# Correlate size of lordosis / pelvic incidence / sacral slope on erect XR to types of lower lumbar facets seen on CT/MRI

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**Abstract/Summary**
This paper proposes that spine type, as determined by pelvic parameters - pelvic incidence (PI), sacral slope (SS) and lumbar lordosis (LL) – correlates to facet joint orientation. This relationship was explored through a retrospective radiographic analysis of 30 patients who received a full spine x-ray, and a CT/MRI of the lumbar spine between 2014-2019. The data showed some correlation between spine type and facet joint orientation. However, we conclude that more research, with a larger sample size, should be completed to reach a more accurate conclusion.

**Introduction:**
The variation in sagittal alignment of the spine has been widely studied due to the impact that deformity can have on health-related quality of life [1-3]. Analysis of key spinopelvic parameters on radiographic images has led to the development of various classification systems [4-6]. By doing so, patterns of degeneration can be identified and a basis for specific surgical planning can be recommended for each type. The interplay between these spinopelvic parameters and spinal type/ global sagittal alignment has been widely investigated. For example, a low PI correlates to a low SS and therefore a flattened lordosis of the spine. [7]. However, little research has been done in relation to facet joint morphology.

Facet joints are imperative in the mechanical stabilization of the spine; regulating the degree of flexion, extension and axial rotation [8]. As such, degeneration of facet joints causes abnormal mobility to the joint [9]. Although there is natural variation in facet joint orientation, a more sagittal orientated lumbar facet joint, which usually assumes a more coronal orientation caudally [10], is proven to be associated with specific pathology such as degenerative spondylolistheses [11]. However, there is dispute in the literature as to whether the orientation of facet joints is due to a primary morphological variation predisposing to pathology [12,13], or a result of secondary remodelling [14,15]. A proposed mechanism of remodelling is that the loss of lumbar lordosis leads to a forward sagittal alignment which abnormally loads the lumbar spine. This increases stress on posterior structures resulting in changes to the mechanical properties of the facet joints [16].

This poses the question as to whether anatomical variation in facet joint morphology has any direct relationship to sagittal alignment and spine type. This relationship has not been studied in great depth. Therefore, we aim to investigate the correlation between size of lordosis / pelvic incidence / sacral slope on erect x-ray to types of lower lumbar facets seen on CT/MRI through a retrospective radiologic study. We hypothesise that spine types with an increased pelvic incidence, which should correlate to a greater SS and LL, will have more sagittal orientated facet joints.

**Methods**
Full spine lateral radiographs were obtained from patients above the age of 15 who presented to the radiology department of University Hospital Wales between 2014 and 2019. Radiographs were selected as suitable if the C7 vertebral body and both femoral heads were visible with the patient in a standardised up-right position. Of these patients, those with an additional CT or MRI of the lumbar vertebrae were identified. Patients were excluded if they had spinal deformity i.e. scoliosis greater than 10°, traumatic spinal injury or spine surgery without preoperative imaging.

Measurements of PI, SS and LL were taken from plain film. PI was measured as the angle between a line drawn from the centre of the femoral heads to the midpoint of the sacral

endplate and a line perpendicular to the centre of the sacral end plate [Fig.1] [17]. SS was measured as the angle between a horizontal reference line and the sacral endplate [Fig.2] [17]. Lumbar lordosis was measured from the cephalad end plate of L1 to the sacral endplate [Fig.3] [18]. Facet joint angles were measured from axial MRI or CT slices as studies show there is good agreement between MRI and CT when assessing lumbar facet joints [19]. Angles were measured for the L3/L4, L4/L5 and L5/S1 facet joints. To do so, a coronal reference line is made by creating a line perpendicular to the sagittal plane. The sagittal plane was defined by a line dissecting the spinous process. The coronal reference line is then measured against a line extending from the anteromedial and posterior lateral margins of the facet joint [Fig.4][20]. All measurements were taken manually by a single user with the assistance of computerised technology. The parameters were measured on three separate occasions and an average created to be used in statistical analysis. Pearsons Correlation was used to analyse the data using SPSS statistical software version 25. Data was considered as significant if the significance level was less than 0.05. The measured parameters also assisted in classifying the spine types according to Laouissat et al. [6] as summarised in table 1.

