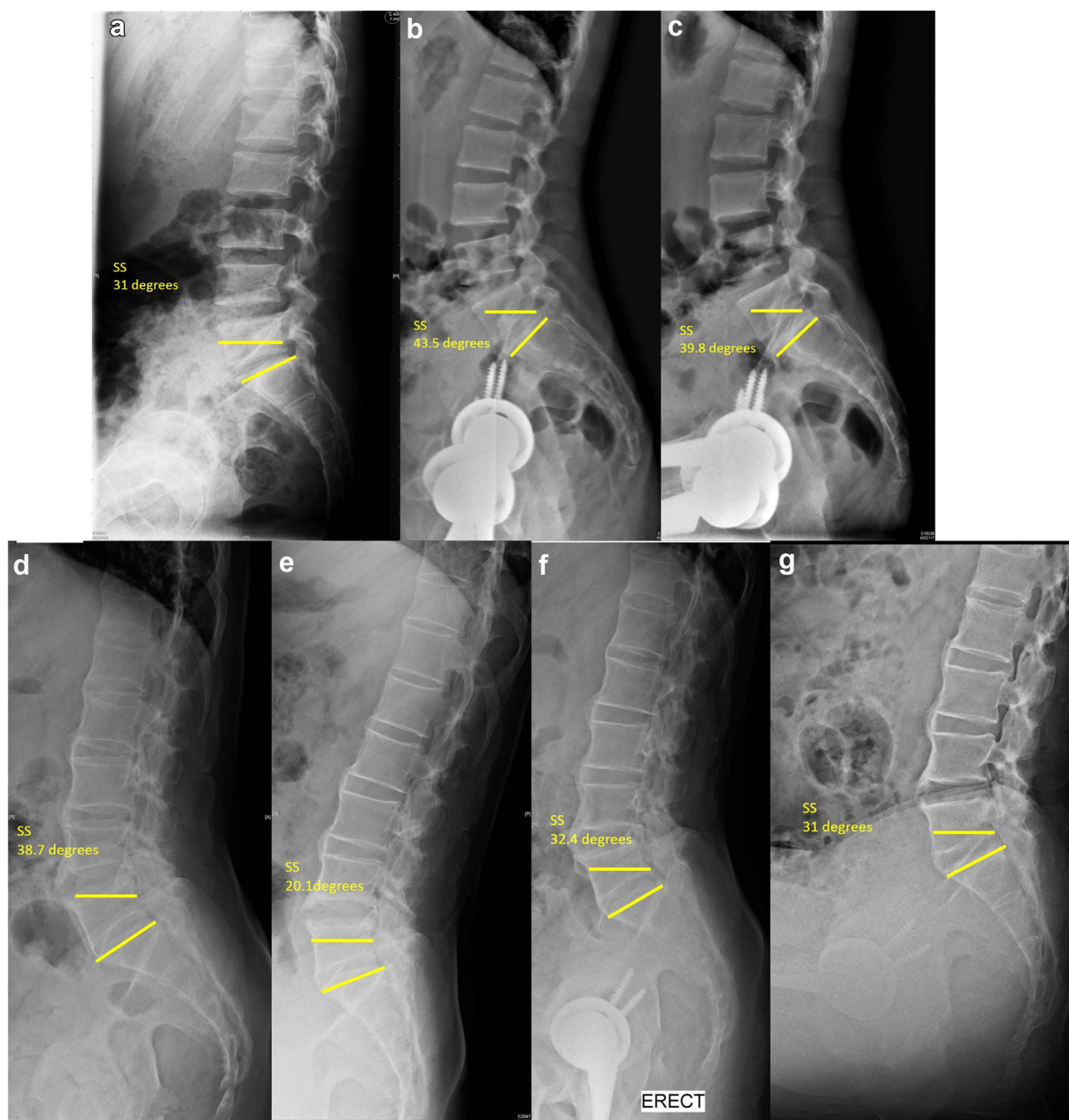
### Material and methods

Seven hundred four THAs were done for 567 patients in our unit for various diagnoses from January 1, 2012, to April 1, 2019. Ninety-four stiff hips (58 patients) with AS who underwent THA during the study period were identified and included after 6 patients were excluded due to insufficient data. The mean age of the patients with AS was 37.05 years (standard deviation [SD]: 10.48), with 52 males and 6 females. Institutional review board approval was obtained for this study, and informed consent was obtained from all participants. Twenty-three hips were clinically fused, and 71 hips had a mean flexion deformity of 17.32° (SD: 13.85). The mean overall preoperative flexion was 37.67°.

