The lumbar-pelvic-femoral complex: applications in hip pathology


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Summary
Everyday clinical practice frequently leads us to suspect a close relationship between the lumbar spine and the hip-joints. Sagittal balance fundamentally expresses a postural strategy mobilizing the dynamic structure of the lumbar-pelvic-femoral complex in an authentic balance by which obligatory coupled movements transmit stresses in a single structure, the spine, to the two-part structure of the lower limbs, and vice-versa. Flexion contracture is a frequent hip pathology, but congenital dislocation and ankylosis of the hip have the greatest impact on the spine, due to excessive mechanical strain and/or spinal malalignment, which is initially supple but becomes fixed. Clinical analysis, backed up if necessary by infiltration tests and imaging, guides indications for surgical management. These considerations suggest a general attitude that considers not just the hip itself, for which the patient is consulting, but the lumbar-pelvic-femoral complex as a whole (and also the knee) before undertaking total hip replacement. Femoro-acetabular impingement is a recently described pathology associating morphological hip-joint abnormality and labral and joint cartilage lesions, leading to early osteoarthritis of the hip. Abnormal spinal or pelvic parameters have not been found associated with femoro-acetabular impingement. Congenital pelvic tilt is a benign and often overlooked pathology in children. Supra- and infra-pelvic pelvic tilt in childhood palsy raises the difficult strategic issue of how to get these children in their wheelchair with a well-balanced spine over a straight pelvis and frontally and sagittally balanced hips.

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Introduction
Everyday clinical practice frequently leads us to suspect a close relationship between the lumbar spine and the hip-joints. Sagittal balance fundamentally expresses a postural strategy mobilizing the dynamic structure of the lumbar-
pelvic-femoral complex in an authentic balance by which obligatory coupled movements transmit stresses in a single structure, the spine, to the two-part structure of the lower limbs, and vice-versa.

The lumbar-pelvic-femoral complex should be taken into account in managing hip pathology in adults and children.

The present study focuses first on the impact of hip deformity on the spine, then the difficulties of arthrodesis and management of congenital hip dislocation (CHD). Is femoro-acetabular impingement relevant to spinal imbalance?

In children, the issues are, on the one hand, benign congenital asymmetric pelvis with infantile scoliosis and, on the other, the difficulty of managing pelvic tilt in childhood palsy.

**Adult incidence of hip-joint pathology and spinal impact**

The spinal impact of hip-joint pathology is well-known, but not always well analyzed or taken into account.

Kerboull et al., in a number of studies [1,2,3] reported improvement in spinal symptoms following total replacement of stable [2] and unstable [3] hips.

**Hip flexion contracture**

Flexion contracture occurs frequently in evolved hip pathology, impairing the backward step and causing a compensatory anterior tilt of the pelvis to align the limb with the ground in the stance phase. The anteverversion increases the sacral slope and induces lumbar hyperlordosis which more or less completely opposes forward flexion of the trunk [4]. The hyperlordosis thrusts the disks and joint capsules into the canal. Hip flexion contracture may thus decompensate pre-existing lumbar disc arthritis. When the hip is symptomatic, total hip replacement (THR) is indicated and should improve spinal symptoms, on condition that the THR eliminates the flexion contracture.

In THR, the anterior capsule should be largely released or resected, and lower limb lengthening, which would hinder correction of the flexion contracture, must be avoided.

**Ankylosis and arthrodesis**

Ankylosis and arthrodesis are sequels of osteoarthritis, often infectious, and/or of a previous arthrodesis.

The hip itself is pain-free, but the ankylosis puts excessive strain on the lumbar spine, always sagittally (in flexion/extension, to compensate for the loss of this movement in the hip) and possibly also frontally (in lateral inclination) and horizontally (in rotation). Faulty ankylosis may further cause infra-pelvic pelvic tilt, causing compensatory spinal malalignment, which is initially reducible but may become fixed (creating a supra-pelvic pelvic tilt).

These two phenomena explain spinal pain and the development of lumbar disk arthritis. The spinal impact of ankylosis is especially rapid and severe when the hip is blocked in a faulty position [1,5], whereas ankylosis in correct position is much better tolerated and does not impact other joints until after some 20 years’ evolution [6,7].