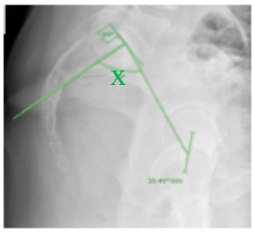

Fig.1 pelvic incidence

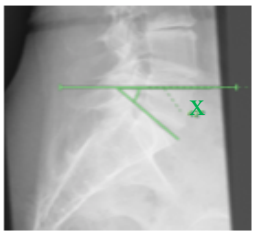

Fig.2 Sacral slope

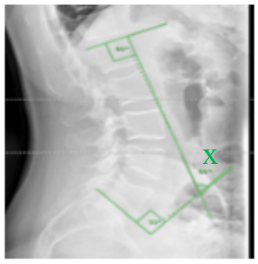

Fig.3 Lumbar lordosis

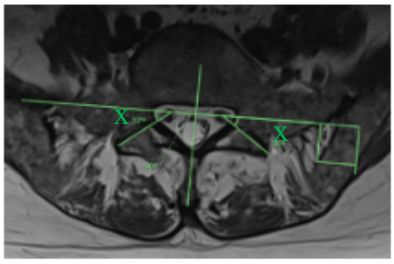

Fig.4 Facet joint angles

Table 1: Classification of spine types according to Laouissat et al.

| | Sacral Slope | Pelvic Incidence: | Notes |
|---|---|---|---|
| Type 1 | SS<35° | Low PI | Inflexion point: L3/L4<br>Short hyper-lordosis<br>Long kyphosis |
| Type 2 | SS<35° | Low PI | Inflexion point: L1/L2<br>Flat long lordosis |
| Type 3 (AP) | SS > 35° | Low PI | Anteverted pelvis<br>Longer lordosis |
| Type 3 | 35° < SS < 45° | High PI | Inflexion point: T12/T1 |
| Type 4 | SS >45° | High PI | Inflexion point: T9/T10<br>Long lordotic curve<br>short kyphotic curve |

## Results

### Patient sample:

30 patients between the age 18-83 were included in the study with a mean age of 56. All subjects were classified into Type 1 (20%), Type 2 (13.3%), Type 3AP (10%), Type 3 (33.3%) or Type 4 (23.3%) spines.

### Spinopelvic sagittal alignment:

PI ranged between 28°- 82° with a mean value of 57°. It varied amongst Type 1, 2, 3AP, 3 and 4 spines with mean values being 43°, 47°, 47°, 65°, 66° respectively. SS ranged between 20°- 55° with a mean value of 37°. The mean SS values for Type 1, 2, 3AP, 3 and 4 spines were 24°, 30°, 35°, 38°, 49° respectively. LL ranged between 26° - 82° with a mean value of 50°. The mean LL values for Type 1, 2, 3AP, 3 and 4 spines were 37°, 43°, 55°, 51°, 62° respectively (Table 2).

Table 2: Mean pelvic incidence, sacral slope and lumbar lordosis according to spine type

| | *Pelvic Incidence* | | *Sacral Slope* | | *Lumbar Lordosis* | |
|---|---|---|---|---|---|---|
| *Type 1* | Mean<br>Std. deviation | 43°<br>8.01 | Mean<br>Std. deviation | 24°<br>3.18 | Mean<br>Std. deviation | 37°<br>6.79 |
| *Type 2* | Mean<br>Std. deviation | 47°<br>2.96 | Mean<br>Std. deviation | 30°<br>4.18 | Mean<br>Std. deviation | 43°<br>12.92 |
| *Type 3AP* | Mean<br>Std. deviation | 47°<br>2.17 | Mean<br>Std. deviation | 35°<br>0.33 | Mean<br>Std. deviation | 55°<br>15.61 |
| *Type 3* | Mean<br>Std. deviation | 65°<br>8.77 | Mean<br>Std. deviation | 38°<br>3.05 | Mean<br>Std. deviation | 51°<br>9.49 |
| *Type 4* | Mean<br>Std. deviation | 66°<br>9.96 | Mean<br>Std. deviation | 49°<br>3.23 | Mean<br>Std. deviation | 62°<br>12.72 |

A strong positive correlation was found between PI and SS (correlation: 0.741, sig. < 0.01). PI was also weakly correlated with LL; however, this was not statistically significant (correlation: 0.352, significance: 0.56). SS was strongly and significantly correlated with LL (correlation:0.703, sig. < 0.01) (Table 3).

Table 3: Correlation between pelvic incidence, sacral slope and lumbar lordosis

| | | *Pelvic Incidence* | *Sacral Slope* | *Lumbar Lordosis* |
|---|---|---|---|---|
| *Pelvic Incidence* | *Pearson Correlation*<br>*Significance* | | 0.741<br>< 0.01* | 0.352<br>0.056 |
| *Sacral Slope* | *Pearson Correlation*<br>*Significance* | 0.741<br>< 0.01* | | 0.703<br>< 0.01* |
| *Lumbar Lordosis* | *Pearson Correlation*<br>*Significance* | 0.352<br>0.056 | 0.703<br>< 0.01* | |

* Sig. < 0.05

**Facet joint orientation**

There was no statistically significant correlation found between the spinopelvic parameters (PI, SS and LL) and facet joint orientation (Table.4).

