



Original Research

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

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ABSTRACT

Background: Sagittal spinopelvic translation (SSPT) is the horizontal distance from the hip center to the C7 plumb line (C7PL). SSPT is an important variable showing the overall patient balance in different functional positions which could affect the rate of hip instability. This study investigates the SSPT modification in patients who underwent total hip arthroplasty (THA).

Methods: A total of 120 patients were assessed preoperatively and postoperatively on standing and sitting acquisitions (primary unilateral THA without complication). SSPT is zero when the C7PL goes through the center of the femoral heads and positive when the C7PL is posterior to the hips' center (negative if anterior). Three subgroups were defined based on the pelvic incidence (PI): low PI <45°, 45° < normal PI <65°, or high PI >65°.

Results: The overall mean preoperative SSPT change from standing to sitting was 2.2 cm ([-7.2 to 17.4]) ($P < .05$). The overall mean postoperative SSPT change from standing to sitting was 1.2 cm ([-14.2 to 22.4]) ($P < .05$). In low- and normal-PI groups, standing to sitting SSPT and preoperative to postoperative changes in standing SSPT were increased significantly after surgery with the C7PL behind the hips' center ($P < .05$). In the high-PI group, standing to sitting SSPT was increased postoperatively ($P = .034$) (no significant changes from preoperative to postoperative status in standing and sitting).

Conclusions: Adaptation from standing to sitting positions combines pelvic tilt and anteroposterior pelvic translation. THA implantation induces significant changes in SSPT mainly for low- and standard-PI patients. This is an important variable to consider when investigating the causes of THA subluxation or dislocation.

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Introduction

Recent literature has reported the postural changes from standing to sitting, which can tremendously affect the stability of total hip arthroplasty (THA) [1–6]. The pelvis kinematics in standing to sitting transition is commonly considered as a rotation around

the axis that connects the center of the 2 femoral heads (hip axis). This motion starts from anterior pelvic tilt in the standing position (pelvic flexion) and continues to posterior pelvic tilt in the sitting position (pelvic extension). Kinematic variation in the sagittal pelvic tilt has substantial effects on the functional orientation of the acetabular implant with potential consequences on biomechanics of the THA [7–9]. Researchers have focused on the sagittal variations for acetabular implant orientation and potential implant or bony impingement situations [10–13]. But the transition from the standing to sitting position is a more complex phenomenon as postural changes are not limited to the pelvis. Moving from the

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Table 1
Study parameters.

Parameter	Definition
Pelvic incidence (PI)	The angle between a line perpendicular to the midpoint of the superior S1 endplate and a line connecting the midpoint of the superior S1 endplate to the axis connecting the centers of the femoral heads. The PI reflects the anteroposterior diameter of the pelvis and varies among the patients.
Sacral slope (SS)	The angle between the horizontal line and the superior S1 endplate.
Lumbar lordosis (LL)	The angle between the superior endplate of L1 and superior endplate of S1.
Anterior pelvic plane angle (APP angle)	The angle between the vertical line and the anterior pelvic plane. The anterior pelvic plane connects the pubic symphysis and the 2 anterior superior iliac spines.
C7 plumb line (C7PL)	The C7 plumb line is the vertical line drawn from the center of the C7.
Gravity line (GL)	The gravity line is the vertical line that passes through the center of the gravity. The GL is always in front of the plumb line and can also measure the translation of the trunk over the hip rotation axis.
Sagittal vertical axis (SVA)	The horizontal distance between the C7 plumb line and posterosuperior corner of the sacrum.
Sagittal spinopelvic translation (SSPT)	The horizontal distance between the C7 plumb line and the axis that connects the center of the femoral heads.

standing to sitting position induces significant modifications of the reaction forces in the hip joint linked to the translation of the trunk over the pelvis [14–16]. Translation of the trunk over the pelvis is a key factor for maintaining the global sagittal balance during this transition from standing to sitting [17].

Investigation of the sagittal balance in the standing position is often conducted using the sagittal vertical axis (SVA), C7 plumb line (C7PL), and gravity line (GL) (Table 1) [18]. But the SVA does not take the sagittal pelvis anatomy and hip position (expressed by pelvic incidence [PI]) into account as the reference point is the S1 vertebrae [19]. Although standing sagittal balance has been extensively investigated, only few studies have focused on the alignment of the whole axial skeleton in sitting position with reference to the C7PL. Thoracolumbar spine alignment has a compensatory function that helps with the transition from standing to sitting and minimizes the change in global balance because of the gradual forward tilt of the trunk with aging [20]. These mechanisms are not only limited to just rotations around the hip axis but also include anterior to posterior translation of the pelvis (sagittal spinopelvic translation [SSPT]) (Figs. 1 and 2).

The aim of this study was to evaluate the combination of the anteroposterior pelvic tilt and translation from standing to sitting to understand the changes in the sagittal pelvic translation. To our best knowledge, it is the first study about the impact of a THA on pelvic rotation and sagittal translation from standing to sitting.

Our study questions were as follows:

1. How different are the SVA and SSPT in standing and sitting positions, and what are the correlations between SSPT and pelvic tilt as measured by the sacral slope (SS) and anterior pelvic plane (APP) angle and lumbar lordosis (LL)?
2. What is the influence of the PI on SSPT?
3. What are the functional types for SSPT in standing and sitting positions, and how they change after THA?