Preoperative templating was done to achieve optimal acetabulum position, sizing with 45-degree inclination. Femur templating was done to assess the appropriate size to achieve restoration of the vertical and horizontal offset. THA for all hips was performed with the modified lateral approach in the lateral position. The surgical approach was the Mallory modification of the Hardinge approach, described as the translateral approach [12,13]. Ankylosed hips underwent osteotomy of the neck after defining the same and reaming into the head until the pulvinar tissue identified the floor. The acetabular component anteversion (average: 15°–25°) was determined at THA with the help of anatomical landmarks, including the transverse acetabular ligament (TAL), acetabular margins, and the acetabular component instrumentation guides. Two screws supplemented the cup fixation for additional stability in fused hips. Hip flexion and rotation were assessed along with combined anteversion before final component implantation.

All individuals had 3 doses of IV tranexamic acid (10–15 mg/kg body weight) administered 15 minutes before skin incision and 2 days of IV antibiotic prophylaxis. In all cases, thromboprophylaxis was done with aspirin, with progressive ambulation from the 2nd postoperative day as tolerated with a walker for 6 weeks. Spine lateral radiographs were obtained in the sitting and standing position before and after THA. The postoperative lateral spine radiographs were done with the patient sitting comfortably after THA at the final evaluation. Postoperative spine lateral radiographs were obtained in standing and sitting positions to assess spinopelvic mobility. Individuals were seated on a stool with the thighs parallel to the floor for the lateral sitting spine radiograph. Preoperative and postoperative sacral slope (SS), PT, pelvic incidence (PI), ante inclination (AI) (the sagittal acetabular angle on the lateral radiograph affected both by inclination and anteversion) [14,15], and LL angles were calculated by a radiologist (MK, one of the authors), with GE Picture Archiving and Communications System (PACS) used for all measurements (Fig. 1). The preoperative sitting lateral spine radiograph before THA was not available in AS with 23 fused hips. Pelvis anteroposterior (AP) views were a useful indicator of the spinopelvic mobility pattern in these hips. The AP view of both hips with the distinctive fused spine and loss of anterior PT was evident from the open view of the obturator foramen and obliterated the view of the pelvic inlet, which persisted after THA (Fig. 2a and b). Spine lateral views revealed obliteration of the LL with the typical stuck sitting pattern seen after THA. The other pattern was characterized by the open pelvic inlet and partly closed obturator foramen in the AP view, indicating an increased anterior PT (Fig. 2c and d). This pattern could be seen with a flexion deformity of the hip. Spine lateral views before and after THA showed the spinopelvic mobility pattern.

Multiplanar images with General Electronics - Discovery 750 helical CT scanner (GE Healthcare, Chicago, IL) were used for calculating the supine acetabular cup position after THA as standard for all patients in this series [1,16]. CT was used to achieve a



**Figure 4.** A 51-year-old male with AS preoperatively and 29 months post bilateral THA. The HHS improved from 21 to 83 at follow-up. (a) Preoperative SS Standing, (b) Post THA SS standing, and (c) post THA sitting. The preoperative sitting view was not obtained as his hips were fused with an inability to sit for optimal sitting lateral spine radiographs.  $SS > 30^\circ$  sitting and standing post THA demonstrates the stuck standing pattern. This pattern is uncommon in AS with 4 out of 58 individuals (6.9%) seen in our series. Acetabular anteversion assessed post THA was  $18.9^\circ$  on the right and  $22.4^\circ$  on the left hip. A 38-year-old male with AS. (d) Preoperative SS standing. (e) Preoperative SS sitting, 18 months post right THA. (f) Post-THA SS standing. (g) post-THA SS sitting, preoperative standing, sitting, post-THA standing, sitting SS. Preoperative sitting SS was less than  $30^\circ$ , not included in the stuck standing group. Spinopelvic mobility from standing to sitting changed from  $38.7$  to  $20.1$  preoperatively and  $32.4^\circ$ – $31^\circ$  post THA. Decreased spinopelvic mobility after hip movement post THA is evident from the sitting and standing lateral radiographs after THA. The HHS improved from 33 to 83 with the SF-12 of 54 and 61 for the physical and mental components, respectively, with a WOMAC score of 16. Anteversion of the acetabular component post right THA measured  $23.6^\circ$ .

reliable, accurate assessment of the acetabular component position. CT has been the standard of measurement, although anteversion assessment with radiographs has been described. The difference in the preoperative and postoperative sitting and standing spinopelvic parameters were also calculated and compared from the radiographs. Measurements were made in a blinded manner for the data sets. Intrarater reliability was measured with the intraclass coefficient (ICC: 0.97) for measurements made at an interval of 6 weeks. We analyzed all the records and scans retrospectively. All patients were contacted during data compilation for clinical and functional assessment.

