Original Article

High values of pelvic incidence: A possible risk factor for zygoapophyseal facet arthrosis in young

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ABSTRACT

In humans the acquisition of the bipedalism caused different structural changes to achieve the new functional demands. In particular, several changes have occurred in the spine and pelvis. In recent years the sagittal morphology of the spine and pelvis has become one of the most focused topics in spine research. The sample consists of 348 volunteers, with no history of low back pain, without any previous major trauma at the spine or at the pelvis. Aged between 20 and 29 years. The presence and severity of zygoapophyseal facet arthrosis were investigated in accordance with Pathria's classification (it considered four parameters: width of interarticular space, the presence of osteophytes, the presence of facet hypertrophy and presence of areas of bone erosion). Volunteers were divided into two group based on sagittal balance subtype classified by Roussouly in 2005. 98 volunteers (35.76%) belongs to group A (subtype I and II), and 176 volunteers (64.24%) belongs to group III and IV. The different weight distribution in the lumbar spine suggests that different subtype of sagittal balance could develop zygoapophyseal facet arthrosis more frequently. Considering the different Groups, a statistically significant difference was found: people belonging in group B (subtype III and IV), shows a prevalence of 36.36% compared with a prevalence of 24.5% for group A (subtype I and II).

1. Introduction

In humans the acquisition of the bipedalism caused different structural changes to achieve the new functional demands. In particular, several changes have occurred in the spine and pelvis¹⁶. In higher primates is present a single kyphotic curvature from the head to the sacrum, whereas in humans there is an alternation of lordosis, at cervical and lumbar regions and kyphosis at the thoracic and sacral regions¹. Furthermore, the presence of a lordotic curvature at the lumbar spine has caused the retroversion of the pelvis, so that these structures are harmonized across them. Moreover, also musculoskeletal "minor changes" has occurred especially in the origin and insertion points of some anti-gravitational extensor muscle groups of the spine and pelvis².

In recent years the sagittal morphology of the spine and pelvis has become one of the most focused topics in spine research. The terms "Sagittal Balance" was introduced in 1992 by Duval-Baupere³, in his article state that the relation between the vertebra, the sacrum, the coxo-femoral rotation axis and the center of weight support present

high inter-individual differences. Berthonnaud et al.⁴ in 2005 have introduced a simple method to describe the global shape of spine and pelvis with a lateral 30 × 90 lateral radiograph. Furthermore, they study the relationship between the curvature of the spine and morphology of the pelvis and found a direct correlation between pelvic incidence (PI) and sacral slope (SS) and between SS and lumbar lordosis (LL). PI is an angle that describes the orientation of the upper plate of the sacrum and the two coxo-femoral heads, is an anatomic angle, independent of the position and acting as driving forces to the development of the global shape of spine and pelvis. The standard values of SS and LL depend on the value of PI if these angles are in agreement muscle economy supports the load forces. P. Roussouly et al.⁵ proposed a classification based mainly on PI, SS, and LL identifying four subtypes. Subtype 1 has an SS < 35° and a little LL, subtype 2 always has an SS < 35° and an almost flat LL, subtype 3 and subtype 4 are characterized by SS values, respectively greater than 35° and 45° with a wide LL (see Table 1). Subtype 3 is also known as "well balanced," with over 90% of the load forces supported by vertebral bodies and the

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Table 1
Subtype of Sagittal Alignment in Healthy Subjects based on Roussouly Classification⁵.

Subtype	Pelvic Index	Sacral Slope	Lumbar Lordosis	Global Balance
1	Low	< 35°	Low ratio LL/ lowerLL	High Thoraco-Lumbar Kipphosis
2	Low	< 35°	Almost Flat	Lumbar Hipolordosis and Thoracic Hyperkyphosis
3	High	35° to 45°	Harmonious with the Pelvis	Well-Balanced
4	High	> 45°	Hyperlordotic	Segmental Hyperextension

intervertebral disc, while only a small amount is backed by the posterior arch and in particular by the zygapophyseal joints. Subtypes 1 and 2, shows a less pronounced LL with additional load forces on the intervertebral disc of the lumbar spine, while subtype 4 the vast LL overloads the posterior arch⁶.

The different weight distribution in the lumbar spine suggests that different subtype of sagittal balance could develop zygapophyseal facet arthrosis more frequently. The prevalence of facet arthrosis increase with increasing age, stands at 18–25% in people younger than 30°, reaching over 90% in people over 60 years⁷. The aim of this study is to evaluate if there is a different prevalence of facet arthrosis in young people according to a different subtype of sagittal balance.