Material and methods

After obtaining institutional review board approval, we included 120 consecutive patients who underwent primary unilateral THA

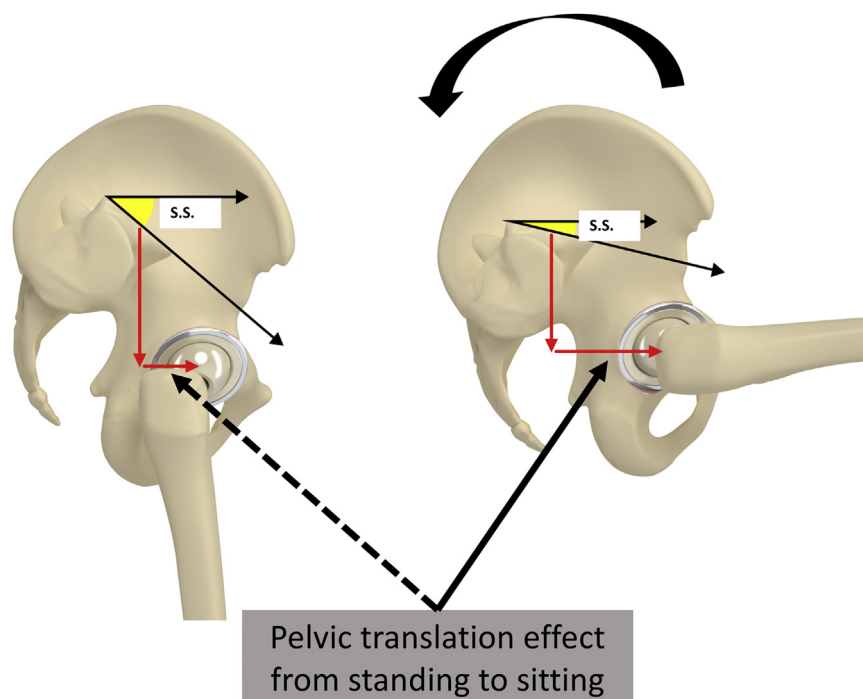


Figure 1. The effect of pelvic translation from the standing to sitting position. The pelvis tilts posteriorly in the sitting position.

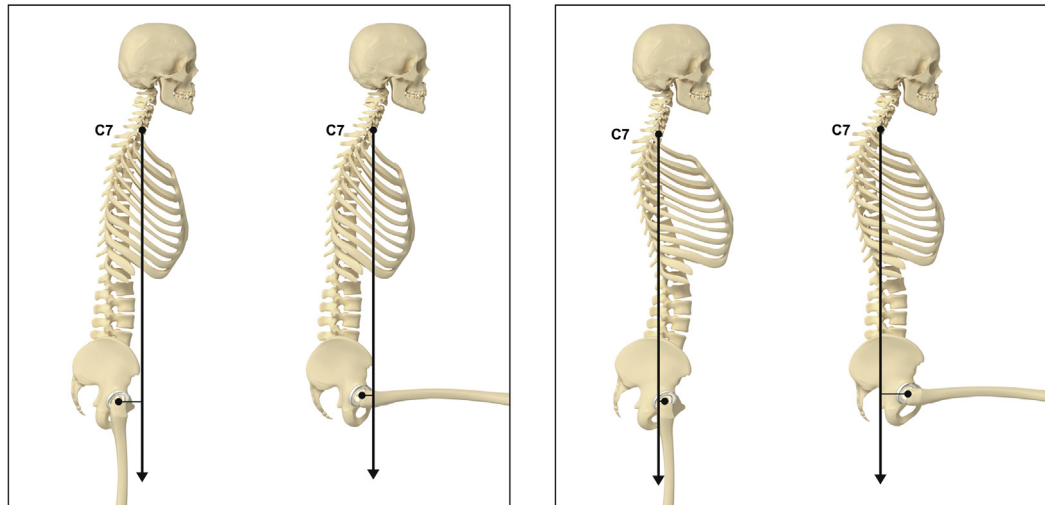


Figure 2. Sagittal spinopelvic translation is measured as the horizontal distance of the C7 plumb line to the hip axis.

for symptomatic, unilateral hip osteoarthritis. All cases had undergone THA without any complications, and the contralateral hip did not have significant painful degenerative disease. We excluded all the patients who underwent a previous lower extremity surgery, had limb-length discrepancy more than 5 mm, had previous spinal fusion, or had significant lower limb deformities (Table 2). Data regarding the surgical approaches are presented in Table 2.

Imaging acquisition

All patients underwent preoperative and postoperative standing and sitting full-body biplanar EOS acquisitions (EOS imaging, SA) according to our standard of care. EOS images of the spine, pelvis, and lower extremities in natural standing and sitting positions were obtained using a previously defined protocol [21,22]. Standing images were obtained while the patients put similar weight on both lower extremities in their comfortable position with horizontal gaze. Sitting images were obtained while the patients sat on a backless seat in accordance with a previously published protocol (feet flat on the floor, patient in a relaxed position, knees flexed 90°, horizontal gaze). Postoperative EOS images were obtained between 6 and 9 months after surgery when patients had achieved most of their functional improvement with minor improvements expected to be achieved within 2 years after THA (mean: 9 months [6–13]).

Study variables

The PI is the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the middle point of the axis of the femoral heads. The SS is the angle between the horizontal line and the superior sacral endplate. The LL was measured as the angle between the superior endplate of L1 and the superior endplate of S1. The APP angle is the angle between the APP and the vertical line (Fig. 3a and 3b). Pelvic tilt was considered positive when the pelvis tilted forward and was considered negative when it was tilted posteriorly [23]. SSPT was considered zero when the C7PL went through the center of the line that was connecting the center of the femoral heads. SSPT was considered positive when the C7PL was posterior to this point, and it was considered negative when the C7PL was in front of this point [17]. Two trained investigators measured all the study variables independently. None of these patients had dislocation risk factors such as neurologic

disorders, dementia, Ehlers-Danlos syndrome, or significant deformities requiring additional lower extremity surgeries.

We defined 5 different groups of patients based on the changes in SSPT in standing and sitting (Table 3). Type 1 was defined as “neutral” with $-1 \text{ cm} < \text{SSPT} < 1 \text{ cm}$ for sagittal balance. As previously described in the literature, patients were categorized into 3 groups based on the PI: low PI $< 45^\circ$, $45^\circ < \text{average PI} < 65^\circ$, or high PI $> 65^\circ$ [24].

Statistical analysis

Statistical analyses were performed using Stata, version 14.1 (StataCorp LP, College Station, TX). The repeatability and reproducibility of the measurements were tested using the Bland-Altman analysis. Normal distribution of the values was checked by means of the Shapiro-Wilk normality test for each series of measurements. The paired Student t test and analysis of variance test were used for analysis as the data were normally distributed. The significance level was set at less than 0.05. As this was a feasibility study, we did not perform a sample size analysis. Correlations were calculated using Pearson’s correlation test.

