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The variability of sagittal spino-pelvic mobility in Indian population

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ABSTRACT

Background: Abnormal spino-pelvic mobility is increasingly recognized as a leading cause for hip instability following arthroplasty.
Methods: We studied the lateral spino-pelvic radiographs of 90 patients, with no spine/hip pathology in standing and sitting positions. We measured the change in sacral slope and grouped them into three spino-pelvic patterns.
Results: We found that 50% of study subjects had normal spino-pelvic mobility. The remaining 50% were either hypermobile (24%) or stiff (26%). The stiff spines were either fixed (11%) or hypomobile (15%).
Conclusions: Our study shows that in a normal population without any prior hip/spine pathology a significant percentage (50%) have abnormal spino-pelvic mobility. The significance of spinal stiffness in younger age group need to be looked further to make any changes in acetabular cup placement during hip replacement.

Keywords: Spino-pelvic mobility, Stuck sitting, Stuck standing, Sagittal plane, Hip arthroplasty, Hip instability

INTRODUCTION

The spine-pelvis-hip is a complex unit with constant interplay in three planes to maintain body balance.[1] A deformity in one unit will be compensated by the other two. The biomechanics of spino-pelvic interplay remains foreign to a spine surgeon as she/he rarely seeks down beyond the sacrum and to a hip surgeon as he/she does not look up beyond the acetabulum. A clear understanding of this interplay is essential for the successful outcome following a spine or hip surgery as neither of them addresses all the three components.[2]

There have been a number of reports suggesting the increased incidence of hip instability in patients who have had surgical spinal fusion, especially the ones that involves lumbo sacral junction.[3-6] Further research has shown that this increased risk of dislocation is not just in those with iatrogenic spinal fusion but in any condition causing stiffness in lumbosacral spine like inflammatory conditions (ankylosing spondylitis) or degenerative spinal stiffness.[7-11] Hence, over the past decade spinal stiffness has been identified as one of the main reasons of instability following total hip arthroplasty (THA).[3,6]

The dynamic sagittal spino-pelvic change from standing to sitting position is unique to each individual.[12] Generally, a preoperative radiological evaluation for THA includes an anteroposterior (AP) view of pelvis usually in supine position. However, this view does not reveal the sagittal plane deformity and its compensation.[13]

A computed tomography (CT) similarly gives only static supine measurements of sagittal alignment and does not reflect the functional position of an individual in his day to day activities.[14]

A true lateral spino-pelvic radiograph in standing and sitting positions can be a useful tool to reveal the pattern of spino-pelvic mobility. It is recommended to get spinal radiographs in standing and sitting positions in elderly prior to THA and in revisions for instability following THA. We aimed to measure the spinal mobility patterns in Indian population with no spinal symptoms.

METHODS

We selected patients with no prior hip/spine symptoms who attended our out-patient clinic. The study population was selected as per National board of education (NBE) guidelines with ethical research committee approval from our hospital. An informed consent of these volunteers was obtained after explaining about the radiographs. The study period was for a year from June 2018 to May 2019. Volunteer with no prior hip/spine symptoms who could undergo an unsupported erect radiograph were included in our study. The exclusion criteria included skeletal immaturity (<18 years), any prior hip/spine symptoms/surgery and any infective or inflammatory pathology.

A true lateral radiograph, imaging first lumbar vertebrae to proximal femur is taken in standing and sitting positions. In standing a weight-bearing lateral radiograph with both feet kept at a shoulder width apart is performed. The studied hip is kept next to cassette with the patient's both hands at shoulder height holding on to a support. Mid-coronal plane of body is aligned to midline of grid and radiograph beam is then centered over L4-L5 junction in a direction perpendicular to patient's axial line (Figure 1).

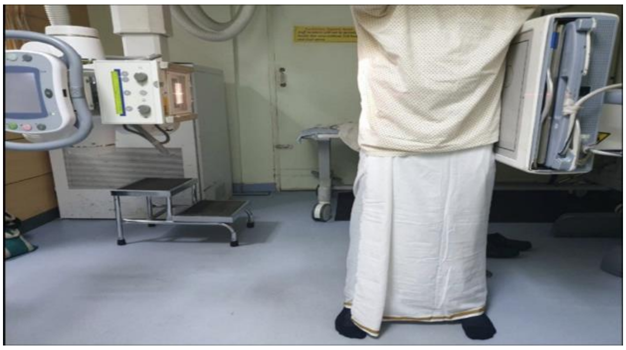

Figure 1: Standing lateral spino-pelvic radiograph with both feet at shoulder width apart.

In sitting radiograph, patient is made to sit on a height adjustable stool to ensure that femur remains parallel to floor. The studied hip is kept next to cassette with arms resting at 90 degrees on a support. Mid-coronal plane of body is aligned to midline of grid and radiograph beam is centered over L4-L5 junction in a direction perpendicular to patient's axial line (Figure 2).