2. Materials and methods

2.1. Subjects

The sample consists of 348 volunteers, with no history of low back pain, without any previous major trauma at the spine or at the pelvis. Aged between 20 and 29 years (with a mean age of 27.6 ± 3.4 years). Subjects come at our department of radiology for a CT scan of the abdomen for investigation of the urogenital tract. Due to the anatomical purpose of this study, the following exclusion criteria were considered: the presence of lumbosacral transitional vertebrae and sign of disc degeneration. Another 20 people were excluded due to the presence of an active muscular compensatory mechanism to maintain sagittal balance. Once informed of the purpose of the study, have signed an informed consensus drawn up by the Helsinki declaration⁸. Finally, the sample consists of 274 healthy subjects, with an average age of 26.5 years, an average weight of 74.8 kg, an average height of 1.72 m (average body mass index or BMI of 24.1 kg/m²); 161 men (58.75%) with an average age of 27.2 years, an average weight of 79.2 kg, an average height of 1.77 m (BMI of 25.2 kg/m²); 113 women (41.25%), with an average age of 25.5 years, an average weight of 66.9 kg, an average height of 1.62 m (BMI of 23.8 kg/m²), see Table 2a.

Table 2

(a) Demographic Data in the whole sample, male and female; (b) Demographic Data of people belonging to different subtypes.

	N° (%)	Age (years)	Weight (kg)	Height (m)	BMI (kg/m ²)
(a) Whole Sex	274 (100%)	26,5 years	74,8 kg	1,72 m	24,1
Male	161 (58,75%)	27,2 years	79,2 kg	1,77 m	25,2
Female	113 (41,25%)	25,5 years	66,9 kg	1,63 m	23,8
(b) Subtype					
I, II	98 (35,76%)	25,8 years	75,2 kg	1,73 m	24,8
III, IV	176 (64,24%)	26,4 years	74,6 kg	1,74 m	24,4

2.2. Imaging

In the remaining 274 volunteers an abdomen CT with a four-channel CT scanner (Mx 8000 quad, Philips medical Systems) with the following parameters: 140 kV, 150–200 mA, collimation of 2 × 0.5 mm, section width of 0.6 mm. On the same day, a 30 × 90 lateral radiograph of the whole spine (from the proximal third of femurs to the cervical spine) was acquired.

2.3. Measurements

2.3.1. CT scan

The presence and severity of zygapophyseal facet arthrosis was investigate in accordance with Pathria's classification⁹, modified by Weisphaht in 1999¹⁰. It considered four parameters: width of inter-articular space, the presence of osteophytes, the presence of facet hypertrophy and presence of areas of bone erosion. It distinguishes between four levels of gravity: in grade 0, which indicates the presence of a normal articular space with a thickness ranging from 2 to 4 mm; in grade 1, there is a reduction of articular space (with a rhyme less than 2 mm) and/or the presence of small osteophytes and/or mild facet hypertrophy; in grade 2, besides the reduction of the articular space at least coexist the presence of medium-sized osteophytes and/or moderate joint hypertrophy and/or the presence of minor areas of bone erosion; in grade 3, besides the reduction of the articular space at least coexist the presence of major osteophytes and/or an important facet hypertrophy and/or the presence of subchondral cysts (see Table 3).

2.3.2. Lateral X-ray measurements

Sagittal balance parameters were evaluated in accordance with Berthonnaud criteria⁴: PI, defined as the angle between the line perpendicular to the upper sacral plate at its midpoint and the line connecting this point to the femoral heads (center of bicoxo-femoral line); SS, defined as the angle between the upper sacral plate and a horizontal line; LL, between L1 and S1 and lower LL between L4 and S1. People that maintain a correct sagittal alignment without any compensatory mechanism were enrolled¹¹.

3. Results

Volunteers were divided into two group based on sagittal balance subtypes⁵ classified by Roussouly. 98 volunteers (35.76%) belongs to group A (subtype I and II), and 176 volunteers (64.24%) belongs to group III and IV. The groups are matched by age, sex, and BMI (see Table 2b).

As shown in Table 4a, facet arthrosis was found in 12.4% at L1-L2; 13.86% L2-L3; 15.7% L3-L4 levels; 32.11% at L4-L5 level and 13.86% at L5-S1 level. People belongs to Group A (subtype I and II) shows a prevalence of 10.2% at L1-L2; 11.1% at L2-L3; 13.3% at L3-L4; 24.5% at L4-L5 and lastly 12.2% at L5-S1. People belong to Group B (subtype III and IV), shows a prevalence of 13.6% at L1-L2; 15.9% at L2-L3; 17.6% at L3-L4; 36.36% at L4-L5; 16.5% at L5-S1. Statistically significant results were observed for L4-L5 with P-Value < 0.05 (chi² statistic 4,0708 Table 5), and for P-Value < 0.10 for L5-S1

Table 3

Pathria⁹ classification adapted by Weisphaht¹⁰ in 1999 of facet arthrosis based on CT scan of the lumbar spine.