Ankylosis can be categorized [1] as:

- in correct position (flexion 15°/20°, adduction 0°/5°, external rotation 0°/5°):
  - unipodal stance is stable,
  - in walking, the forward step induces retroversion of the pelvis with lumbar cyphosis, and the backward step induces anteverversion of the pelvis with lumbar lordosis, without pelvic or spinal rotation;
- in faulty frontal position:
  - in adduction: the ipsilateral lower limb appears “shorter”, there is pelvic tilt (contralateral hip in abduction) and ipsilateral inclination of the spine,
  - in abduction: the ipsilateral lower limb appears “longer”, there is pelvic tilt (contralateral hip in abduction) and contralateral inclination of the spine,
  - in flexion: the extension of the hip required for the backward step induces anterior flexion of the trunk, which can only be compensated by lumbar hyperlordosis, beyond a certain degree of flexion in ankylosis:
    - backward step amplitude is reduced (as of 30°) then abolished (as of 50°) [1],
    - anterior flexion of the trunk is unavoidable during the backward step,
  - in rotation: the patient has to pivot the pelvis around the healthy hip for the flexion plane of the knee to be parallel to the direction of gait; the pelvis is tilted with respect to the direction of gait, spinal rotation counter to the pelvic rotation is required to keep the shoulders facing forwards.

THR can improve spinal symptoms, especially if the spine is not yet arthritic, the hip recovers sufficient stability and the gain in mobility is enough to significantly reduce the preoperative strain on the spine. In case of pelvic tilt with spinal malalignment, straightness can only be restored if the spine remains supple and there is no residual faulty position of the hip postoperatively, as sometimes reported in severe faulty ankylosis [8].

Hamadouche et al. [2] reported results of 45 THRs for ankylosis or arthrodesis in 45 patients with a mean age of 55.8 years (range: 28–80 years). Mean duration of ankylosis was 36 years (range: 3–65 years) and mean FU 8.5 years (range: 5–21 years). Mean postoperative flexion was 88° ± 23° (range: 30–130°), comparable to other reports [8] for Kilgus et al. [8] and 78° for Arlaud et al. [9] and function was satisfactory in 91% of cases (more frequently than in other reports [8,9,10]). Patients must be informed of the risk of residual limp, detracting from the spinal result. Thirty-seven of the patients had preoperative spinal pain, which reduced in intensity in 21 cases (60%), remained unchanged in 14 and worsened in one scoliotic patient (who underwent arthrodesis at 6 years post-THR).

Reikerä et al. [11], in a series of 55 cases, found moderate or medium improvement in lumbar pain in 26 patients; two showed aggravation. Kilgus et al. [8] reported that 25 of a series of 41 cases had lumbar pain, which resolved entirely or almost entirely in 20 cases.

**Congenital hip dislocation (CHD)**

There are three types of CHD [1], depending on the position of the head of the femur with respect to the paleo-
acetabulum. Other classifications have also been made [12], including Hartofilakidis’s et al. [13] and especially Crowe’s et al. (four types, I to IV), the most widely used, based exclusively on the degree of proximal migration of the femoral head [14].

The lesion is often bilateral; it may be symmetric or, more frequently, asymmetric. Unequal leg length is frequent. Strain on the lumbar spine during stance phase on the dislocated side is multiple.

Frontally
Due to the instability of the hip, the contralateral iliac crest is lowered, while the spine curves inward on the side of the hip in stance phase.

Sagittally
In posterior dislocation, the pelvis is anteverted on loading and the sacral slope is steepened, with compensatory lumbar hyperlordosis; this does not occur in anterior dislocation (except in case of osteoarthritis with flexion contracture).

Horizontally
There is frequently asymmetry between the two hips (and/or stiffening of one hip in rotation), causing a pelvic tilt (the ipsilateral iliac crest is more anterior the more the dislocation is posterior), compensated by a counter-rotation of the lumbar spine.

In the contralateral stance phase, what happens depends on the status of the other hip, whether normal (in which case, the pelvis and lumbar spine will be in a normal position) or dislocated.

These often young patients thus frequently complain of lumbar and sometimes radicular pain.

THR is particularly indicated in case of painful neo-joint osteoarthritis (severe dislocation). Spine and knee symptoms contribute to this indication.

In unilateral dislocation, pelvic balance should be restored. In bilateral dislocation, the second hip is liable to be operated on, and the pelvis will be re-balanced at that time. Whatever the initial situation, the functional length of the lower limbs should be equalized.

THR may restore straightness if the spine is supple, the hip is stable and equal limb length can be achieved. Stability is not always ensured, even after satisfactory reconstruction [12]: Trendelenburg sign remained positive in 10 out of 118 cases in Kerboul’s series [3].

Very few reports specify lumbar column and knee status before and after THR. Crowe et al. [14] reported that, out of 24 patients, nine had knee pain and 10 lumbar pain; postoperative evolution, however, was not reported. For Hess and Umben [15], nine out of 17 patients showed symptomatic lumbar hyperlordosis, which influenced indications for surgery; lumbar pain was significantly improved by THR.

Kerboul et al. [3] provides the most detail regarding knee and spine pain, in a series of exclusively high dislocations (Crowe’s type IV: 118 THRs in 89 patients). THR was indicated for disabling hip pain in 78 patients but for predominantly lumbar or ipsilateral knee pain in the other 11. Lower lumbar pain was alleviated in 40% of cases and lateral pelvic tilt corrected in half.