The Chi-square test was used for the association between categorical variables. The Pearson correlation coefficient was used for the continuous variables. Tests were 2-sided at  $\alpha = 0.05$  level of significance. Analysis was carried out using Statistical Package for Social Sciences (SPSS, IBM, Armonk, NY) software.

## Results

$SS < 30^\circ$  in both sitting and standing with a difference of  $< 10^\circ$  constitutes a stuck sitting pattern, and  $SS > 30^\circ$  in sitting and standing with a change of  $< 10^\circ$  represents a stuck standing pattern

**Table 1**  
Sacral slope values before and after THA in AS.

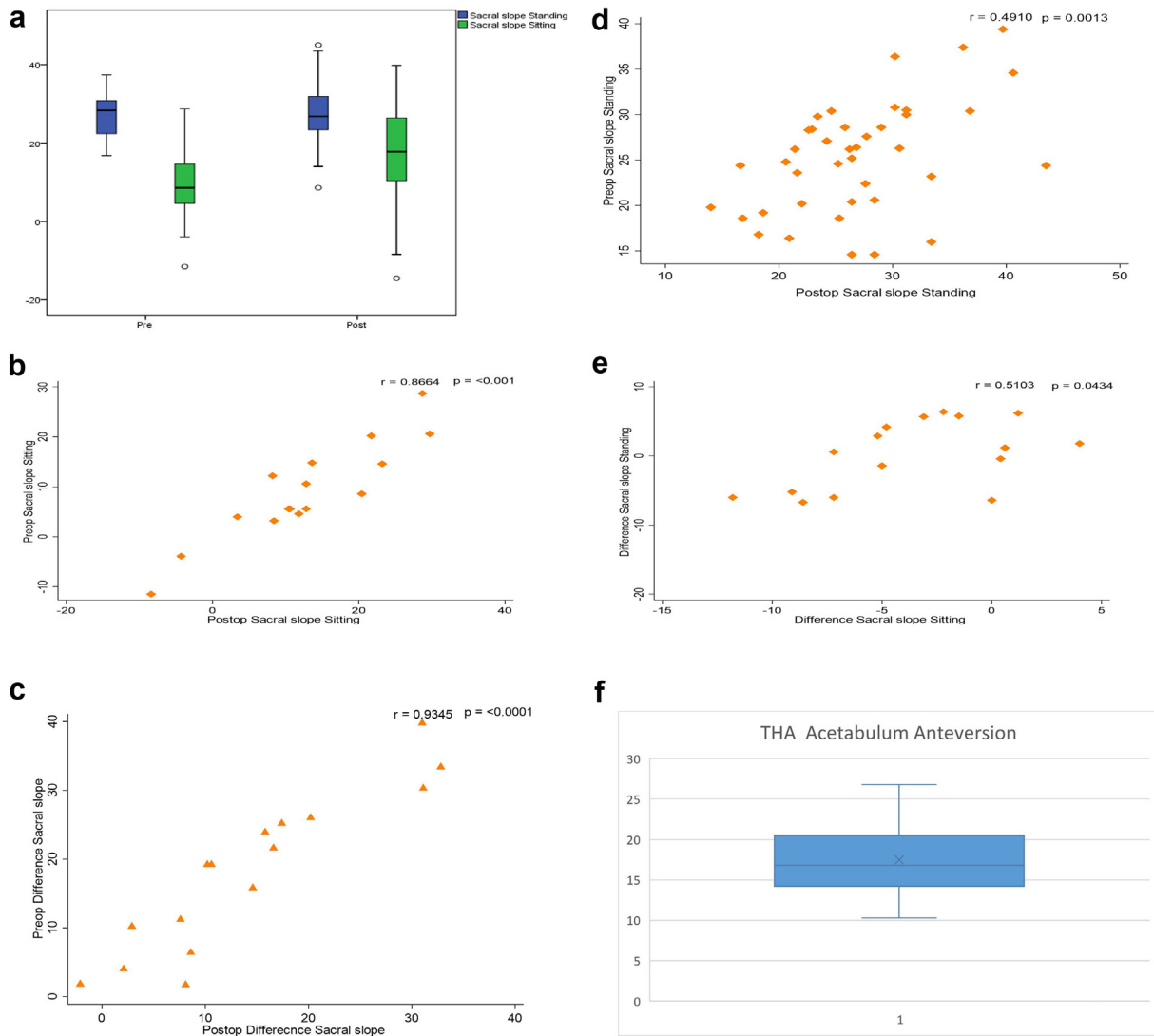
Variable	Mean	SD	P25	Median	P75	Min	Max
Postoperative sacral slope standing	27.30	7.20	22.80	26.40	31.20	8.60	45.00
Postoperative sacral slope sitting	16.80	11.40	10.40	17.80	26.40	-14.50	39.80
Preoperative sacral slope standing	25.08	6.02	20.40	24.80	28.60	14.30	39.40
Preoperative sacral slope sitting	8.99	9.44	4.60	8.60	14.60	-11.50	28.70
Difference sacral slope standing	-1.58	6.47	-5.60	-0.40	2.85	-19.10	7.80
Difference sacral slope sitting	-3.72	4.38	-7.20	-3.95	0.20	-11.80	4.00
Preoperative difference sacral slope	18.48	11.29	10.20	19.20	25.20	1.70	39.80
Postoperative difference sacral slope	10.85	10.31	2.10	8.60	17.00	-2.50	32.80