Results

The detailed results of the measurements are shown in Table 4. The overall mean preoperative SSPT change from standing to sitting was 2.2 cm ($[-7.2 \text{ to } 17.4]$) ($P < .05$). The overall mean postoperative SSPT change from standing to sitting was 1.2 cm ($[-14.2 \text{ to } 22.4]$) ($P < .05$). No significant correlation could be found between SSPT and the SS, APP angle, or LL (Tables 4 and 5). Correlations were strong between SSPT and the SVA (Table 5). There was no significant

Table 2
Demographics and surgical approaches.

Number of patients	120
Gender (M/F)	61/59
Mean age [range] (years)	64.5 (SD 13.7) [37 to 81]
BMI [range] (kg/m^2)	25.0 (SD 4.9) [20.6 to 33.1]
Surgical approaches	Anterolateral approach: 78 patients Posterior approach: 27 patients Direct anterior approach: 11 patients Direct lateral approach: 4 patients

SD, standard deviation; M, male; F, female; BMI, body mass index.

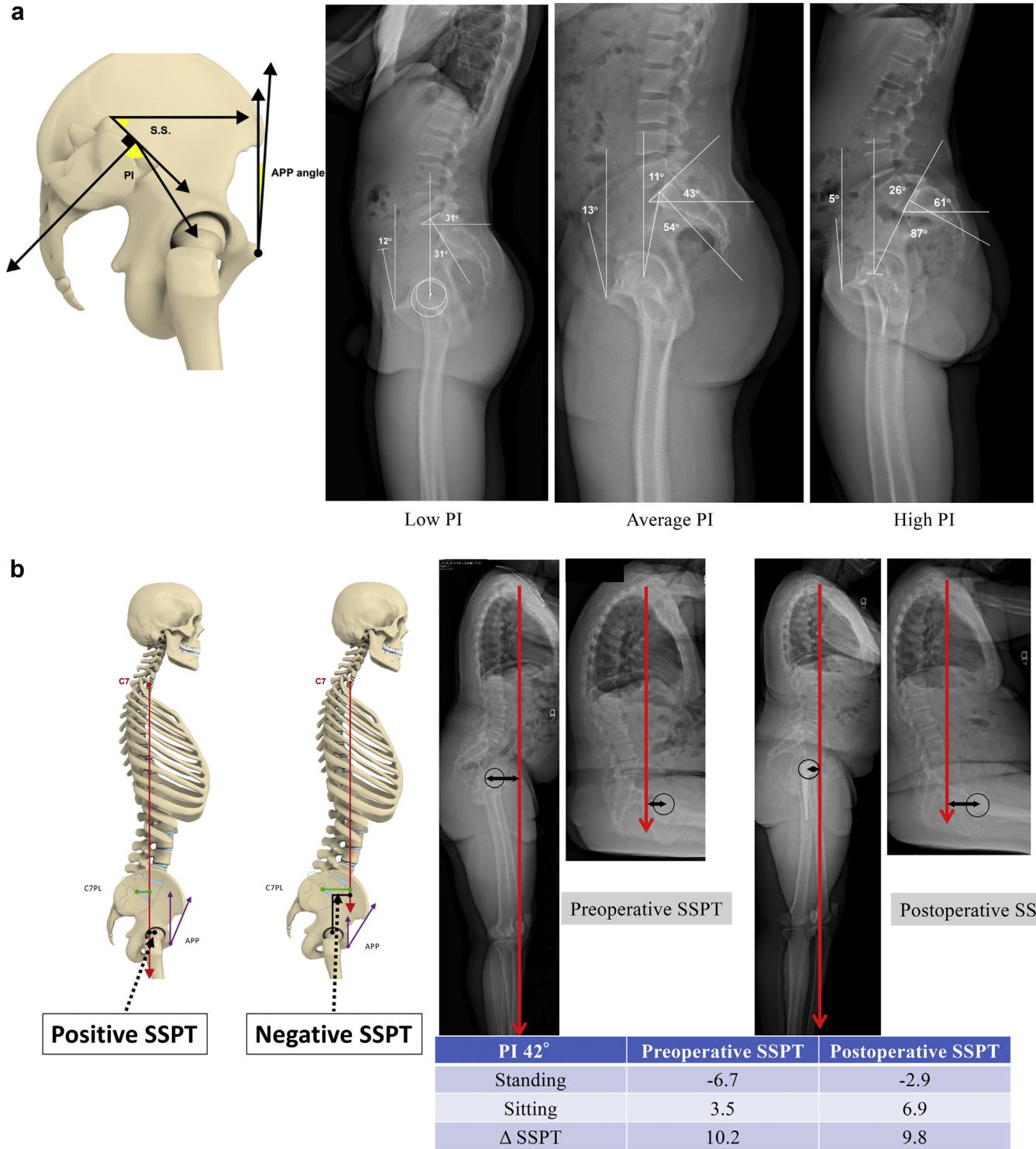


Figure 3. (a): Measurements of the pelvic tilt. Low PI <45°; 45° < average PI <65°; high PI > 65°. (b): If the hip axis was anterior to the C7 plumb line, SSPT was considered positive. If it was posterior to the C7 plumb line, it was considered negative.

difference between the preoperative and postoperative PI. This means that the location for the center of the rotation for the operative hip was not modified during the surgery.

In the average-PI group (Fig. 4), preoperatively, SSPT increased from standing to sitting ($P = .004$). SSPT was always positive in the sitting position (pelvic anterior translation regarding the C7PL). When comparing preoperative and postoperative changes, SSPT increased in the standing position ($P = .006$) and the mean SSPT

value became positive (anterior pelvic translation regarding the C7PL). SSPT variation (sitting-standing) decreased significantly ($P = .04$) when comparing postoperative to preoperative status. No significant correlation could be found between SSPT and the SS, LL, and APP angle.