The spino-pelvic angular parameters measured in our study were pelvic tilt, lumbar lordosis and sacral slope. Pelvic tilt in our study is measured as the angle between the coronal plane and a pelvic reference plane i.e. line between anterior superior iliac spines and midpoint of the pubic tubercles as described by Buckland et al. On a lateral standing radiograph this is represented by a line from anterior superior iliac spine to pubic tubercle (Figure 3). The angle measured between the upper plate of first lumbar vertebrae and lower end of fifth lumbar vertebrae gives lumbar lordosis (Figure 4). Sacral slope is the angle between line joining the sacral end plate and the horizontal (Figure 5). The measurements in our study were obtained using PACS SYNAPSE software separately in standing and sitting positions.

Figure 2: Sitting lateral spino-pelvic radiograph on a height adjustable stool and thigh parallel to floor.

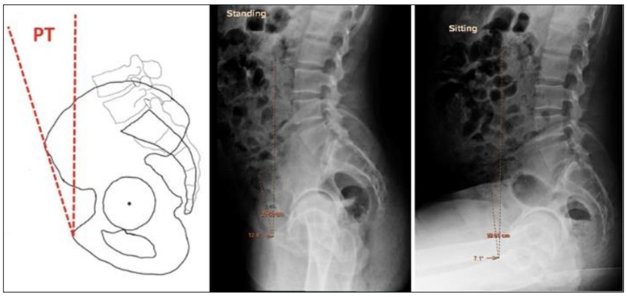

Figure 3: Pelvic tilt measurement in standing and sitting positions.

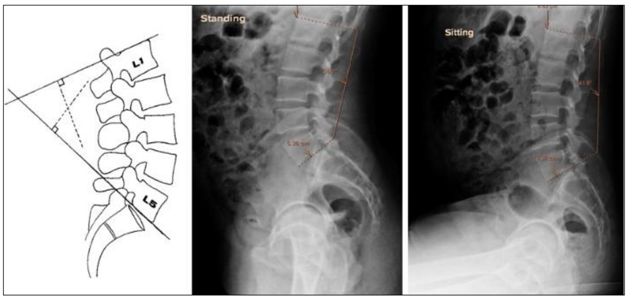

Figure 4: Lumbar lordosis measurement in standing and sitting positions.

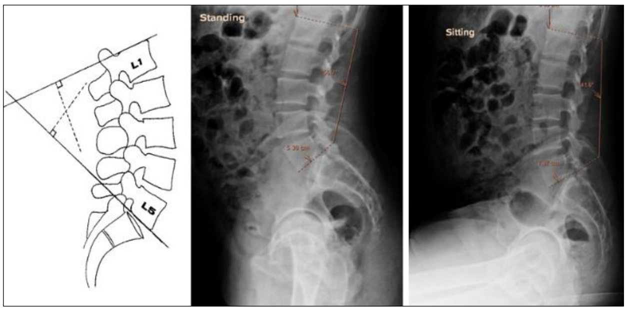

Figure 5: Sacral slope measurement in standing and sitting positions.

Table 1: Spino-pelvic measurements of our study population.

Spino-pelvic measurements		Mean±standard deviation (range)		
		Stiff (n=19)	Normal (n=42)	Hypermobile (n=26)
Pelvic tilt	Standing	10.32±7.66 (3.50–29.30)	7.71± 5.49 (1.40–21.90)	8.90±5.52 (1.20–22.60)
	Sitting	13.57±11.67 (1.0–48.90)	14.47±9.55 (1.0–45.20)	26.88±10.76 (3.40–39.40)
	Difference	3.25±9.26 (-12.10–19.60)	6.76±±9.74 (-15.40–25.60)	17.98± 13.52 (-8.90–34.20)
Sacral slope	Standing	38.79±13.24 (10.0–70.0)	43.55±10.06 (24.30–70.20)	47.37±10.30 (15.70–72.30)
	Sitting	35.22 ±14.27 (1.8–67.70)	26.41±14.18 (8.0- 68.80)	12.33±11.75 (1.0–48.60)
	Difference	5.63 ±3.14 (0.90–9.80)	18.52 ±5.13 (11.70–29.0)	37.58 ±5.93 (30.0–48.50)
Lumbar lordosis	Standing	44.95 ±14.28 (16.0–64.70)	45.55±13.44 (11.0–81.10)	41.99±12.49 (8.60–59.60)
	Sitting	33.27±11.79 (12.10–50.50)	26.52±13.13 (1.60–55.80)	13.96±14.60 (1.60–70.0)
	Difference	-11.68±10.61 (-32.60–5.70)	-19.03±11.90 (-54.30–6.70)	-28.03±18.61 (-48.10–27.0)

Table 2: Details of study population.