Change from sitting to standing before and after THA compared.  
Differences between sitting and standing are indicative of reduced spinopelvic mobility.  
The change before and after THA in the standing as well as the sitting values are  $<10^\circ$  indicative of reduced spinopelvic mobility.

**Table 2**  
Comparison of Sacral slope before and after THA both sitting and standing.

Values compared	Pre SS & post SS (standing)	Pre SS & post SS (sitting)	$\Delta$ Sacral slope standing & $\Delta$ Sacral slope sitting	Pre $\Delta$ SS& post $\Delta$ SS
r-value	0.4910	0.8664	0.5103	0.9345
P-value	.0013	<.0001	.0434	<.0001

The difference before and after THA were compared. Correlation before and after THA indicated reduced spinopelvic mobility.  
 $\Delta$ Sacral slope standing &  $\Delta$ Sacral slope sitting, Difference pre and post THA, Pre  $\Delta$ SS& Post  $\Delta$ SS Difference standing and sitting.



**Figure 5.** (a–e) Relationship between SS standing and sitting preoperatively and post THA. Distribution chart. Difference between standing and sitting pre and post THA compared. The change from sitting to standing before and after THA suggests decreased spinopelvic mobility seen in AS. (f) Distribution of acetabular anteversion (mean:  $17.48^\circ$ ; SD: 4.41). Acetabular component version measured post THA ranged from  $10.4^\circ$  to  $26.8^\circ$ .

**Table 3**  
Pre- and post-THA measurements comparing mean (SD) standing with sitting values.

Measurements	Standing	Sitting	Difference	P-value
<b>Post</b>				
Ante inclination	21.80 (4.17)	33.77 (5.85)	-11.97 (6.09)	<.0001
Pelvic inclination	50.48 (6.32)	53.20 (6.17)	-2.72 (4.67)	.0007
Pelvic tilt	25.82 (6.68)	30.46 (6.85)	-4.64 (8.90)	.0021
Lumbar lordosis	42.79 (11.11)	30.85 (12.09)	11.94 (13.55)	<.0001
<b>Pre</b>				
Ante inclination	21.64 (2.55)	32.47 (5.29)	-10.82 (4.51)	<.0001
Pelvic inclination	48.87 (5.49)	47.40 (5.93)	1.47 (5.29)	.301
Pelvic tilt	26.00 (8.07)	32.6 (7.25)	-6.6 (10.47)	.0347
Lumbar lordosis	46.19 (12.28)	28.27 (14.59)	17.92 (16.99)	.0005

Ante inclination (AI) (the sagittal acetabular angle on the lateral radiograph affected both by inclination and anteversion) were compared before and after THA. Change in the pelvic tilt and Lumbar lordosis before and after THA was compared and found to be similar, indicating reduction in spinopelvic mobility with stiff spines.

**Table 4**  
Comparison of pre- and post-THA values, difference in sitting and standing.

Values compared	Pre PT & post PT (standing)	Pre PT & post PT (sitting)	Pre SS & post SS (standing)	Pre SS& post SS (sitting)	Pre LL& post LL (standing)	Pre LL & post LL (sitting)
r-value	0.48	0.81	0.49	0.86	0.61	0.78
P-value	.010	.001	.0013	.0001	.001	.0005

Values compared	Pre ΔPT & post ΔPT	Pre ΔSS & post ΔSS	Pre ΔLL & post ΔLL
r-value	0.66	0.93	0.76
P-value	.02	<.0001	.001