In the low-PI group (Fig. 5), preoperatively and postoperatively, SSPT increased significantly from standing to sitting ($P < .05$) (pelvic anterior translation regarding the C7PL). When comparing

Table 3
Spinopelvic parameters in the standing and sitting positions.

Parameters	Standing	Sitting	Δ (sitting – standing)
Preoperative			
SSPT [range] (mm)	–8.7 (SD 45.3) [–151 to 72]	13.2 (SD 33.3) [–77 to 118]	21.9 (SD 54.9) [–72 to 174]
SVA [range] (mm)	45.6 (SD 46.6) [–44 to 190]	62.6 (SD 30.6) [–5 to 140]	17.0 (SD 48.8) [–136 to 112]
PI [range] (°)	57.7 (SD 13.7) [30 to 86]	57.7 (SD 13.7) [30 to 86]	57.7 (SD 13.7) [30 to 86]
SS [range] (°)	42.9 (SD 13.2) [2 to 85]	23.3 (SD 15.2) [–17 to 55]	13.2 (SD 33.3) [–77 to 118]
LL [range] (°)	34.6 (SD 12.6) [23 to 47]	23.7 (SD 9.63) [13 to 39]	12.8 (SD 7.9) [8 to 28]
Postoperative			
SSPT [range] (mm)	2.1 (SD 46.6) [–170 to 81]	14.0 (SD 35.2) [–73 to 104]	12.0 (SD 55.0) [–142 to 224]
SVA [range] (mm)	37.0 (SD 47.2) [–43 to 171]	57.1 (SD 29.2) [–20 to 146]	20.2 (SD 47.0) [–13 to 182]
SS [range] (°)	42.0 (SD 13.3) [8 to 73]	24.7 (SD 13.3) [–15 to 54]	17.3 (SD 11.5) [–9 to 46]
LL [range] (°)	35.3 (SD 13.2) [24 to 45]	23.1 (SD 9.84) [12 to 39]	11.9 (SD 8.9) [6 to 30]

SD, standard deviation.

preoperative and postoperative changes, standing SSPT significantly increased but the mean SSPT value remained negative ($P = .001$). Preoperative to postoperative SSPT variation (sitting–standing) decreased significantly ($P = .01$). No significant correlation could be found between SSPT and the SS, LL, and APP angle.

In the high-PI group (Fig. 6), preoperatively and postoperatively, SSPT increased from standing to sitting ($P = .034$). SSPT remained positive in the standing and sitting positions (pelvic anterior translation regarding the C7PL). There were no significant changes from preoperative to postoperative status in standing and in sitting. No significant correlation could be found between SSPT and the SS, LL, and APP angle.

Table 6 shows the change in SSPT in the 5 different functional types in the standing and sitting positions before and after THA. Types 2 and 4 are the more frequent types among patients. Interestingly, 4 subluxation cases were reported postoperatively in type 3 group (positive SSPT standing and negative SSPT sitting) ($P = .0001$). All these subluxations occurred during the transition from standing to sitting. None of these patients had THA dislocation.

Discussion

In this feasibility study, we showed the importance of SSPT and its changes in the standing and sitting positions after THA. Interestingly, 4 patients in group 3 (positive SSPT in standing and negative SSPT in sitting) had subluxation of their hip joint while moving to the sitting position. This supports the concept of possible increased instability risk in patients with negative SSPT in the sitting position even when the implant orientation is within the accepted range and femoral offset and length have been recreated. It also shows that assessment of the global sagittal balance is a key point to understand hip spine relation and patients who are at high risk for THA dislocation.

Recent THA literature points out the importance of sagittal pelvic alignment in the standing and sitting positions. More studies have recently focused on the sitting position and provide valuable information regarding sagittal pelvic tilt as measured by the SS and APP plane angles and functional acetabular orientation [25–27]. Hips are where the mass of the body transfers to the ground and the location of the gravity axis of the upper body is a key point for an ergonomic posture [28]. A stiff, lordotic lumbar spine requires greater hip flexion to achieve a sitting posture, and conversely, stiff hip joints demand more lumbar flexion to achieve sitting [26]. The increased hip motion contributes to femoroacetabular impingement and THA instability [29,30]. The postural change from standing to sitting cannot just be summarized as the sum of the lumbar and hip flexion and then converted to a “regional” phenomenon only. This is particularly evident when aging results in degenerative loss of lordosis and moving the spine and then whole-body mass forward. In an attempt to maintain the global spinal balance to maintain the head over the pelvis, compensatory changes occur in the standing position such as posterior pelvic tilt and knee flexion to shift the trunk gravity center posteriorly.

The impact on the hip joint is intuitive and difficult to describe, but the consequences of surgical correction of the spinal balance after spinal fusion have been described on THA [1,4,31]. Global sagittal balance has been assessed with the GL. The GL is located slightly to the rear of the line that connects the femoral heads in the standing position in patients without significant hip or spine pathology [32]. But the position of the GL is not well studied in hip joint literature and especially for THA instability problems [7,25]. It seems rationale to express the sagittal balance in the standing position according to the C7PL projection regarding femoral heads as the balance conditions are the result of morphological parameters (PI based on the hip center position) and functional adaptation of the pelvis (SS and APP). The C7PL provides an acceptable

Table 4
Preoperative and postoperative spinopelvic parameters in the standing and sitting positions preoperatively and postoperatively.

Parameters	Standing	Sitting	Δ(Sitting – Standing)
SSPT (mm)			
Preoperative	–87 (SD 45.3) [–151 to 72]	132 (SD 33.3) [–77 to 118]	219 (SD 54.9) [–72 to 174]
Postoperative	2.1 (SD 47.2) [–170 to 81]	14.3 (SD 35.3) [–73 to 104]	12.2 (SD 55.1) [–142 to 224]
SVA (mm)			
Preoperative	45.6 (SD 46.6) [–44 to 190]	62.6 (SD 30.6) [–5 to 140]	17.0 (SD 48.8) [–136 to 112]
Postoperative	37 (SD 47) [–43 to 171]	57 (SD 29) [–20 to 147]	20 (SD 47) [–133 to 182]
SS (°)			
Preoperative	42.9 (SD 13.2) [2.0 to 85.0]	23.3 (SD 15.2) [–17.0 to 55.0]	–19.6 (SD 12.3) [–49.0 to 11.0]
Postoperative	42.0 (SD 13.3) [8.0 to 73.0]	24.7 (SD 13.3) [–15.0 to 54.0]	–17.3 (SD 11.5) [–46.0 to 9.0]
LL (°)			
Preoperative	34.6 (SD 12.6) [23 to 47]	23.7 (SD 9.63) [13 to 39]	12.8 (SD 7.9) [8 to 28]
Postoperative	35.1 (SD 13) [25 to 50]	22.8 (SD 10.2) [12 to 41]	13.2 (SD 8.9) [9 to 30]

SD, standard deviation.