Table 4: Correlation between pelvic incidence/ sacral slope/ lumbar lordosis and L3-L4/ L4-L5/ L5-S1 facet joint angles

| | | *L3/L4 Facet joint* | *L4/L5 Facet joint* | *L5/S1 Facet joint* |
|---|---|---|---|---|
| *Pelvic Incidence* | *Pearson Correlation* | - 0.26 | 0.035 | 0.286 |
| | *Significance* | 0.891 | 0. 854 | 0.125 |
| *Sacral Slope* | *Pearson Correlation* | 0.229 | 0.13 | 0.160 |
| | *Significance* | 0. 224 | 0.494 | 0.398 |
| *Lumbar Lordosis* | *Pearson Correlation* | 0.281 | 0.079 | -0.112 |
| | *Significance* | 0.133 | 0.678 | 0.557 |

The mean facet joint angles of each spine type are summarised in Table 5. Due to a small sample size, we were unable to run an ANOVA test to accurately analyse the homogeneity of variances.

| | | *Mean* | *Std Deviation* |
|---|---|---|---|
| *L3-L4 facet joint* | *Type 1* | 52° | 7.8 |
| | *Type 2* | 51° | 9.12 |
| | *Type 3AP* | 67° | 4.38 |
| | *Type 3* | 55° | 7.73 |
| | *Type 4* | 56° | 7.53 |
| | *Total* | 55.04 | 8.34 |
| *L4-L5 facet joint* | *Type 1* | 41° | 9.36 |
| | *Type 2* | 42° | 11.21 |
| | *Type 3AP* | 57° | 4.28 |
| | *Type 3* | 46° | 13.57 |
| | *Type 4* | 44° | 7.7 |
| | *Total* | 45° | 10.9 |
| *L5-SI facet joint* | *Type 1* | 35° | 5.16 |
| | *Type 2* | 41° | 4.7 |
| | *Type 3AP* | 39° | 11.01 |
| | *Type 3* | 46° | 12.14 |
| | *Type 4* | 40° | 10.33 |
| | *Total* | 41° | 9.93 |

Table 5: Facet joint angles according to spine type

However, analysis of facet joint orientation in graphic form displays a trend. Figure 6a shows the average facet joint angle of all spine types from L3 to S1 decreases which confirms the more coronal orientation of facet joints in the caudal region. There also seem to be a difference between spine types as displayed in figure 6b. However, there is some degree of overlap suggesting there may not be a significant difference between these categories.

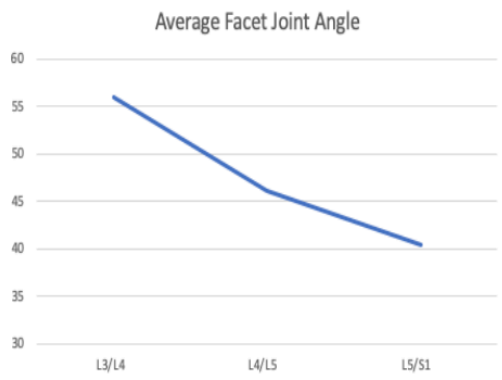


Figure 6a

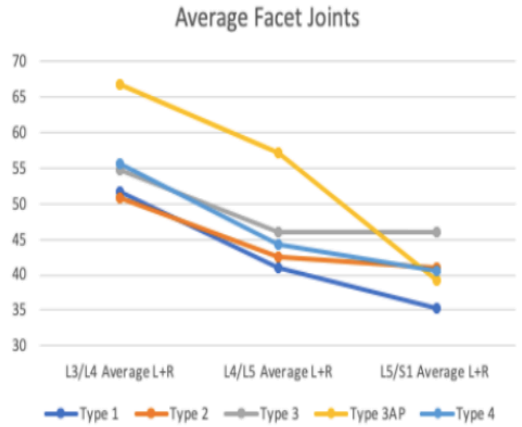


Figure 6b

Displaying this data in histogram form better demonstrates the distribution of this data [Fig.7]. With the exception of Type 3AP, which made up only 1/10 of the subjects analysed in the data, facet joint angle does seem to increase from Type 1 to Type 4. This trend is visible at all three joints assessed however there is overlap between types again.