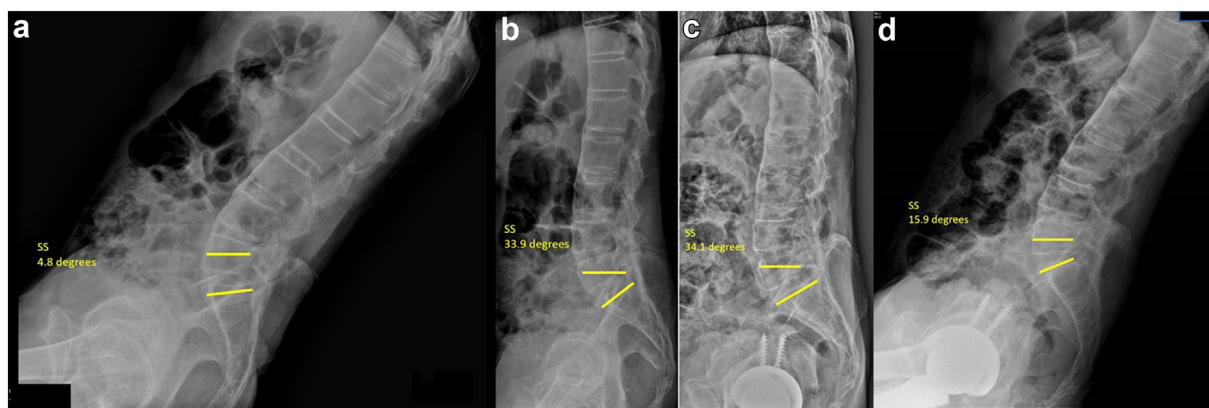
Correlation for all spinopelvic mobility parameters after THA resulting in increased hip ROM were suggestive of similar pattern indicative of spine stiffness. Delta(Δ) = Difference in standing and Sitting.

[17]. Thirty-seven of 58 (63.8%) had stuck sitting (Fig. 3, Fig. 1g-j), and 4 of 58 (6.9%) had stuck standing pattern (Fig. 4a-c) in our series. Three individuals had features of stuck standing with sitting SS <30° and were included in the stuck sitting group (Fig. 4d-g), as the sitting SS was less than 30°. Spinopelvic mobility with <20° change from sitting to standing was seen in 17 (29.3%).

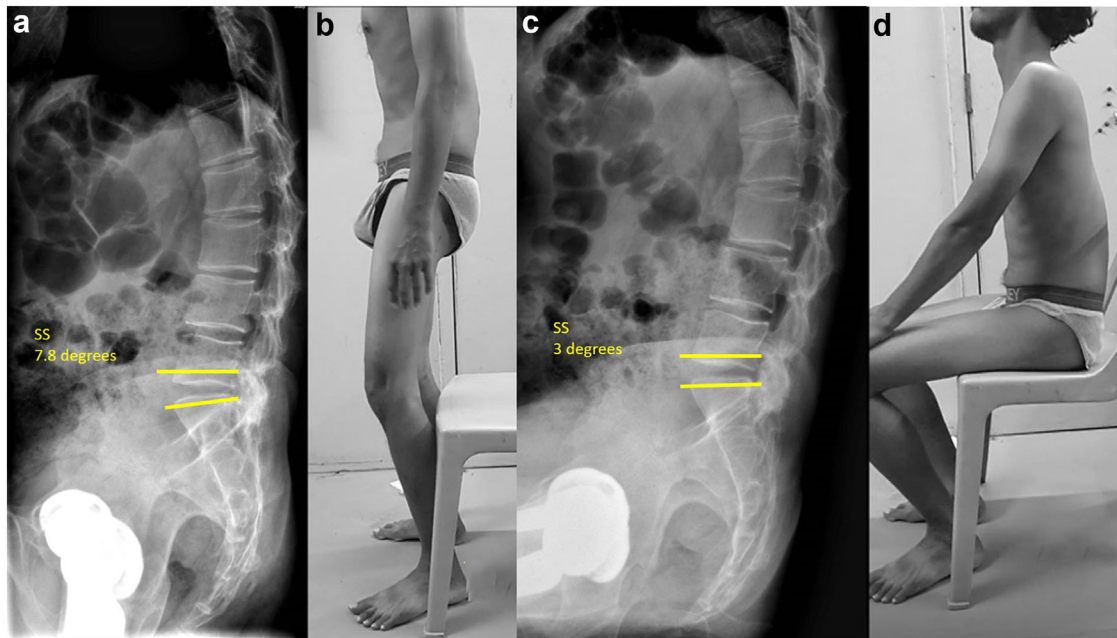
The spine mobility is limited in AS, as indicated by the difference between sitting and standing [18]. The SS change from standing to sitting was compared before and after THA (Tables 1 and 2). The difference before and after THA was compared to assess the change in spinopelvic mobility pattern. The correlation of preoperative ΔSS and postop ΔSS (sitting to standing) suggested minimal change before and after THA (r-value: 0.93, P-value: .0001). The preoperative standing SS was 25.08 (SD: 6.02),

compared to the preoperative sitting SS of 8.99(SD: 9.44). Post-operative standing SS was 27.30 (SD: 7.20), while sitting SS analyzed was 16.80 (SD: 11.40) (Fig. 5a-e). Standing SS was similar before and after THA with minimal change indicating spine stiffness and reduced spinopelvic mobility.