Table 5
Correlation analysis between parameters for all patients.

Parameters	Preoperative				Postoperative			
	SS/SSPT	SVA/SSPT	APP/SSPT	LL/SSPT	SS/SSPT	SVA/SSPT	APP/SSPT	LL/SSPT
Standing	0.0	-0.9	0.1	0.3	-0.1	-0.8	0.1	0.2
Sitting	SS/SSPT -0.2	SVA/SSPT -0.8	APP/SSPT 0.3	LL/SSPT 0.2	SS/SSPT -0.2	SVA/SSPT -0.7	APP/SSPT 0.2	LL/SSPT 0.1
Δ(Sitting–standing)	SS/SSPT -0.3	SVA/SSPT -0.9	APP/SSPT 0.2	LL/SSPT 0.2	SS/SSPT -0.2	SVA/SSPT -0.8	APP/SSPT 0.2	LL/SSPT 0.1

approximation of the GL location in the standing position, and the variation of the relation between the C7PL and the femoral head center suggests new insights into the sitting position.

The spinal balance conditions are generally expressed by the SVA using the sacrum as the reference in the standing position. But the SVA does not take into account the sagittal pelvic anatomy expressed by the PI, which influences the role of the hips as a transmitter in the balance of the trunk [28]. In this study, we could observe a robust correlation between the SVA and SSPT as they express the same rebalancing process between standing and sitting. Nevertheless, SSPT is more representative of the hip-spine relationship as it describes the lever arm of the GL relative to the hip joints [17]. On the contrary, we did not observe correlations

between SSPT and the SS and APP. This seems logical because the SS is limited to the expression of the pelvic rotation. This emphasizes the need for a new parameter (SSPT) to describe the pelvic translation during the standing position toward the seated position.

SSPT variations from standing to sitting are regulated by the complex hip-spine functional relation. Different stand-to-sit adaptation patterns have been described such as if the patient is a “spine user” rather than a “hip user” [33]. Changes in SSPT are driven by 2 combined phenomena. The first phenomenon is the hip kinematics with sagittal rotation around the femoral head axis. The second phenomenon is the whole-spine adaptation previously described for the SVA including pelvic extension with SS decrease and LL decrease. The postoperative sagittal adaptation of patients

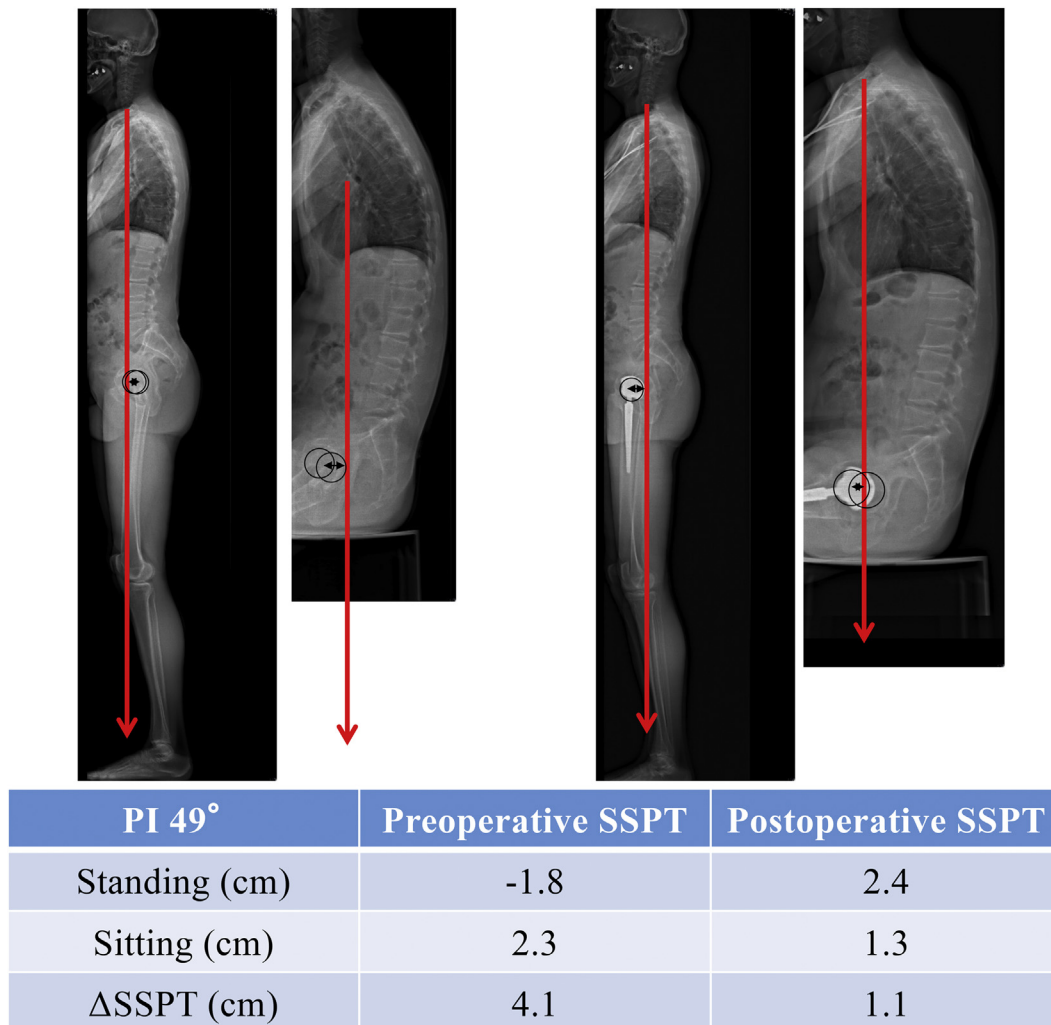


Figure 4. Sagittal spinopelvic translation in a patient with average pelvic incidence.