Group	Sacral slope (SS) change	Total, n=90	Male	Female	<40	40-60	>60
Normal	11-29 degree	44	22	22	13	17	14
Hypermobile	>30 degree	22	10	12	5	14	3
Normal variant	>30 with sitting SS>10	8					
Kyphotic variant	>30 with sitting SS<10	14					
Stiff	<10 degree	24	14	12	3	6	15
Stuck standing	<5-10 with sitting SS>30	4					
Stuck sitting	<5-10 with standing SS<30	6					
Hypomobile	<5 degree	14					

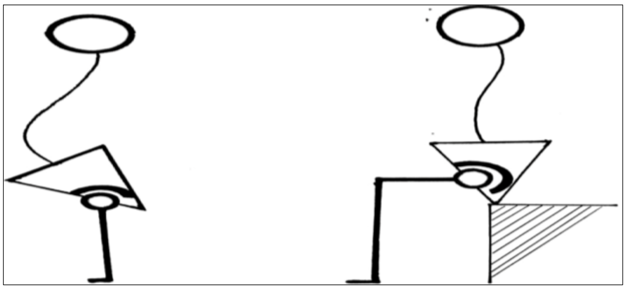

Figure 6: Normal standing and sitting positions.

RESULTS

This is a prospective observational radiographic study. A total of 90 participants who fulfilled the criteria were involved in the study (Table 1). The average age was 49.9 years (19-79 years). All radiographs were measured twice by two independent orthopaedic surgeons (SAN and ABT). Inter-observer reliability was calculated using Lin's concordance as suggested by our statistician and the correlation coefficient ranged from -1 to 1 with 1 indicating perfect agreement. The study groups were grouped based on the most reproducible saggital spino pelvic angular parameter i.e. sacral slope.[14-16]

The study population was grouped according the spino-pelvic mobility patterns described in the literature.[14] A sacral slope value in the range of 11-29 degrees between standing and sitting was considered as normal spino-pelvic motion. A value <10 degree is considered as spino-pelvic stiffness and a value >30 degree as spino-pelvic hypermobility. The total number of patients is divided into these three groups. Spino-pelvic stiffness is further subdivided into stuck (change in sacral slope 5-10º) and hypomobile (change in sacral slope <5º). Stuck group is again divided into two, based primarily on the sacral slope into stuck standing/fixed lordotic spine, having sitting sacral slope >30º and stuck sitting/flat back spine, having standing sacral slope <30º. Stuck standing (fixed lordosis) hip means that their pelvis is fixed in anterior tilt, and with sitting does not shift posteriorly. Stuck sitting (flat back) on the other hand is pelvis fixed in posterior tilt which does not tilt anteriorly when standing. A pelvis which is not fixed (neither stuck standing nor stuck sitting) in anterior or posterior tilt, but having a reduced spino-pelvic mobility is termed as hypomobile. Spino-pelvic hypermobility is divided into two as normal variant (sitting sacral slope >10º) and as kyphotic variant (sitting sacral slope <10º).

We found that nearly half of patients (44 of 90) had normal spino pelvic mobility (Table 2). 25% patients had spino-pelvic stiffness (4 of 24 stuck standing, 6 of 24 stuck sitting, 14 of 24 hypomobile spine) with majority in older age group (15 of 24 with age >60 years) but was also seen in younger individuals (3 of 24 with age <40 years). We could also find that our group of hypermobile spino-pelvic mobility (normal 8 of 22, kyphotic 14 of 22) was young females (8 of 22).

DISCUSSION

The upright position of homosapiens is the result of a well-organized spine-pelvis-hip complex. A normal standing position of an individual is a balance between lordotic lumbar spine, anteriorly tilted pelvis and a hip extension. As the individual sits, a flexed and internally rotated hip is balanced by a posterior tilt of pelvis and less lordotic or flattening of spine (Figure 6).

The anterior pelvic plane or Lewinnek plane used as the body reference axis for navigation in hip arthroplasty is an unreliable marker as it is highly variable among individuals and also changes with position.[17-19] Blondel et al and Maratt et al suggested using the pelvic tilt as a reference as it was found to be a constant sagittal parameter.[20,21]

The definition of pelvic tilt differs among spine and hip surgeons.[3] Spine surgeons measure pelvic tilt by the angle formed by a vertical line through the center of the femoral heads and the line from the center of the femoral axis and the midpoint of the sacral end plate. From a hip surgeons' perspective, we think of pelvic tilt is like a plumbline, based on which we define the anterior or posterior tilt of pelvis. To avoid confusion between the two Buckland et al1 calls the measurement used by spine surgeon as spino pelvic tilt and the measurement commonly used by hip surgeons (and which we have measured in this paper) as pelvic tilt.