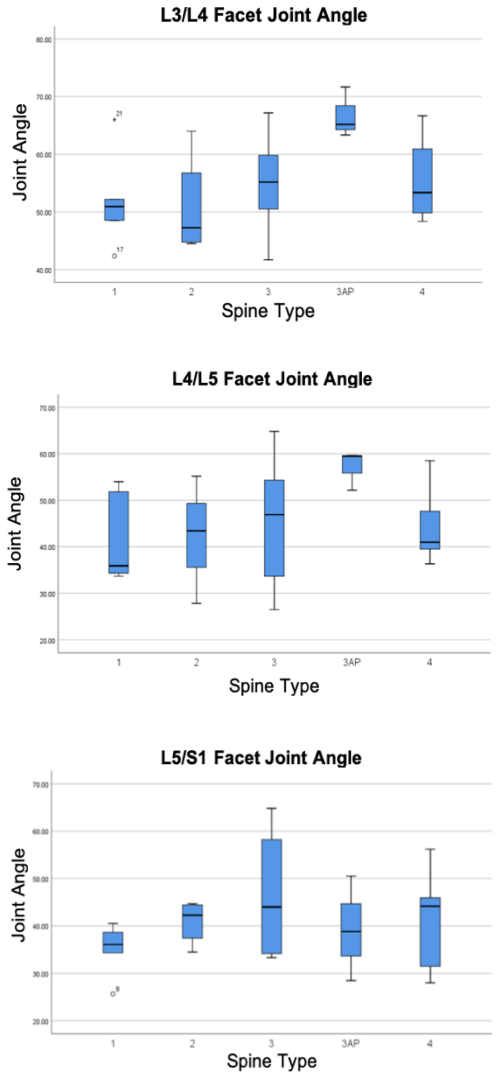


Figure 7: Facet joint angles according to spine types

## Discussion

This study primarily investigated the relationship between spine type and facet joint orientation. The data provided mean values for PI, SS and LL and showed a correlation between all three values. However, the correlation was only statistically significant for the relationship between PI and SS, and SS and LL. We were able to use the data to classify each spine into the updated Roussouly Classification and analysed the spinopelvic parameters and facet joint angles according to each spine type. No significant correlation was found between the spinopelvic parameters (PI, SS, LL) and facet joint angles, and a larger sample size is required to accurately analyse whether there is a statistically significant difference in facet joint angles between spine types.

However, graphically there seems to be an increase in facet joint angles from Type 1 to Type 4 spines which suggests a Type 4 spine is likely to have more sagittal orientated facet joints. The significance of facet joint orientation in relation to segmental motion has been reported in previous studies. Sagittal orientation of the facet joint, seen more in the upper lumbar region, allows a greater degree of movement in the sagittal plane i.e. during flexion and extension. This supposedly protects the intervertebral disc which is greatly affected by excessive bending and torsion. Meanwhile, coronal facet joints in the lower lumbar region are more involved in bending and torsion; therefore, at a greater risk of disc pathology [21]. Roussouly claimed to see a preliminary observation between Type 1 and Type 2 spines presenting more commonly with symptomatic disc herniations [4]. If the results of this current study are accurate, and Type 1 and Type 2 spines do indeed have a more coronal orientation, this could be a possible explanation. It could also explain why Type 4 spines, with more sagittal facet joints, have a larger lordotic curve due to greater mobility in the sagittal plane.

The main limitation of this study is the sample size. To accurately analyse the relation between spine type and facet joint orientation, the sample size for each spine type should be much larger to allow an accurate comparison of means. Furthermore, as this was a retrospective study, it was difficult to control the patient population and ensure all patients were healthy individuals. Although efforts were put into ensuring subjects with scoliosis or serious spinal pathology were excluded, a small proportion did have evidence of such pathology. It was also difficult to ensure imaging was done with the patient in a standardised position, and that all anatomical landmarks for measurements were clearly visible. This could affect the validity of the data. As the data was collected by a single individual, the reproducibility of the data has also not yet been assessed.

## Conclusions

In conclusion, this study confirms the relationship between the spinopelvic parameters PI, SS and LL. It also demonstrates the coronal orientation of facet joints in the caudal region of the lumbar spine. The data showed some evidence of increasing facet joint angles from Type 1 to Type 4 spines which confirmed the hypothesis of sagittal orientated facet joints in spines with a greater PI/SS/LL. However, the study was limited in its sample size and no statistically significant correlation was able to be identified. Further research, with a larger sample size must be done to truly appreciate this relationship.

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