The sitting PT before THA (32.6 [SD: 7.25]) was compared to sitting PT after THA (30.46 [SD: 6.85]) with a correlation coefficient r = 0.81 (P-value: .001). ΔPT Pre-op (sitting to standing) was correlated to Δ PT Post-op (sitting to standing) with r value 0.66 (P-value .02) (Table 3 and 4). The change in PT from standing to sitting before and after THA was compared (Table 3 and 4). The change in SS was compared with the change in PT before and after THA (Table 3). Preoperative PI changed from a mean standing of 48.87 (SD: 5.49) to a mean sitting of 49.28 (SD: 5.93), and the



**Figure 6.** A 54-year-old male with AS with spine stiffness in extension unchanged 24 months post THA. Loss of hip mobility with spine stiffness has significant functional impairment. (a, b) Spine lateral radiographs with preoperative SS standing and sitting. (c, d) Post THA 24 months spine lateral radiographs SS standing and sitting, spine stiffness with extension is evident with sitting lateral spine radiograph. Spine stiffness with extension is seen in individuals presenting with AS with stiff hips. He had a good functional outcome till 24 months post THA. The Harris Hip Score improved from 38 to 82, and his WOMAC was 18 at 2 years post THA. Post-THA acetabular anteversion measured 22.3°. THA for stiff hips improves hip mobility with functional improvement with persistent spine stiffness in extension.



**Figure 7.** (a-d) Post-THA lateral spine radiographs and pictures standing (a, b) and sitting (c, d) at 80-month follow-up for bilateral fused hips with AS in a 23-year male. The standing and sitting radiographs and images show the typical stuck sitting pattern with lumbar kyphosis and limited spinopelvic mobility. Sacral slope measured standing and sitting compared to the visible obliteration of the lumbar lordosis seen. SS change from sitting to standing  $<10^\circ$  is indicative of spine stiffness evident at follow-up. The lumbar deformity remains unchanged from sitting to standing. The Harris Hip Score improved from 14 to 85 at review with a good functional outcome at 80-month follow-up. His SF-12 assessed was 52 and 62 for the physical and mental components, respectively.

postoperative PI changed from mean standing of 50.48 (SD: 6.32) to a mean sitting of 53.20 (SD: 6.17).

The preoperative LL angle standing was 46.19 (SD: 12.28) and sitting LL was 28.27 (SD: 14.59). The differences in LL for both sitting and standing, before and after THA, were lesser than the normal [8,19] (Table 3 and 4). Change in LL before and after THA was reduced, indicative of spine stiffness (Table 4). The change in SS, PT, and AI was correlated with sitting and standing before and after THA (Table 3). The overall LL is expected to be within  $10^\circ$  of

PI [20], and this was seen with the comparison of standing LL and PI before and after THA. The difference between PI and LL changes from sitting to standing (50.48 and 42.79 standing vs 53.20 and 30.85 sitting) could be due to the decreased spinopelvic mobility and stiffness in extension or flexion seen in our series.

Seventeen individuals had spinopelvic mobility with  $>10^\circ$  change from sitting to standing before and after THA. Four individuals with stiff spines had LL with spine extension, which