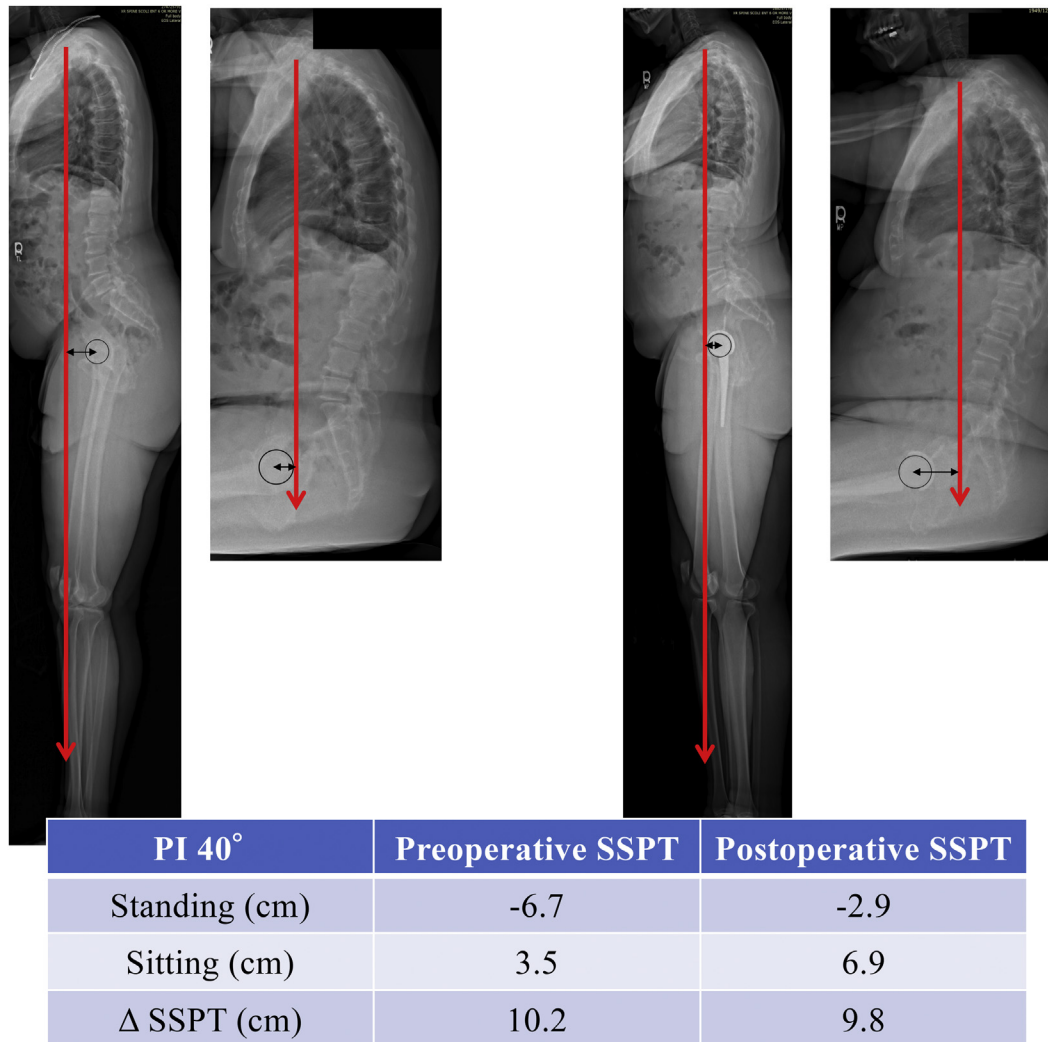
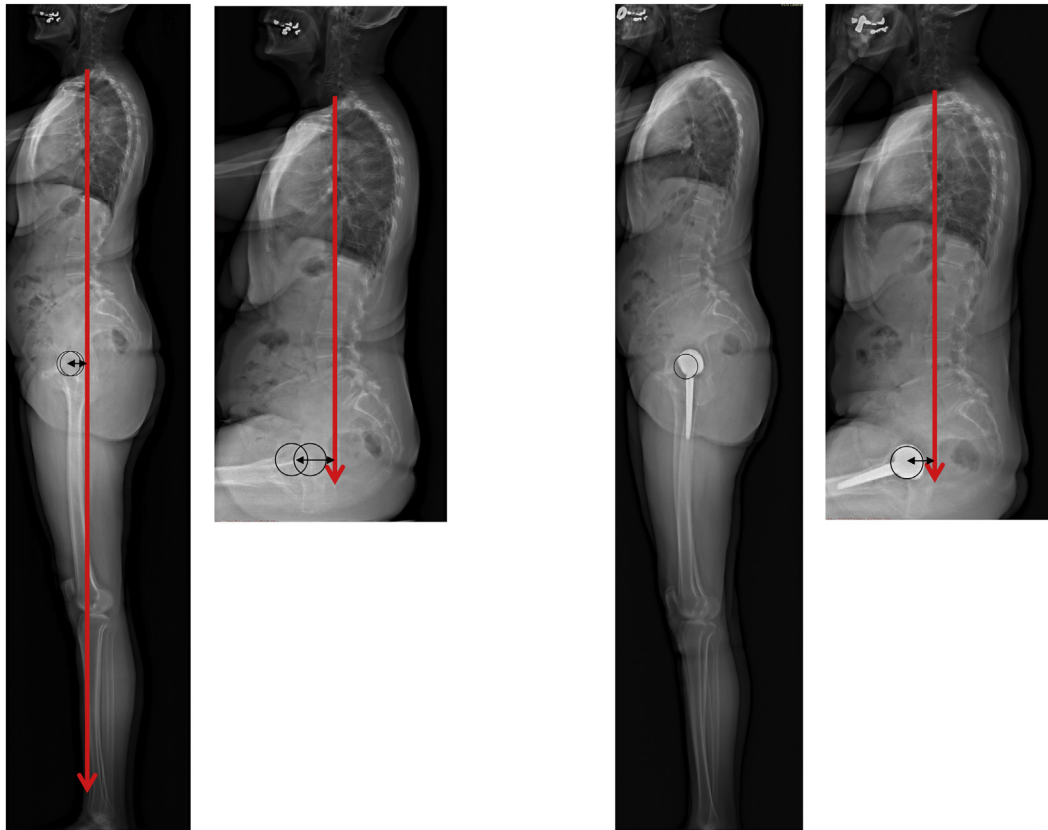