Grade	Articular Space Width (mm)	Presence of Osteophytes	Hypertrophy of Zygapophysis	Bone Erosion	Subcondral Cist
0	2 mm–4 mm				
1	< 2 mm	Small	Mild		
2	< 2 mm	Moderate	Moderate	Mild	
3	< 2 mm	Large	Severe	Severe	Presence

Table 4

Prevalence of Facet Osteoarthritis at zigoapophyseal joints in the Lumbar Spine. No statistically significant differences were observed in the two groups, except at L4–L5.

	L1–L2	L2–L3	L3–L4	L4–L5	L5–S1
Whole	34 (12,4%)	38 (13,86%)	43 (15,7%)	88 (32,11%)	38 (13,86%)
Subtype I, II	10 (10,2%)	11 (11,1%)	13 (13,3%)	24 (24,5%)	12 (12,2%)
Subtype III, IV	24 (13,6%)	28 (15,9%)	31 (17,6%)	64 (36,36%)	29 (16,5%)

Table 5

Chi² statistic (4.0708) for the prevalence of facet osteoarthritis at L4–L5. The P-value is 0.43631 (significant at $p < 0.05$).

	Pathria 0	Pathria ≥ 1	Row Tot.
Subtype I, II	74	24	98
Subtype III, IV	112	64	176
Column Tot.	186	88	274 (Grant Tot.)

Table 5 shows the severity of facet OA at L4–L5 level in groups A and B (in accordance with Pathria and Weishaupt criteria) the majority of the subjects presents a low grade (grade 1) arthrosis characterized only by the reduction of interarticular space (less than 2 mm), only 9 people, 3 in group A and 6 in group B shows a grade 2 OA (no statistically significant correlation).

4. Discussion

In this study, a sign of facet OA, such as reduction of inter-articular space, that corresponds to Grade 1 Pathria OA, was found in 32.11% of young people (32.11%) at L4–L5. Considering the different Groups, a statistically significant difference was found: people belonging in group B (subtype III and IV), shows a prevalence of 36,36% compared with a prevalence of 24.5% for group A (subtype I and II). Among the many biomechanical models proposed to explain the functional anatomy of the spine¹⁷, the one proposed by Berthoinaud⁴ is one of the most comprehensive. Spine, on the sagittal plane, is considered to be an open linear chain linking the head to the pelvis, where the shape and orientation of a segment influence the adjacent one. In particular, he considered the LL structured into two section: the first, or lower arch, ranges from the upper sacral plate to the apex (the most anterior point) of the LL (approximately at the midpoint of the body of L3); the second, or upper arch, extends from the upper plate of S1 to the upper plate of L4. Considering a geometric reconstruction of this model, 2/3 of the entire LL value are located at L4–S1, while the remainder is dependent on the proximal region (L1–L3) and is approximately 20°. As the subtypes vary, the lower LL will change, while the degree guarantee by the proximal region will not change³. As the subtype of sagittal alignment changes as the morphology and size of the posterior element of the vertebrae changes¹⁵. Considering L4–L5 functional spine unit with a “flat lordosis” (subtype II), the spinous processes and the zygoapophyseal mass are more widely spaced than L4–L5 functional spine unit with a heightened lordosis; facet and spinous processes are smaller in people with high PI.

Classically forces acting at the thoracolumbar spine are: compressive forces, defined as the forces acting down the long axis of the vertebra; shear forces, defined as the forces parallel to the anteroposterior axis of the vertebra; and the torsional forces, defined as the rotation forces acting on the axial plane. A person of 70 kg, standing in upright position with an L4–L5 disc with a sagittal tilt of 30° shows a compressive force of 335 N and a shear force of 190 N¹². If the intervertebral disc tilt increase, there will be an increase in term of shear force and a reduction of compressive force, on the contrary, if the intervertebral disc tilt decrease, there will be a decrease in term of shear

force and a reduction of compressive force. Recently Filardi¹³ and his colleagues showed the different pattern of forces acting on the lumbar spine with a finite element model analysis into the different subtype of sagittal balance. They found a statistically significant difference in term of shear forces acting on the lower part of the model (L4, L5, and pelvis) in subtype III and IV (with a PI > 35°).

Facet arthrosis is a common condition with a prevalence increasing as the age increases⁷, standing about 18–25% in young people (20–29 years). Butler¹⁴, states that “disc degeneration often occur without facet arthrosis. Facet OA, on the other hand, occurred in ‘normal’ spine” only when disc degeneration was present”. Our results are in contrasts with this statement. Certainly, the pathophysiologic mechanics described by Butler play a major role in adulthood, but given the prevalence of the young person, where degenerative disc disease is absent (is one of the exclusion criteria of our study), can’t be the only mechanics.

Conflict of interest statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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