**Table 5**  
Comparison With Other Series.

Author	Preoperative		Ante inclination standing	Ante inclination sitting	Pelvic tilt standing	Pelvic tilt sitting	Pelvic incidence standing	Pelvic incidence sitting
	ST sacral slope standing	ST sacral slope sitting						
Steffl 2017 (15 fused) [3]	31.0	27.4	45.6	51.7	NA	NA	NA	NA
Normal Kanawade 2014 [14]	$39 \pm 8.8$ (17-60)	$12.4 \pm 8.1$ (211-34)	NA	NA	$0.2 \pm 7.6$ (-12 to 26)	$-28.6 \pm 7.9$ (-48 to -7)	NA	NA
Stiff Kanawade 2014 [14]	$35.3 \pm 8.6$ (22-52)	$20.7 \pm 9.4$ (4-41)	NA	NA	NA	NA	NA	NA
Ike 2018 [4]	$40 \pm 10$	$20 \pm 9$	$35 \pm 10$	$52 \pm 11$	NA	NA	$53 \pm 11$	$53 \pm 11$
ZC Lum et al 2018 [5]	$35.3 \pm 8.6$	$20.7 \pm 9.4$	NA	NA	NA	NA	NA	NA
Innmann et al 2020 [9]	NA	NA	NA	NA	NA	NA	NA	NA
Our series AS (ankylosing Spondylitis) 2021	$27.36 \pm 6.61$	$18.99 \pm 7.18$	$21.71 \pm 3.28$	$32.47 \pm 5.29$	$28.82 \pm 5.76$	$33.32 \pm 7.61$	$47.85 \pm 5.63$	$49.78 \pm 5.79$

Available data from other published data so far, were tabulated to compare the values with our series. Data from our series were only from Ankylosing spondylitis with stiff hips.

NA, not available.

persisted after THA (Fig. 6). Two individuals with a stuck sitting pattern had lumbar kyphosis (Fig. 7).

The mean acetabular inclination was 42.54° (SD: 3.83). The mean acetabular anteversion was 17.48° (SD: 4.41) (range: 10.3°–26.8°) (Fig. 5f). Seven hips in 4 individuals with stuck standing had a mean acetabular component anteversion of 18.64° (16.4°–22.4°).

The mean preoperative flexion increased from 37.67 to 98.47°, with preoperative flexion deformity ranging from 10 to 60°. The hip flexion had significant improvement after THA. The difference from preoperative to final evaluation indicated no significant change in the spinopelvic mobility after THA (Table 3 and 4).

The Harris Hip Score (HHS) improved from 25.31 to 82.29. All the patients with AS in our series of stiff hips had a significant disability with an inability to sit comfortably before THA. The mean 12-item Short Form Survey (SF-12) at review was 52.18 and 59.55 for the physical and mental components, respectively. The SF 36 was not assessed in our series. The mean overall Western Ontario and Mc Master Universities Arthritis Index (WOMAC) score was 17.56, with all AS individuals in this series having significant functional improvement with the ability to sit comfortably after THA. Limited data are available on functional assessment after THA in AS [21–23].

One hip dislocated at 5 days postoperatively following a fall which was treated by closed reduction doing well at 20-month follow-up. This 35-year-old male who underwent THA for the contralateral hip before 3 years had the stuck sitting pattern with no apparent factors associated with the dislocation. There were no other hip complications in this series.

A 56-year-old male, 2 years post THA with stiff lumbar and cervical spine, who had C6-7 fracture dislocation with paraplegia following a fall on the stairs is being rehabilitated for the same.

**Discussion**

Preoperative planning for THA must include spinopelvic mobility assessment which could be responsible for early or delayed complications [3–5,24]. Spinopelvic mobility patterns have been well described, with recommendations for component placement at THA [4,5,14]. AS has significant spine stiffness with hip involvement at THA [24]. The spinopelvic mobility patterns in AS with THA have not

been reported. We aimed to study the spinopelvic mobility parameters in AS in our series to improve our understanding and planning for THA. The change in spinopelvic mobility parameters differs from stiff spines due to degenerative disease [9,19,25]; however, specific literature regarding AS with fused hips does not exist (Table 5). Preoperative planning includes spinopelvic mobility assessment considering deformity and stiffness [10]. The predominant stuck sitting pattern was seen in these stiff hips with posterior PT [3,5,17,26] (63.8% in our series: 37 out of 58 individuals). Sitting SS more than 30° were seen in 4 individuals in our series, which conformed to the stuck standing pattern (4/58; 6.9%).

Loss of spinopelvic mobility with stiffness is evident from spine extension and lumbar kyphosis pattern seen in this series (Figs. 6 and 7). Spinopelvic mobility in AS with posterior PT, low PI, and AI is characteristic of the rigid unbalanced pattern [20], which showed minimal change after THA. Spine stiffness was evident with decreased PT change from sitting to standing, seen in our series [19]. Spinopelvic mobility change after THA, indicated by SS, was less than 10° as seen in our series. SS change from sitting to standing before and after THA indicated stiffness with posterior PT [19,26,27]. AI change from standing to sitting before and after THA was reduced, compared with reported values (33 and 52, for standing and sitting, respectively) [8,28].

SS values were less than expected with minimal change from sitting to standing and before and after THA. Spine stiffness with AS is seen with late presentation for THA in all our cases at preoperative assessment. The risk of fractures and falls is considerable in these individuals with spine stiffness and reduced mobility [29].