Figure 5. Sagittal spinopelvic translation in a patient with low pelvic incidence.

with average PI is specific with no significant modification of SSPT, suggesting that these patients are predominantly “hip users.” Otherwise, in all other categories, patients are combined hip and spine users. Patients with low and average PI generally have a negative SSPT in standing, while the patients with high PI have a positive SSPT. These different patterns are all due to the difference in the distance between the femoral heads and the sacrum (closer in patients with low PI and farther away in patients with high PI) (Figs. 3 and 4). Postoperatively, patients with low PI have rebalancing limitations even after the release of the joint flexion contracture. These patients generally continue to have less hip extension and negative SSPT postoperatively and have limited global extension ability and LL adaptation [1]. Patients with high PI have a higher SS and LL. This explains positive values for SSPT in both preoperative and postoperative measurements and the lack of significant modifications for standing and sitting after THA. Overall, in all patients, the tendency is to move toward a positive SSPT for the sitting position with posterior pelvic tilt and lower LL.

To understand the importance of SSPT and its potential role in THA instability, we classified the patients into 5 groups. In patients with “neutral” SSPT in sitting and standing ($-1 \text{ cm} < \text{neutral} < 1 \text{ cm}$) (type 1), the postural changes are not significant. The transition from sitting to standing may include a transient step of negative SSPT, but the amplitude of variation is low. Patients whose type of

equilibration is characterized by positive or neutral SSPT in the standing position can move to the sitting position either with positive or neutral SSPT (type 2) or with negative SSPT (type 3). Patients whose pattern in the standing position is negative SSPT can move to the sitting position with positive or neutral SSPT (type 4) or remain with negative SSPT (type 5). Patients with negative SSPT in the sitting position could be considered as the worst-case scenarios for dislocation risk (types 3 and 5). These 2 types may have higher risk for THA instability as these hip-spine biomechanics can induce a liftoff of the lever arm in the sitting position (Fig. 7a and 7b). Interestingly, we noticed cases of 4 patients who had THA subluxation who were type 3 (positive SSPT standing, negative SSPT sitting) with a high transitional amplitude for translation. Preoperatively, 2 of these patients were SSPT type 2, and the other 2 were SSPT type 4. This subluxation could not be attributed to local anatomical variables such as anatomical cup and stem orientation or osteophytes or functional cup orientation. This could suggest that more attention should be pointed on significant sagittal balance modifications after THA in addition to classical analysis, which concentrates on limited body regions such as the lumbar spine and pelvis only [34]. We investigated the spine stiffness via measuring the LL but did not find any significant correlation between SSPT and the LL. We did not classify our patients according to the lordosis-incidence relationship. As underlined by the literature [19], the



PI 74°	Preoperative SSPT	Postoperative SSPT
Standing (cm)	2.8	1.3
Sitting (cm)	5.1	3.7
Δ SSPT (cm)	2.3	3.4

Figure 6. Sagittal spinopelvic translation in a patient with high pelvic incidence.

often used $PI = LL + 9^\circ$ formula [35] is only valid for cases with a small PI angle. This has been reported to lead to significant errors when the PI is greater than 50° . In addition, this concept has been based only on data collected from 75 asymptomatic adult subjects (mean age of 48 years) and then with a limited validity and generalizability, especially in patients with a pathologic LL.

As for the SVA, SSPT reflects a global adaptation including the relative relationships between the thoracic and lumbar curvatures and the PI. The repartition of thoracolumbar sagittal curvatures has been described as very heterogeneous in the standing position. The Rousouly classification is widely used in the spine literature with 5 types of sagittal patterns in the standing position but without any data about the adaptation from the standing to sitting position [36]. Despite large standard deviation and a wide range of the described values in spine literature, the SVA is considered to be a good description of spinal balance but does not provide sufficient information for the hip arthroplasty cases as it does not take the PI into account. The SVA can be used to evaluate the posture evolution of each individual but is not valuable in comparison of patients [19]. On the contrary, SSPT allows comparison of the patients regarding their posture and balance strategy using the PI and SS angles in standing to sitting.

Table 6

The change in SSPT in the 5 different functional types in the standing and sitting positions before and after THA.

Parameters	Preoperative Patients	Postoperative				
		Change	No change	Final		
Type 1	7	6 (85.7%)	Type 2	4	1 (14.3%)	6
			Type 3	0		
			Type 4	0		
			Type 5	2		
			Type 1	3		
Type 2	51	9 (17.6%)	Type 1	3	42 (82.4%)	63
			Type 3	2		
			Type 4	4		
			Type 5	0		
			Type 1	0		
Type 3	10	6 (60%)	Type 1	0	4 (40%)	12
			Type 2	3		
			Type 4	1		
			Type 5	2		
			Type 1	2		
Type 4	34	20 (58.8%)	Type 1	2	14 (41.2%)	26
			Type 2	9		
			Type 3	3		
			Type 5	6		
			Type 1	0		
Type 5	18	15 (83.3%)	Type 1	0	3 (16.7%)	13
			Type 2	5		
			Type 3	3		
			Type 4	7		
			Type 1	0		