Sagittal pelvic balance in femoro-acetabular impingement
Femoro-acetabular impingement associates morphological hip-joint abnormalities and labral and joint cartilage lesions, leading to early osteoarthritis of the hip [16]. Two types are described [17]:

- cam impingement is due to a femoral head that is non-spherical in the antero-superior part, with increased curve radius; this area comes in contact with the edge of the acetabulum in hip flexion and internal rotation. This is more frequent in young, athletic males;
- pincer impingement involves linear contact between the edge of the acetabulum and antero-superior head-neck junction due to an abnormality of the edge of the acetabulum, with a normal femoral head. Thus in coxa profunda there is acetabular retroversion or excessive antero-superior femoral head cover by an overhanging acetabular edge; a lever effect is induced when the femoral head penetrates the acetabulum, causing postero-inferior lesions. It is most often found in women over the age of 40 years.

Clinically, patients complain of progressive mechanical pain in the groin, exacerbated by sport or prolonged sitting in a low chair. Hip blockage and jerks are also described, and can be attributed to a labral lesion. Normal walking is pain-free. Impingement test is positive, with groin pain on passive mobilization in 90° flexion associated to internal rotation and adduction, which brings the antero-superior edge of the acetabulum in contact with the anterior side of the head-neck junction.

The abnormality best described at present is filling of the head-neck junction. It is quantified by measuring the alpha angle, described by Nötzli et al. in 2002 [18], on a lateral arthoro-MRI slice of the femoral head through the femoral neck axis and the center of the femoral head (Fig. 1). Nötzli et al. reported a mean alpha angle of 42° in healthy subjects and of 74° in subjects with suspected femoro-acetabular impingement without acetabular dysplasia. This abnormality has also been described on arthro-CT and standard X-ray.

In pincer impingement, acetabular retroversion is the principal abnormality [19], causing an antero-superior overhang of the acetabular edge, leading to conflict with the femoral neck on flexion in internal rotation. Acetabular retroversion has been shown to depend on sacral slope [20]: the steeper the latter, the greater the acetabular retroversion on frontal pelvic X-ray.

We therefore investigated whether there was abnormal sagittal pelvic balance in case of femoro-acetabular impingement. Seventeen patients were diagnosed with cam or pincer femoro-acetabular impingement, on the basis of a positive impingement test and head-neck junction abnormality (increased alpha angle) or acetabular retroversion. All underwent standing lateral pelvic X-ray, hands on shoulders, to assess sacral slope and pelvic incidence and tilt, measured as described previously. A lateral hip X-ray was also taken, to measure the alpha angle. Mean angles were then calculated, and compared with literature data.
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Figure 1  Nötzli’s et al. alpha angle, measured between, on the one hand, the line through the center of the femoral head and the midpoint of the femoral neck, and, on the other, that through the center of the femoral head and the point at which the head ceases to be spherical (at which the distance between the center and external edge of the head first exceeds the radius of the head).

Table 1  Means ± standard deviation for pelvic parameters in patients with femoro-acetabular impingement compared to controls.

<table>
<thead>
<tr>
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<th>Nantes femoro-acetabular impingement series</th>
<th>Healthy subjects (Guigui et al. [21])</th>
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<tbody>
<tr>
<td>Incidence</td>
<td>56 ± 12°</td>
<td>55 ± 11°</td>
</tr>
<tr>
<td>Pelvic version</td>
<td>16 ± 6°</td>
<td>13 ± 6°</td>
</tr>
<tr>
<td>Sacral slope</td>
<td>40 ± 9°</td>
<td>42 ± 9°</td>
</tr>
</tbody>
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Mean incidence was 56 ± 12°, mean pelvic tilt 16 ± 6°, and mean sacral slope 40 ± 9° (Table 1). Mean alpha angle was 58.6 ± 13°. These values were compared with those of Guigui et al. [21] series of healthy subjects. No correlation emerged between the size of the alpha angle and the pelvic sagittal balance parameters (Fig. 2).

Comparison with the literature showed mean values to be equivalent in healthy subjects and subjects with femoro-acetabular impingement. There would thus seem to be no anatomic or static abnormality of pelvic sagittal balance in standing position associated with femoro-acetabular impingement.

Furthermore, there was no correlation between the pelvic parameters and the alpha angle. One might imagine that patients with a narrow alpha angle, with acetabular retroversion and pincer impingement would have a steeper sacral slope; conversely, pelvic balance might be supposed to adapt according to the alpha angle: patients with a large antero-superior bump at the head-neck junction could thus relieve the anterior part of the acetabulum by tilting the pelvis back (reducing the sacral slope). But in fact there is

Figure 2  Correlation between sacral slope and alpha angle.