From a practical point of view getting the 4 landmarks (both pubic tubercles and both anterior superior iliac spines) in the same plane to measure pelvic tilt was more difficult than getting the true lateral of the sacral slope.[22] Hence we found that sacral slope was more reliable than pelvic tilt for measurement.[23] Philippot et al emphasized that the most reproducible sagittal angular measurement to assess dynamic pelvic motion is sacral slope.[15]

Sagittal lumbar alignment is greatly influenced by pelvic alignment; Endo et al have suggested that measuring lumbar lordosis (L1-L5) in sagittal plane alone is insufficient.[23] A study by Stefl et al has shown that only lower three lumbar vertebrae actually contributed to hip mobility.[14]

The ideal placement of acetabular component in THA is still evolving. Lewinnek advised to place the component in the safe zone of 15°±10° of ante-version to prevent instability.[13,21] Hip surgeons started to understand spino-pelvic mobility properly, only in the past decade. Depending on how stiff the spine is and also in what positions is the stiffness the functional position of acetabulum changes. Recent papers suggest that "safe zone" should be modified if there is stiffness or spinal deformity.[24]

A bouquet of studies analyzed the biomechanical change of acetabular component with spino-pelvic imbalance. However, each study ultimately came out defining a new terminology or a new angle.[14,25,26] Legaye and Tang suggested that compensatory adjustments during cup positioning were required to match sagittal plane imbalance.[27,28] The change in spino-pelvic parameters as an individual move from standing to sitting position is greater than from standing to lying down position.[16] As an individual stand, the pelvis tilts forward and lumbar spine become lordotic to maintain balance. While sitting the opposite happens. When sitting the acetabulum tends to antevert and open up to accommodate flexion of proximal femur. When an individual sit at 90 degrees, only 70 degrees happen at the hip joint per se.[16] The rest 20-degree tilt happens by posteriorly tilting pelvis and this occurs only if the spine is flexible. In stiff spines (26% in our series) there will be reduced movement at the spine on sitting. This in turn means that the hip joint itself has to flex to 90 degrees increasing the risk of impingement.

In cases with spine stiff in lordosis (stuck standing) the acetabulum does not antevert on sitting and hence they are at a higher risk of anterior impingement and posterior dislocation on sitting. Hence to avoid a posterior dislocation one needs to increase anteversion in such cases. In contrast a flat-back spine is the spine stiff in a relatively kyphotic position. In such cases the spine is stuck in a sitting position. Hence whilst the patient stands there is no lordosis and pelvis remains in an excessively anteverted position. This can cause posterior impingement when the leg is externally rotated in standing position resulting in an anterior dislocation. In patients with a flat-back deformity it is recommended to reduce the version to prevent anterior instability.

Stefl et al classified spino-pelvic mobility into 5 patterns based on the change in sacral slope from standing to sitting position.[14] The study elaborates on the classification and provides guidelines on acetabular cup placement for each in order to prevent impingement and dislocations. Biomechanical studies have shown that for each degree change in pelvic tilt the version changes by 0.7-0.8 degrees.[29,30] However, we still do not have enough clinical data to advise how much change in version should be made for each degree change in normal lumbar lordosis. It is also unclear from the present literature whether the hypermobile group needs any modification in acetabular position. Ike et al reported hypermobility protects against dislocation.[14,16] There are also papers suggesting that one needs to worry about an anterior dislocation with these hypermobile spines.[25]

Several studies have shown that prior to hip arthroplasty, it is essential to get spinal radiographs in elderly and revisions for instability.[1,2,4-6,13] Our study shows the variability of spinal mobility in Indian population. In our study on 90 patients, 50% have normal spino-pelvic mobility. The 'normal group' should be reconstructed along standard guidelines.[17] Patients with stiff spine are at risk following hip arthroplasty because restricted pelvic movement does not allow the acetabulum to compensate and thus there is higher risk of impingement resulting in instability. The acetabular position will need to be adjusted based on the stiffness and deformity.

Limitations

The study concentrated only on the sacro-pelvic orientation that represents only a part of the spino-pelvic movement. The assessment of coronal plane and transverse plane may also play a part and needs further evaluation.

CONCLUSION

Our study shows that in a normal population without any prior spine pathology a significant percentage (50%) have abnormal spino-pelvic mobility. The stiffness was more in >60 age group. We found spinal stiffness (12.5%) even in younger population without any previous spinal symptoms and this has previously not been reported. The acetabular cup positioning based on the incidence of spinal stiffness in younger age group need to be looked by looking at a larger study and comparing with the patients who have undergone THA in the similar age group.

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