Our series has shown that individuals with AS have a low PI, reduced PT, and SS compared with existing data (Table 5). THA improved hip ROM significantly in these stiff hips with spinopelvic mobility change of less than 10°. HHS change after THA showed significant improvement in AS. The 12-item Short Form Survey (SF-12) and WOMAC at review indicated a good overall functional score. Loss of spinopelvic mobility is caused by spine stiffness in AS. The spine stiffness in our series with AS did not affect the functional capacity of the individual requiring any further intervention.

Stuck standing with stiffness in flexion and extension also exists as seen in our series. Spinopelvic mobility patterns were evident from the SS values; however, the change was

Postoperative									
ST standing	ST sitting	Ante inclination standing	Ante inclination sitting	Pelvic tilt standing	Pelvic tilt sitting	Pelvic incidence standing	Pelvic incidence sitting	Implant inclination	Implant anteversion
33.1	22.7	40.0	48.6	NA	NA	NA	NA	45.3	21.7
38.1 ± 8.5 (20-59)	13.1 ± 9.1 (-10 to 43)	29.1 ± 8.7 (5-47)	54.4 ± 9 (32-75)	-1.3 ± 7.4 (-19 to 11)	226.7 ± 8.6 (246-27)	NA	NA	39.4 ± 3.5 (31-48)	21.9 ± 4.4 (12-31)
33 ± 6.6 (24-47)	15.6 ± 11.7 (-13 to 31)	30.3 ± 7 (12-39)	49.1 ± 8 (36-60)	NA	NA	NA	NA	38.6 ± 3.5 (31-45)	22.1 ± 4.7 (14-31)
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
33 ± 6.6	15.6 ± 11.7	NA	NA	NA	NA	NA	NA	38.6 ± 3.5	22.1 ± 4.7
42 ± 9	22 ± 11	NA	NA	15 ± 9	36 ± 12	58 ± 12	58 ± 12	NA	NA
29.28 ± 7.16	29.28 ± 8	21.74 ± 4.08	21.74 ± 4.08	33.91 ± 5.82	30.14 ± 6.91	50.53 ± 6.16	53.30 ± 6.07	42.54 ± 3.83	17.48 ± 4.41



less than 10° with THA. The AP pelvis view provides additional information regarding spinopelvic mobility (Fig. 2). This is useful, especially in individuals unable to sit comfortably before THA.

There are 2 significant limitations with this series. Our series (94 hips in 58 individuals with AS with different spinopelvic mobility patterns) is not adequately powered to provide recommendations regarding acetabular component anteversion. Using anatomical landmarks and acetabular instrumentation guides, the intra-operative cup positioning technique remains unreliable to adjust acetabular component anteversion for altered spinopelvic mobility. Preoperative anteversion was not assessed in our series; hence, comparison was not possible with the postoperative values obtained. Acetabular anteversion before THA would have provided data regarding any variation in the native anteversion. Acetabular component positioning is important at THA with abnormal spinopelvic mobility. The stuck sitting group has an increased risk of posterior impingement and anterior instability, and the stuck standing would be at risk for anterior impingement posterior instability, according to Lum et al [5]. Ike et al and others have recommended cup position to avoid impingement in spinopelvic stiffness with 15°–20° anteversion in the stuck sitting group and 20°–25° anteversion in the stuck standing group [4,10,17]. The lack of long-term follow-up data was the other significant limitation. This series had an average follow-up of 34.60 months (range: 24–90) with a clinical and functional assessment obtained along with radiographs. This analysis is part of the ongoing study to include more stiff hips and more extended follow-up data with the knowledge that risk for late dislocation exists for these hips with stiff spines [28]. The ongoing study with eventual larger numbers and spinopelvic mobility data including anteversion before and after THA with review will add value to our knowledge in planning THA in AS.

These spinopelvic mobility measurements in AS provide information regarding different patterns seen in these individuals before and after THA.

## Conclusions

Spinopelvic mobility change after THA in AS was less than 10° as evident from the SS measurements. AS with stiff hips and spine has reduced PI with loss of spinopelvic mobility and predominant stuck sitting pattern after modified lateral approach THA with significant improvement of hip flexion. Spinopelvic mobility in AS reveals a stiff pattern with predominant stuck sitting. A stuck standing pattern is also seen (6.9% in our series). Acetabular anteversion assessed was a mean of 17.48° (SD: 4.41) in these hips. These stiff AS hips with residual spine stiffness and reduced spinopelvic mobility after THA have significant functional improvement.

## Conflict of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2022.05.006>.

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