Figure 3  a: congenital asymmetric pelvis; b: correction without treatment.
Management of hip pathology in childhood pelvic tilt

Congenital asymmetric pelvis (and infantile scoliosis)

Congenital asymmetric pelvis, identified and brought to public attention by Raphaël Seringe's team [22], is the earliest, most frequent and most easily treatable cause of pelvic tilt. The typical case is a 4-month-old child undergoing pelvic X-ray with diagnosis of hip dysplasia. On the one hand, there is clearly less abduction when the child is supine with the hips bent. The hip, however, is perfectly stable under Ortolani or Barlow maneuver. Inspection finds other reassuring points: plagiocephaly, facial asymmetric, incurved spine, and sometimes a talus or varus foot at birth which rapidly normalized, all of which strongly point to defective posture.

Diagnosis is confirmed by prone examination, which shows the hip to be limited in abduction and also finds clear contralateral limitation in adduction with the thigh impossible to bring to the median line. The reason for this is unilateral retraction of the thigh abductors, gluteals and fascia lata tensor: these are causing the pelvic tilt.

Evolution for this asymmetric pelvis is favorable (Fig. 3). There is often associated spinal incurvation in the form of a large thoraco-lumbar curve, and sometimes even a rounded hump, but with no vertebral deformity on X-ray, and little rotation or thoracic asymmetry on the Mehta index. Such infantile scoliosis shows favorable evolution, like asymmetric pelvis (Fig. 4).

Paralytic pelvic tilt (and paralytic scoliosis)

Severe cerebral palsy and multiple disability are the usual situations in which pelvic tilt is encountered. The origin may be upper or lower spinal or mixed.

In a study of 234 adults with multiple disability, Isabelle Hodgkinson et al. [23] found pelvic tilt in two thirds of cases. She found no straightforward causal relationship between windblown hip deformity, scoliosis and pelvic tilt; even so, in severe disability, when growth accelerates, the harmful effects of these elements combine to make sitting and nursing care increasingly difficult.
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Figure 6  a: neurologic scoliosis with left hip adduction contracture; b: primary spinal arthrodesis...; c: followed by left total hip replacement (THR).

The respective roles of the spine and lower limbs in the onset of pelvic tilt can easily be determined by examination of the patient in ventral decubitus with the thighs hanging over the edge of the table (Fig. 5). Ventral decubitus is also suitable for assessing lower limb asymmetry and the degree of both frontal and transversal retraction, the abduction contracture being systematically associated with an attitude in external rotation and the contralateral adduction contracture with retraction in internal rotation.

The side which is in adduction is the more liable to partial or complete dislocation, with consequent pain; the side in abduction, however, which usually remains well centered, can also become painful and stiff, due to chondrolysis induced by hyperpressure.

Maintaining maximal symmetry of movement in the hips is a logical objective in order to avoid pelvic tilt, and is pursued by physiotherapy, with the lying and seated positions that are needed throughout the growth phase in order to avoid retraction.

When, however, retraction occurs, and if the hip in adduction becomes excentric while bone deformity remains slight, then an effective attitude may be to release the adductors just enough to restore symmetry of movement.

Where there is greater deformity, with partial or complete dislocation of the hip in adduction, conservative surgery may be recommended in young patients; but pelvic surgery by Dega or Chiari acetabuloplasty and femoral shortening with varization/derotation should be associated to soft tissue adductor and psoa muscle release. On the contralateral side, if abduction contracture remains moderate, abstention is recommended, as abductor and external rotator release proves seldom effective. Where abduction contracture is more severe and hinders installation, directional femoral osteotomy is recommended [24].

In adolescents, and all the more so in adults, surgery is indicated only in case of pain or where comfortable sitting is prevented by extreme windblown hip deformity or stiffness. Conservative surgery is rarely recommended, due to bone deformity; rather, THR is to be performed on the symptomatic side, which will usually but not always be the side with the dislocation.

Where vertebral fusion down to the pelvis is indicated for scoliosis contributing to pelvic tilt, it is recommended to operate first on the spine (Fig. 6), unless the hip is very painful or stiff in extension, either of which is liable to prevent recovery of a comfortable sitting position after the pelvis has been fixed to the spine [25].

Conclusion

Congenital dislocation and ankylosis of the hip have the greatest impact on the spine. Rigorous clinical and radiological analysis of the causes of pelvic and spinal imbalance is indispensable. Flexion contracture is frequently associated with hip pathology, and must be eliminated if there is to be any hope of relieving spinal symptoms. These findings imply a general attitude which takes account not only of the hip itself for which the patient is consulting but of the entire pelvic-spinal-femoral complex (including the knee) before undertaking THR. No abnormality in standing sagittal pelvic balance parameters is associated with femoro-acetabular impingement. In children, congenital pelvic tilt is a benign but often overlooked pathology. Supra- and infra-pelvic pelvic tilt in paralyzed children raises a difficult strategic problem.

Conflict of interest statement

None.

References