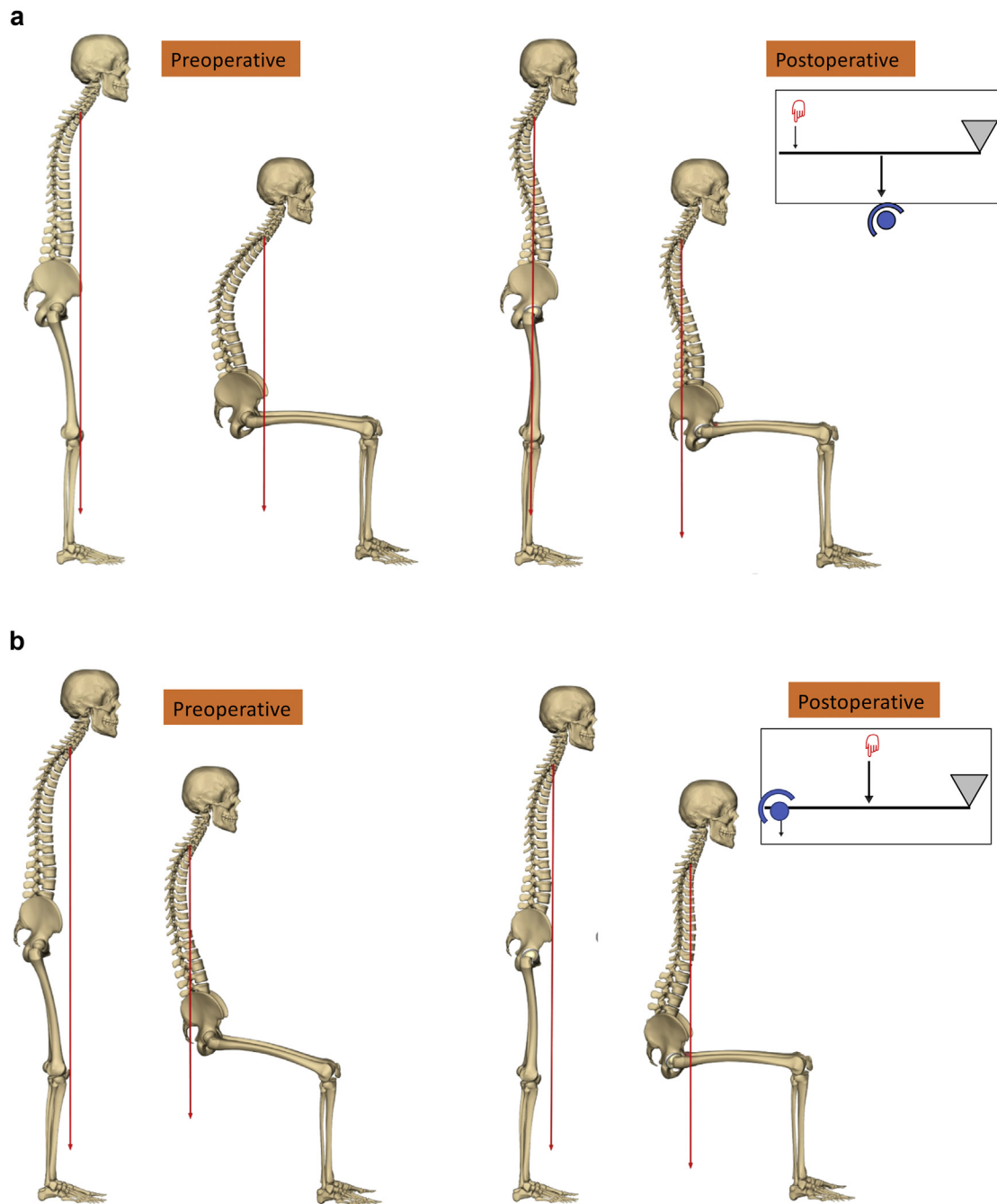


Figure 7. (a): The “favorable scenario” for THA. Preoperatively, the patient experiences a sagittal imbalance in standing and sitting. The recovery of mobility after THA modifies the sagittal balance favorably. The axis of movement is focused on the hip joints for rotation during sitting to standing. In this case, the pressure on the knees is counterbalanced by the trunk’s weight as the gravity line is posterior to the hip axis. (b): The “worst-case scenario” for THA. Preoperatively, the patient experiences a sagittal imbalance in standing only. The recovery of mobility after THA does not modify the sagittal balance favorably; in the standing position, the patient is still imbalanced. The axis of movement is focused on the hip joints. The pressure on the knees is not counterbalanced by the trunk weight as the gravity line is anterior to the hip axis. The mechanical schema of forces induces a liftoff effect on the hips.

This study has limitations. This study describes the concept of SSPT. Our sample is too small to draw conclusion regarding the importance of SSPT modifications in THA instability as this complication is multifactorial including the femoroacetabular relations, muscle function status, and surgical approach. Standing and sitting global sagittal evaluations are only snapshots of a complex phenomenon. EOS only provides the amplitude and direction of SSPT changes, without detailed information about the chronology and relative extent of implementation of hip flexion and spine

adaptation. The effect of the body mass index on sagittal balance variations was difficult to analyze as the morphological characteristics of the patients were heterogeneous. Owing to our strict inclusion and exclusion criteria, our results are not generalizable to the patients who underwent spinal fusion. Nevertheless, the reported higher risk for THA instability in patients who had undergone lumbar fusion could be attributed to unexpected adaptations of SSPT during the standing to sitting motion. This hypothesis will require further studies.

Conclusion

SSPT can be considered as a significant mechanism of global adaptation during functional activities such as sitting and rising from the sitting position after THA even in those patients whose implant orientation is within the acceptable range and their femoral offset and length have been recreated. Comparison of preoperative and postoperative sagittal translation points out the difference in transition between the standing and sitting positions for those patients with a low PI. SSPT types 3 and 5 could potentially be the types that have higher risk for THA instability. Larger series are needed to analyze this point. Further studies are needed to study the impact of SSPT on subluxation or dislocation especially after spinal fusion.

Conflict of interest

The authors declare there are no conflicts of interest.

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